The effects of acute self-paced exercise and respiration biofeedback on anxiety and affect in high-stress university students

by

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ABSTRACT

High rates of stress-related problems in college students and low utilization of treatment options show a need for simple, effective interventions for stress management. Both exercise and breathing biofeedback have proven effective in reducing state anxiety in the past, but have never been compared. The purpose of this study was to evaluate the efficacy of brief exercise and breathing biofeedback interventions on altering state anxiety and affect in high-stress, college students. Thirty-two participants (mean age=21.5±3.2 years; 21 female) experienced the following 10-minute interventions on separate days: self-paced walk (EX), breathing biofeedback (BF) and a placebo condition of quiet study (QS). Anxiety and affect data were gathered using the State Anxiety Inventory (SAI) and Activation Deactivation Adjective Checklist (AD-ACL), respectively, before (Pre), immediately after (Post0), and 15 minutes after (Post15) the intervention in each condition. Heart rate variability (HRV) was measured at 2 time points (Pre- and Post-intervention). Mixed-factor Condition (3) x Time (3) repeated-measures ANOVAs were run on State Anxiety and Affect. Condition (3) x Time (2) ANOVAs were performed on HRV variables. Follow up time (3) repeated-measures ANCOVAs were run on EX and BF conditions for State Anxiety and Affect variables with ΔHRV variables as covariates.

Findings demonstrated that BF reduced anxiety, with the effect size for the BF condition nearly double that of the EX condition (Pre to Post15: BF $d=-.39$, EX $d=-.21$). Secondly, the EX condition increased Energy from Pre to Post0 ($d=.68$) that then returned to
baseline by Post15. In contrast, the BF condition showed a temporary increase in Calmness (\(d = .5\)). The QS condition produced no change in state anxiety or affect constructs. Finally, change over time was seen in the pNN50 variable indicating that, regardless of the intervention, a short break from normal stressors can increase HRV. However, changes in HRV did not explain the improvements in psychological states. In conclusion, the findings of the present study provide evidence for the benefits of acute bouts of both self-paced exercise and respiration biofeedback in improving anxiety and affect in high-stress college students. The mechanisms underlying these effects remain unclear.
CHAPTER 1

GENERAL INTRODUCTION

Physiologic systems activated by stress can protect and restore the body but also damage it (Selye, 1956/1976). Accommodating stress resulting from either chronic and acute over-activity or under-activity produces wear and tear on the body (McEwen, 1998). Chronic over-activation of stress response systems can lead to the development of serious pathology, for example increased blood pressure, antagonism of insulin by the highly catabolic glucocorticoids, impaired growth and tissue repair, and suppression of immune function (Khan, King, Abelson, & Liberzon, 2009). Excessive and chronic activation of stress systems can lead to a syndromal state, feeding into a sustained vicious cycle (Chrousos & Gold, 1992).

Students are especially susceptible to many stressors. Exams, time demands, financial pressure, changes in sleeping and eating habits, new responsibilities, increased workload, meeting new people, career decisions, fear of failure, and parental pressure are common stressors for college students (Robotham & Julian, 2006). In a 2007 survey on mental health, just over half of the 5,689 college students sampled screened positive for a mental disorder, such as depression, anxiety, or suicide behavior (Keyes, et al., 2012). Over the past decade, researchers have reported a rise in the severity of mental health problems as well as a sharp increase in the demand for counseling services (Kitzrow, 2009). Universities with good mental health services may better retention students (Kitzrow, 2009). The dropout rate for students on a waitlist of mental health services has
been reported at about 14% (Wilson, Mason, & Ewing, 1997). Therefore, it is important to present stress management options to students that are easy to initiate and fit into their schedules.

Aerobic exercise has been proposed in a variety of interventions for stress management to, for example, control physiological reactivity. Participants with greater physical fitness reported reduced responses to psychological stressors (Hamer, Taylor, & Steptoe, 2006). Other research has linked regular exercise to lower neuroticism, anxiety, and depression (De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006). Exercise can also boost low levels of positive-activated affect (PAA) associated with depressed mood (Mineka, Watson, & Clark, 1998) and improve PAA (Ekkekakis & Petruzzello, 1999). Even low-intensity, 10-minute walks (Ekkekakis, Hall, Van Landuyt, & Petruzzello, 2000) produced acute psychological benefits such as decreased distress and increased positive affect (Rudolph & Butki, 1998). Therefore, recommending a self-paced walk could be an inexpensive, effective, and accessible option for students to deal with anxiety and improve affect.

Another stress management option is an acute bout of paced-breathing with biofeedback. Respiration training has therapeutic effects that influence the body’s modulatory processes, such as the baroreflex modulating blood pressure, through which vagal and sympathetic reflexes can be controlled (Lehrer et al., 2003). Gaining awareness and control of autonomic functions, for example respiration and heart rate, is the purpose of biofeedback training (Basmajian, 1981). In one study, though, it was shown that slow abdominal breathing alone was not as effective in lowering blood
pressure as breathing plus biofeedback (Wang, et al., 2010). Therefore, simple breathing exercises alone may not produce the desired reduction in anxiety and improvements in positive affect. A bout of respiration biofeedback may be effective in teaching breathing skills that could be effective and accessible for stress management and improving affect in students.

Heart rate variability (HRV) is an important clinical assessment tool of the cardiac autonomic regulation in health and disease (Billman, 2011). Reduced heart rate variability has been linked to “cardiovascular disorders, including sudden death, particularly when accompanied by left ventricular hypertrophy, sudden death, ventricular arrhythmia and severe heart disease” (Lehrer, Vaschillo, & Vaschillo, 2000, p. 179). The sino-atrial node, the pace-maker of the heart, is innervated by parasympathetic fibers of the vagus nerve and sympathetic nervous thoracic efferents, which exert an inhibitory and an excitatory influence on the heart rate, respectively (Valentini & Parati, 2009). The amplitude of the respiratory sinus arrhythmia (RSA) wave, which contributes to the variability of the heart rate, tends to be dampened in disorders involving anxiety or depression (Lehrer, Vaschillo, & Vaschillo, 2000). Therefore, practice that would amplify the RSA wave may increase heart rate variability.

It is clear that students are a high-risk population in need of pertinent recommendations to handle anxiety and stress. Short bouts of aerobic exercise and paced-breathing with biofeedback may help students combat stress and protect themselves from the effects of chronic stress. The purpose of this study is to investigate whether aerobic exercise and paced-breathing with biofeedback will improve affect and
reduce state anxiety more than quiet study. The main hypothesis is that both acute exercise and paced-breathing with biofeedback will produce greater improvement in state anxiety and affect than quiet study. It is also hypothesized that pre-post intervention changes in heart rate variability (an indicator of autonomic nervous system activity) could provide some explanation for the psychological changes observed.
CHAPTER 2
LITERATURE REVIEW

Stress

Environmental pressures subject organisms to stress and adaptation. The response to the environment, to threats, and to predators creates stress. This enhances the odds of survival and reproduction, in mammals, by increasing oxygen and glucose delivery to the heart and affecting immune responses. Though serious environmental threats do not exist for most modern humans, many other stressors still exist and have serious physical effects on the body, including immune responses. Environmental events affect the nervous system and endocrine system, which in turn can elicit responses from the immune system (Segerstrom & Miller, 2004).

Stress itself is not only a negative concept (Lupien, McEwen, Gunnar, & Heim, 2009); it is a necessary tool for survival. Seyle (1956, 1976) noted the physiologic systems activated by stress can protect and restore the body but also damage it. McEwen (1998) highlighted immune-enhancing effects of acute stress as an example of eustress, which can last for three to five days, preparing the immune cells to respond (McEwen, 1998), however, the more chronic it becomes, the more components of the immune system are affected in a potentially detrimental way (Segerstrom & Miller, 2004).

Lazarus (1993) argued that physiological and psychological stresses differ greatly. He noted that this is an issue psychologists have been challenged with, namely the personal meaning of the stress. An individual’s appraisal gives meaning to the stress.
For example, two individuals can experience the same event and have differing emotional responses (Lazarus, 1993). Perceptions of stress and their general state of physical health determine an individual’s response to potentially stressful situations (McEwen, 1998). Stress also comes from an individual’s perception that they do not have the resources to cope with a perceived situation (Lazarus & Folkman, 1987). Coping may involve attempting to change the environment (problem focus), or making changes to the perceptions of the events involved (emotion focus). Coping mechanisms buffer physiological and psychological stress and the effects on the body (Lazarus, 1993).

Whether inflammatory, traumatic, or psychological stress is encountered, the body reacts physiologically to stress by activating the sympathetic-adrenal-medullary (SAM) and the hypothalamic-pituitary-adrenal (HPA) axis (Aich, Potter, & Griebel, 2009). The body must then work to maintain or restore homeostasis (Lupien, et al., 2005), which is biologically expensive (Abelson, Khan, & Giardino, 2010). Both neuronal systems respond to stress, but the SAM axis responds more acutely by releasing epinephrine and norepinephrine (Dinan, 2001). The HPA axis responds more to long-term stress by releasing cortisol.

Accommodating stress resulting from either chronic and acute over-activity or under-activity produces wear and tear on the body (McEwen, 1998). Allostatic load is a term for the prolonged effect of the stress response. It can be increased through four situations: frequent stress, prolonged exposure to stress hormones (cortisol) and catecholamines (epinephrine and norepinephrine), inability to shut off an allostatic response, and response system imbalance (McEwen, 1998). The result of prolonged
activation could be pathological arousal and increased allostatic load (Schulkin, McEwen, & Gold, 1994), but subjects who showed a higher level of physical and mental functioning had a lower allostatic load score and a lower incidence of cardiovascular disease, hypertension, and diabetes (McEwen, 1998).

It is clear the brain and the body are constantly in communication with each other via the autonomic nervous system, endocrine, and immune systems (McEwen, 2004). Acute stress, dealt with through the HPA and SAM axes release of neurotransmitters, cytokines, and other hormones, promotes adaptation and is generally beneficial (McEwen, 2004). Stress responses are meant to be acute or at least of a limited duration (Chrousos & Gold, 1992). Issues can arise when the systems are not turned off when the stress is over, when the systems weren’t adequately activated when stress was encountered, or when many stressors overwhelm the systems (McEwen, 1998). Failure to deal with acute stress at key points in brain development could alter long-term brain development (Lupien, McEwen, Gunnar, & Heim, 2009). Excessive and chronic activation of stress systems can lead to a syndromal state, feeding into a sustained vicious cycle (Chrousos & Gold, 1992).

Chronic stress can result in the over-activation of the HPA, which presents health risks such as increased blood pressure, antagonism of insulin by the highly catabolic glucocorticoids, like cortisol, impaired growth and tissue repair, and suppression of the immune functions. Extensive research has provided a detailed understanding of the harmful consequences of prolonged or repeated activation of autonomic nervous system and limbic-hypothalamic-pituitary-adrenal axis (Khan, King, Abelson, & Liberzon,
2009), such as the development of hyperlipidemia, hypertension, chronic immune suppression and reduced virus resistance, states of anxiety and dysphoria, and sleep disorders (Francis & Meaney, 1999). Exposure to stress and stress hormones over the lifespan play a substantive role in aging (Sapolsky, Krey, & McEwen, 1986). Chronic inflammatory stress, such as IL-6, can play a major role in the immune stimulation of the HPA axis (Tsigos & Chrousos, 2002). The severity of chronic stress is clearly evidenced by Miller and O’Callaghan’s (2002, p. 5) assertion that “of the 10 leading causes of death, stress has been directly implicated in 4 (heart disease, stroke, musculoskeletal disorders or injuries, and suicide/homicide) and indirectly in 3 (cancer, chronic liver disease, and lung disorders such as chronic bronchitis and emphysema)”.

**Heart Rate Variability and Stress**

Other health disorders have been linked to heart rate variability (HRV), the beat-to-beat variation of the heart. The sino-atrial node, the pace-maker of the heart, is innervated by parasympathetic fibers of the vagus nerve and sympathetic nervous thoracic efferents, which exert a slowing down and a speeding up influence on the heart rate, respectively (Valentini & Parati, 2009). Reduced HRV has been associated with “cardiovascular disorders, including hypertension, particularly when accompanied by left ventricular hypertrophy (Mancia, Giannattasio, Turrini, Grassi, & Omboni, 1995), sudden cardiac death (Goldberger, 1991), ventricular arrhythmia (Rosenbaum et al., 1994), and severe heart disease (Peng et al., 1996)” (Lehrer, Vaschillo, & Vaschillo, 2000, p. 179). The amplitude of the respiratory sinus arrhythmia wave tends to be dampened in disorders involving anxiety or depression (Lehrer, Vaschillo, & Vaschillo, 2000).
Heart rate variability (HRV) is an important clinical assessment tool of the cardiac autonomic regulation in health and disease (Billman, 2011). Generally, time domain or spectral domain methods are used to evaluate HRV (Force, 1996). Time domain variables, such as RMSSD and pNN50, are usually measures of short-term variation which are easy to calculate and estimate high frequency variation in heart rate (Force, 1996). Spectral domain variables are divided into three main components, very low frequency (VLF), low frequency (LF) and high frequency (HF), and are measured in time or normalized units also called nu (Force, 1996). VLF, ≤ 0.04 Hz, is less defined and specific physiological processes have not been associated with changes in VLF (Force, 1996). LF, 0.04 - 0.15 Hz, is accepted by some researchers as “a marker of sympathetic modulation and by others as a parameter that includes both sympathetic and vagal influences” (Force, 1996, p. 366). HF, 0.15 – 0.40 Hz, is greatly contributed to by the efferent vagal or parasympathetic activity (Force, 1996). LF and HF, when expressed in normalized units, represent the controlled and balanced behavior of the two branches of the autonomic nervous system, sympathetic and parasympathetic (Force, 1996). The LF/HF ratio is a common index of sympathetic and parasympathetic balance (Billman, 2011).

**Stress in Students**

Stress research has been limited in the student population because they have not been a priority (Michie, Glachan, & Bray, 2001). Research has not examined stress-reducing strategies once students arrive at university (Nonis, Hudson, Logan, & Ford, 1998). Recent data show that anxiety and depression in university students is at
concerning rates (Regehr, Glancy, & Pitts, 2012). A 2009 web-based survey of 8,487 undergraduate and graduate students from 15 U.S. universities showed 6.65% of respondents reported suicidal ideation and 0.05% actually made a suicide attempt in the past year (Downs & Eisenberg, 2012). Less than half (49.3%) of 5,689 graduate and undergraduate students in the 2007 Healthy Minds Survey were free from mental disorder and flourishing; the rest (50.7%) tested positive for depression, panic disorder, and/or generalized anxiety (Keyes, et al., 2012). Universities must meet the needs of its student by employing preventative interventions to reach larger groups of students and not just individual counseling services (Regehr, Glancy, & Pitts, 2012).

Students are exposed to a significant number of stressors while attending university. Stressors include exams, time demands, financial pressure, changes in sleeping and eating habits, new responsibilities, increased workload, meeting new people, career decisions, fear of failure, and parental pressure (Robotham & Julian, 2006). Minor stressors, such as work deadlines, interpersonal conflicts, and exams, negatively influence health and psychological well-being. However, as long as the stressor is terminated there is generally a rebound effect (Bolger, DeLongis, Kessler, & Schilling, 1989).

Striving to meet deadlines (Misra, McKean, West, & Russo, 2000) and feeling the workload is overwhelming (Reisberg, 2000) can lead to a fear of failure in university students (Robotham & Julian, 2006). Much stress comes from anticipation of threats, whether or not they are real, for example the threat of social rejection and negative social evaluation (Lupien, McEwen, Gunnar, & Heim, 2009). The fear of failure can help positively motivate students to prepare but it can also create unnecessary emotional and
physical distress if the stress is too great to handle (Scafer, 1996). Time constraints and the perception of control over time can put students under significant stress (Nonis, Hudson, Logan, & Ford, 1998). Students as young as high school level forgo sleep, straining their ability to cope with raised stress levels (Hardy, 2003). Sleep deprivation and other challenges to the circadian rhythm have major influence on health (Lupien et al., 2009).

Students’ response to stress can be seen emotionally, cognitively, behaviorally, and physiologically (Misra, McKeon, West, & Russo, 2000). Students under high stress engage in more unhealthy eating behaviors, exercise less, and experience less satisfaction in regards to their GPA and overall health, including their weight and fitness level (Hudd, et al., 2000). Stress also led to an increase in alcohol consumption, smoking, tendency to consider suicide, and a decrease in academic performance (Robotham & Julian, 2006).

The consequences of chronic stress can have a major effect on students. Research has suggested a significant relationship between cumulative high-level glucocorticoid exposure and impaired memory function and atrophy of the hippocampus, a part of the brain that has been shown to play a role in learning and memory (Squire, 1992; Sapolsky, Krey, & McEwen, 1986). Long-term as well as currently high glucocorticoid levels are associated with cognitive impairments (Lupien, et al., 2005). Research has also shown that minor stressors (an exam, deadlines, arguments with friends or family) influence health and psychological well-being (Kessler & Schilling, 1989). People who are already anxious or depressed are more likely to view the world as threatening (Schulkin, McEwen, & Gold, 1994), which may lead to repeated reactivation of the stress response.
and subsequently increase allostatic load.

Therefore, it is important to present options to administrators and students of brief, effective methods to handle stress and prevent its negative effects. The following two sections present the benefits of two different behavioral strategies that have been demonstrated as effective for stress management: aerobic exercise and paced-breathing.

**Acute Exercise as a Method of Reducing Anxiety and Improving Affect**

There are numerous health benefits associated with exercise. Aerobic exercise has been proposed in a variety of interventions in stress management by controlling physiological reactivity (Hamer, Taylor, & Steptoe, 2006). Better physical (Ostir, Markides, Black, & Goodwin, 2000) and mental health (Diener & Seligman, 2004) are associated with well-being and positive mood (Reed & Ones, 2006). Individuals with higher well-being exercise more when compared to those reporting lower well-being (Lox, Burns, Treasure, & Wasley, 1999), and overall, they are healthier and function more effectively in relationships and at work (Diener & Seligman, 2004). Conversely, low levels of positive-activated affect (PAA) are associated with depressed mood (Mineka, Watson, & Clark, 1998). In general, exercise improves affect (Ekkekakis & Petruzzello, 1999).

Chronic exercise may be a factor in reducing sympathetic responses to stress (Crews & Landers, 1987). Regular exercise has been shown to be associated with lower neuroticism, anxiety, and depression. Exercise is associated with anxiety, depression, and personality that hold in both male and female and across age (De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006).
Acute bouts of exercise also have physiological benefits. Acute episodes of aerobic exercise lessen cardiovascular responses during subsequent exposure to threat or challenge. Ebbesen, Prkachin, and Mills (1989) found that one bout of 1 or 2 hours on a stationary cycle resulted in attenuated blood pressure responses to various stressors. Acute bouts of aerobic exercise were seen to result in post-exercise hypotension, with the greatest effects seen in subjects with the highest baseline ambulatory blood pressure (Pescatello & Kulikowich, 2001). Acute aerobic training may also buffer real-life, psycho-social stressors, such as exams, performances such as a speech or concert, or daily work demands (Matthews, Owens, & Allen, 1992; Kamarck, Schwartz, & Janicki, 2003). Acute exercise may be more beneficial than common alternatives, for example one study showed increased short-term affect after a brisk 10-minute walk compared to eating a sugar snack (Thayer, 1987).

Some of the acute psychological benefits of 10-minute bouts of exercise, such as better physical and mental health as well as higher feelings of well-being and overall better functioning, are associated with decreased psychological distress and increased positive affect and exercise-related self-efficacy (Rudolph & Butki, 1998). These are associated with increased adherence (Brassington, Atienza, Perczek, DiLorenzo, & King, 2002). Enjoyment also influences the intention to exercise (French et al., 2005). Shorter bouts (10 minutes) of exercise are associated with greater adherence to exercise programs than longer bouts (Jakicic, Wing, Butler, & Robertson, 1995). That increased adherence could boost physical fitness levels, which has resulted in reduced responses to psychological stressors (Hamer, Taylor, & Steptoe, 2006). Bouts of exercise also have
been used as a self-regulatory strategy to improve feelings of energy and positive affect (Thayer, 1997).

The intensity of the exercise is an important variable. Hobson and Rejeski (1993) found that a short bout of moderate to high intensity exercise could reduce cardiovascular reactivity to a challenge or stressor but did not show that intense exercise could produce a significant change in affect. Employing aerobic exercise of very high intensity or long duration could result in adverse psychological effects (Hassmen & Blomstrand, 1991). On the contrary, Ekkekakis, Hall, Van Landuyt & Petruzzello (2000) showed that short, self-paced walks at low intensity resulted in significant shifts toward higher activation and more pleasant affect using multiple measures of the circumplex dimensions. Recovery from walking for 10 to 15 minutes was accompanied by a return toward calmness and relaxation (Ekkekakis, Hall, Van Landuyt, & Petruzzello, 2000). Affect peaked shortly after exercise ended and then declined back towards baseline (Reed & Ones, 2006). Therefore, it is expected that a short bout of self-paced exercise could be an effective, simple, and fast method of reducing state anxiety and improving affect that could be recommended to students.

**Respiration Biofeedback as a Method of Reducing Anxiety and Improving Affect**

Breathing should be nearly effortless. Abdominal or diaphragmatic breathing at a slow pace can result in a relaxation effect and a reduction in sympathetic arousal (Sovik, 2000). On the contrary, chest breathing or thoracic breathing can result in chest pain (Taylor, 2001). Any labored breathing can generate intense emotional responses (Abelson, Khan, & Giardino, 2010), which may lead to some negative psychological or
physiological effects in thoracic breathers. For this reason, it is important to understand and practice abdominal breathing.

Breathing at a slow rate, like 6 breaths per minute, requires attention and practice. Normally, people breathe between 12-20 breaths per minute. The increase in tidal volume compensates for the reduction in respiration rate. Paced breathing at 0.25 Hz (15 breaths per minute) did not alter cardiovascular autonomic regulation when compared to spontaneous breathing (Pinna, Maestri, La Rovere, Gobbi, & Fanfulla, 2005). Simple paced-breathing at 12 breaths per minute resulted in increased parasympathetic activity (Driscoll & DiCicco, 2000). Vaschillo, Vaschillo, and Lehrer (2006) had participants practice paced-breathing at different rates for 2-minute sessions to determine their resonant breathing, the rate at which they experience the greatest respiratory sinus arrhythmia. Then, during subsequent visits participants had four 5-minutes training sessions. They proposed that paced-breathing at 5.5-6 breaths per minute for all people may produce clinical effect as a result of breathing close to the resonant frequency (Vaschillo, Vaschillo, & Lehrer, 2006). The resonant frequency is about 0.1 Hz (6 breaths per minute), at which heart rate and blood pressure oscillate 180 degrees out of phase, while heart rate and respiration oscillate in phase with each other. At this frequency, the respiratory effects on heart rate variability support the baroreflex effects and high HRV and baroreflex gains are seen (Lehrer et al., 2003). Reducing the stress response and increasing HRV has been accomplished through slow diaphragmatic breathing (Schipke, Pelzer, & Arnold, 1999). Increases in respiratory interval would amplify respiratory-related vagal (parasympathetic) modulation of the heart (Hayano et al., 1994). Simply
teaching diaphragmatic breathing to increase finger temperature was seen to increase parasympathetic stimulation and decrease sympathetic over-activity in migraine patients (Kaushik, Kaushik, Mahajan, & Rajesh, 2005).

The use of biofeedback equipment, however, can ensure that participants can effectively learn the breathing skills through self-correction and eventually alteration of physiological state (Schwartz, 1987). Gaining awareness and control of autonomic functions, for example respiration and heart rate, is the purpose of biofeedback training (Basmajian, 1981). Biofeedback falls under the field of applied psychophysiology, a field which strives to understand and effect changes that help humans move toward and maintain healthier physiological functioning (Birbaumer & Flor, 1999). One recent study showed that slow abdominal breathing alone was not as effective in lowering blood pressure as breathing with biofeedback (Wang et al., 2010). Therefore, simple breathing exercises alone may not produce the desired reduction in anxiety and improvement in positive affect.

Using respiration plus various types of biofeedback have had positive results. Respiration training with heart rate variability (HRV) biofeedback has therapeutic effects that influence the body’s modulatory processes, for example the baroreflex modulating blood pressure, through which vagal and sympathetic reflexes may be controlled (Lehrer et al., 2003). Paced-breathing with EMG biofeedback in pre-hypertensive, post-menopausal women for ten 20-minute sessions, breathing at 6 breaths per minute, was effective in lowering blood pressure for up to 3 months (Wang et al., 2010). Reiner (2008) found that participants with anxiety disorders had reductions in state and trait
anxiety after using a Respiratory Sinus Arrhythmia BF device for about 20 minutes per day for 3 weeks. Reduction in negative affect was seen, which Reiner suggested may be explained through reinforcement from increased HRV.

The effect of respiration biofeedback on anxiety in high-stress populations has been the subject of several studies in the last few years. High-anxious, professional musicians were given a 30-minute breathe training session (either with or without BF) and showed, compared to a control group (preferred reading), improved control over physiological arousal in anticipation of psychosocial stress when presented with a graded music performance (Wells, Outhred, Heathers, Quintana, & Kemp, 2012). This particular sample appears to have consisted of flute players, with significant diaphragmatic breathing experience, which may explain the lack of difference between intervention groups. Two other interventions offered biofeedback training for several weeks. Undergraduate nursing students in the intervention group were taught to use a handheld biofeedback device in 2 training sessions with researchers and then instructed to train 3 times per day for 5 weeks (Ratanasiripong, Ratanasiripong, & Kathalae, 2012). The control group did not receive training or a device. Perceived stress went up significantly in the control group but was maintained in the intervention group. State anxiety decreased significantly in the intervention group, but did not significantly change in the control group. In another study, undergrads in two groups were put into immediate and delayed treatment groups (Henriques, Keffer, Abrahamson, & Horst, 2011). They were given guidelines for using a computer-based biofeedback program that focused on paced-breathing and shifting affect. Participants were to attend 20 laboratory-based
biofeedback sessions and use a hand-held biofeedback device as desired. Both groups showed a decrease in negative mood over time on 4 of the 6 subscales of the Mood and Anxiety Symptoms Questionnaire. No change over time was seen in the groups on the Scales of Psychological Well-Being questionnaire (SPWB). Unfortunately, no control group was used, so it is unclear whether the changes in mood were truly a consequence of the intervention. Taken together, the findings of these studies show promise for the use of respiration biofeedback to reduce anxiety and improve affect. Therefore, it is expected that this strategy could be an effective, simple and fast method of reducing state anxiety and improving affect that could be recommended to students.

**How do the Effects of a Single Bout of Acute Exercise Compare to that of Respiration Biofeedback?**

Little research has directly investigated the acute effects of respiration or paced-breathing biofeedback on affective responses or state anxiety. The only known study to investigate acute psychological responses to biofeedback involved a group of 18 senior business managers, who reported high stress levels (Prinsloo et al., 2011). Participants performed a Stroop test before and after a 10-minute training session with a handheld biofeedback device, and showed improved cognitive performance and improved affect compared to a placebo control group, who had a device that did not teach respiration biofeedback (Prinsloo et al., 2011). Although, there were improvements in cognitive performance and affect, they did not show decreased state anxiety.

To date, no studies have compared the effects of acute exercise and respiration biofeedback on state anxiety and affect. Furthermore, no work has been done to explore
the relationship between state anxiety and affect with measures of autonomic nervous system activity, like heart rate variability, in response to exercise or biofeedback. Because university students are often under both stress and time constraints, they need brief, effective strategies to self-manage stress. Both short bouts of aerobic exercise and paced-breathing are feasible and efficacious means of dealing with stress in students. The purpose of this study is to investigate the degree to which each intervention affects state anxiety and affect in college students. The main hypothesis is that both a bout of self-paced exercise and respiration biofeedback will produce greater reductions in state anxiety and improve affect than a quiet study control. The secondary hypothesis is that the changes in HRV variables from pre- to post-intervention will provide some explanation for changes in anxiety and affect.
CHAPTER 3

METHODS

Study Design

Participants visited the laboratory on three separate occasions to complete each intervention (self-paced walk [EX], respiration biofeedback [BF], quiet study [QS]) with at least one day between sessions. Before and after each intervention, physiological variables (to evaluate heart rate variability [HRV]) and psychological variables (anxiety and affect) were gathered. Interventions were counterbalanced to prevent any order effects. The study was approved by the institutional review board at Iowa State University and data collection was conducted in the fall semester, 2012.

Participants

The inclusion criteria for recruitment were an above average score on the Perceived Stress Scale (PSS) compared to the age-based norms: 18-29 years old=14.2 (Cohen & Williamson, 1988) and full-time student status. Exclusion criteria for recruitment were diagnosed psychological disorders, medication use that would affect heart rate and blood pressure, and below average score on the PSS. Recruitment was done via posters, flyers, and emails (see Appendix) distributed throughout a large university in the Midwest. Some students were offered extra credit by professors unconnected with the study for participating in research.

A total of 69 college students responded to recruitment efforts. Of those, 32 did not meet inclusion criteria. The other 37 participants completed the study, but five
individuals’ data were removed from the analyses due to failing to meet the minimum coherence score during BF (See Figure 1).

Figure 1. Participant recruitment and completion flow diagram

**Measures**

**Physiological Measures**

Body mass was measured using a scale (model BF-626, Tanita, Tokyo, Japan) and height was measured using a stadiometer. Body Mass Index (BMI) was calculated based on the participant’s body mass and height (BMI=Weight in Kilograms / Height in Meters²). Nexus 10 hardware (NeXus-10, Oldenzaal, Netherlands) and Biotrace+
Software (Biotrace+ Software for NeXus-10, Version 2010A, Netherlands) were used to display biofeedback information on a laptop. The NeXus-10 Device recorded heartbeats using a standard 3-lead ECG at 1024 Hz. A sampling rate of 256 Hz is considered adequate in normal adults but 500-1000 Hz is optimal (Berntson et al., 1997). The electrodes were placed at standard Lead II locations, right arm (RA) negative, left arm (LA) ground and left leg (LL) positive, after the skin was cleaned with an alcohol pad.

Square root of mean squared differences in successive NN intervals (RMSSD) and the percentage of adjacent NN intervals differing by more than 50ms in the entire recording (pNN50), were selected as time domain measures of HRV. These two variables are common measures of short-term variation, which estimate high frequency variations in heart rate (Force, 1996), calculate total variability and quantify respiratory sinus arrhythmia (Billman, 2011). High frequency (normalized units) and low frequency / high frequency ratio were selected as spectral domain HRV measures. The controlled and balanced behavior of the sympathetic nervous system and parasympathetic nervous system can be seen in LF and HF when expressed in normalized units (Force, 1996). Many consider the LF/HF ratio to be a mirror of sympatho/vagal balance or sympathetic modulation (Force, 1996). To generate the spectral-density measures, fast Fourier transform (FFT) was used. Because oscillation frequency in participants’ data is expected to vary over time, FFT modeling is optimal (Berntson et al., 1997).

**Psychological Measures**

The Perceived Stress Scale (PSS) was used to assess participants’ level of perceived stress in the past month (Cohen, Kamarck, & Merzelstein, 1983). The PSS
consists of 10 items. There are positive and negative questions ranked on a Likert scale ranging from 0 (never) to 4 (very often). Positive questions are reverse scored and then summed across all 10 items. Items 4, 5, 7, and 8 are reverse scored (0=4, 1=3, 2=2, 3=1, and 4=0) with possible scores ranging from 0-40. The higher scores indicate higher levels of perceived stress. The survey's reading level was designed for middle school or higher education and has easy to understand vocabulary, which is free of content specific to any sub-population. Cohen, Kamarck, and Mermelstein (1983) tested the PSS with college students and found it to have adequate internal (α=.85) and test-retest (r=0.85) reliability. The PSS score produced a strong internal reliability score (alpha coefficient=.78) across many populations (Cohen & Williamson, 1988).

Trait Anxiety (TAI) and State Anxiety (SAI) were measured by the State Trait Anxiety Index (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The 20 TAI and SAI survey questions are each scored on a 4-point Likert-type scale ranging from 0 (not at all) to 3 (very much so). The items are summed to give one state anxiety score with the following items reverse scored (i.e., 0=3; 1=2; 2=1; 3=0): 1, 2, 5, 8, 10, 11, 15, 16, 19, 20 and one trait anxiety score with the following items reverse scored: 1, 3, 6, 7, 10, 13, 14, 16, 19. Possible scores range from 0-60. Higher scores indicate higher levels of trait or state anxiety. This instrument is widely used and has been tested with college students, as well as many other groups (Spielberger et al., 1983). Furthermore, it has high internal consistency (TAI: alpha=0.9, SAI: alpha=0.93) in samples of students, working adults, and military recruits (Spielberger & Sycleman, 1994).

Affect was measured using the Activation Deactivation Adjective Checklist or
AD-ACL (Thayer, 1967). The AD-ACL is a self-report measure of the affective dimensions of Energetic Arousal (EA) and Tense Arousal (TA). It can be scored as two bipolar dimensions of EA and TA or individually as Energy, Tiredness, Tension, and Calmness. Each item is scored by a 4-point Likert-type scale ranging from 1 (definitely do not feel) to 4 (definitely feel) with possible scores of 5-20 per subscale. “All four scales of the AD-ACL exhibited satisfactory internal consistency” with Cronbach’s α coefficients ranging from 0.91 to 0.7 (Ekkekakis, Hall, & Petruzzello, 2005, p. 90). Thayer’s (1978) Evaluation of the circumplex structure of the Activation Deactivation Adjective Checklist before and after a short walk reported test-retest reliability coefficients ranging from .93 to .79 across the four subscales.

Exertion was measured using the Rating of Perceived Exertion Scale (Borg, 1982; Chen, Fan, & Moe, 2002). Rating of Perceived Exertion (RPE) is a scale from 6 (very, very light exertion) to 20 (very, very hard). All measures are included in the Appendices.

**Procedures**

Potential participants responded to advertisements by emailing the researchers. They were sent pre-scripted email responses that included a link to a short informed consent and series of surveys to determine eligibility. The surveys, hosted at Qualtrics (www.qualtrics.com), consisted of demographic information, 7D-PAR, TAI, and PSS. Participants who scored above average perceived stress for their age groups (PSS > 14.2 for 18-29 year olds) and had no exclusion criteria were scheduled for laboratory sessions. The participants reported to the laboratory for three sessions at the same time of day with at least one day in between sessions (repeated measures design). Each session was about
50 minutes long. During the first session, the participant read and signed the informed consent document and height and weight assessments were taken. In email communication, the participants were asked to abstain from alcohol within 24 hours of the session and caffeine and working out within 2 hours before each session. Researchers verbally confirmed that participants complied with the request before each session.

Intervention order was randomized for each participant. Specifically, participants were assigned to a repeating list of possible intervention orders based on the order in which they were scheduled for their first session.

Participants were instructed to answer survey questions with their honest opinion of how they felt at that moment. They were then asked to rest in a comfortable chair for 15 minutes (10 minutes of rest without sleeping, cell phone, reading material or talking, followed by 5 minutes completing simple math worksheets, in which pre-intervention HRV data was recorded using the ECG). This simple math protocol is a strategy to obtain physiological baseline through a low-concentration task (Fishel, Muth, & Hoover, 2007). Having a low-concentration task can help control for voluntary breathing, which can have a direct effect on HRV variables (Billman, 2011). Immediately prior to and immediately following each intervention, the participant completed the SAI and AD-ACL surveys (Pre and Post0). Then, after completing the intervention and the pre-post intervention psychological assessments, participants were seated again for 15 minutes (10 minutes of rest followed by 5 minutes completing simple math worksheets, in which post-intervention HRV data was recorded using ECG). The participants then completed the final round of SAI and AD-ACL surveys (Post15). This same procedure was
followed in each of the three sessions, with the only difference between sessions being the type of intervention that the participant received (See Figure 2 for the Intervention Protocol).

SELF-PACED WALK: For this (EX) condition, participants were familiarized with the RPE scale before they stepped onto the treadmill (Trackmaster TMX425C, Newton, KS, USA) for a 10-minute, self-paced walk. Participants were encouraged to self-select a comfortable walking speed, which they were allowed to vary until the 2-minute mark. The 2 minute ‘active familiarization’ allowed participants to gain familiarity with the equipment while actively engaging in the intervention. At minutes 5 and 10, RPE was recorded.

RESPIRATION BIOFEEDBACK: For the BF intervention, participants were introduced to diaphragmatic breathing using a simple script, which instructed them to breathe naturally (not too deep, not too shallow). The participants wrapped a respiration belt around their abdomen, were told to orient it at the belly button (umbilicus), and placed the blood volume pulse clip on their left forefinger. The participants were shown a respiration pacing screen (Respiration and HRV- Pacer screen3, Biotrace+ Software for NeXus-10, Netherlands) on a laptop (Hewlett Packard ProBook 6550b) which displayed a pacer bar and a pacer line set to 6 breaths per minute (bpm). Next to the pacer line, their respiration data were displayed in another color. They were instructed to breathe at 6 bpm and make a similar shape as the pacer line with their own breath data. The total intervention lasted approximately 10 minutes.

Participants were given 2 minutes to orient themselves and to start breathing at 6
bpm, following the pacer on the screen. The 2 minute ‘active familiarization’ allowed participants to gain familiarity with the equipment while actively engaging in the intervention. Next, the students asked any questions about the paced-breathing and biofeedback, and the researchers provided feedback about their breathing. Over the next four minutes, the participant practiced the paced-breathing. This was followed by a short rest period in which they were allowed to ask any questions and the researchers were able to provide any feedback about their breathing, and another four-minute session where their data was recorded. The researcher noted coherence data as calculated by BioTrace+ (percentage of respiration data that coincided with in-phase increase and decrease in heart rate) and subjectively evaluated the shape-matching of the participants respiration data compared to the 6-bpm line after each training session.

Several participants were unable to meet the requirements after the two training sessions and were allowed a third training session. The participants who were unable to meet 50% coherence or failed to match the shape of the respiration line failed the training.

QUIET STUDY: For the QS (control) condition, participants were seated in a comfortable chair and instructed to study current class materials of their choosing for 10 minutes. Participants were notified of this intervention in advance to ensure they had class material to study.
Data Reduction and Statistical Analyses

All survey responses were recorded electronically using Qualtrics, an online survey tool. Data were downloaded and placed in a spreadsheet. Any missing data were imputed by averaging the scores from that specific survey or subscale and replacing the missing value with that average (i.e., AD-ACL – Calmness: Question 2 was blank, Q7=2, Q10=2, Q14=2, Q17=2, [2+2+2+2=8/4=2]. Therefore, a 2 was entered into the blank field for Q2). No surveys or subscales were missing a majority of the data points. Fifty-one data points out of 7030 total data points were calculated and entered across the whole experiment (0.7% missing). For datasets with few missing entries (<2%), single imputation or substitution methods should be considered because minor levels of missing data will lead to nearly identical results across methods and detrimental effects of using simple mean or individual mean substitution will not occur (Widaman, 2006).

HRV data points were exported from BioTrace+ in an interbeat interval table (IBI). IBI outliers were considered to be values more than 2.5 SD above or below the mean and were removed (Kassam, Koslov, & Mendes, 2009). Those data were imported
into Kubios HRV (version 2.0, 2008, Biosignal Analysis and Medical Imaging Group, University of Kuopio, Finland, MATLAB) and reduced to 5-minute segments, in which the simple math protocol was followed, for Pre-Intervention and Post-Intervention recordings. Low artifact removal and first order detrending in Kubios was run (Wells, Outhred, Heathers, Quintana, & Kemp, 2012). Detrending has been shown to remove the slow varying components without significantly altering spectral variables of HRV (Shafqat, Pal, Kumari, & Kyriacou, 2007). Pre- and Post-Intervention HRV variables (RMSSD, pNN50, HFnu, LFHF) were entered into the spreadsheet for the three interventions for each person. All data was then imported into IBM SPSS Statistics (Version 19) for statistical analyses.

Data were explored for normality, ANOVA assumptions, and outliers. The significance level was set at $\alpha=0.05$. To test the first hypothesis, a series of mixed-factor ANOVAs were then performed on psychological variables (State Anxiety, Affect: Energy, Tiredness, Tension and Calmness) to investigate differences across time (3; Pre, Post0, and Post15) and condition (2; EX, BF, and QS). Physiological variables (HRV variables: RMSSD, pNN50, HFnu, LFHF ratio) were also compared across time (2; Pre and Post) and condition (3; EX, BF, and QS). Sphericity was checked for violations and corrected using Greenhaus-Geisser data when necessary. Effect sizes were calculated for any significant main or interaction effects using Cohen’s $d$ ($d = \frac{(x_1-x_2)}{s}$), where $s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}}$. An effect size around 0.2 is considered small, 0.5 medium and 0.8 large (Cohen J., 1992). Finally, to investigate whether changes in HRV variables
explained psychological responses to the experimental conditions (hypothesis 2), repeated measure (time=3) ANCOVAs were performed on State Anxiety and Affect subscales (Energy, Tiredness, Tension, and Calmness), with pre/post intervention changes in HRV variables (ΔRMSSD, ΔpNN50, ΔHFnu, and ΔLFHF) included as covariates. Bonferroni corrections were made at the ANOVA level (α=0.05 / 5, corrected α=0.01 for psychological variables, α=0.05 / 4, corrected α=0.0125 for physiological variables).
CHAPTER 4

RESULTS

Data Reduction and Participant Details

All survey responses were checked for valid outcome values by exploring the data for outliers, minimum scores, and maximum scores in SPSS (Version 19). On average 1.82% of heart beat data points fell outside the 2.5 SD range used to identify outliers, and were removed from the dataset before analysis. The maximum amount of beats removed from a single session was 6.12% of the total number. Kubios HRV software’s Low Artifact Removal was run on each session’s Pre- and Post-Intervention HRV 5-minute recording. Low Artifact Removal eliminated on average 0.01% of the total data points, with a maximum of 2 data points from a single session.

Participants (18-32 year olds, PSS=22.1±4.3, n=32) had much higher levels of perceived stress compared to the age-based norms (PSS=14.2±6.2, n=648; Cohen J., 1992) with a large effect size (Cohen’s $d=1.3$). See Table 1 for Participant Characteristics.
Table 1

*Characteristics of participants included in analyses (n=32)*

<table>
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<tr>
<th>Characteristics</th>
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<tr>
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<tr>
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<td></td>
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<td>Trait Anxiety Inventory (out of 60)</td>
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<tr>
<td>Preferred Walking Speed</td>
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<tr>
<td>RPE during exercise (10 min.)</td>
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<tr>
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A two-way mixed-factor Condition (3 levels) x Gender (2 levels) ANOVA was conducted to compare each of the psychometric variables (State Anxiety and Affect: Energy, Tiredness, Tension, and Calmness) across conditions to check for potential baseline differences between conditions (i.e., at the Pre-intervention time point). There was an interaction (Condition x Gender) effect for Tension, in which females showed a significantly higher level of pre-intervention Tension in the QS condition compared to males ($F (2, 31)=3.174, p<.05, \eta^2=.096$). Males reported Tension of $7.4\pm.8$ and females $10.2\pm.9$ on a scale of 5 being low tension and 20 being high tension. No significant differences in Pre values of other psychometric measures (State Anxiety, Energy, Tiredness, and Calmness) or HRV variables (RMSSD, pNN50, HFnu, and LFHF) were observed; therefore, Pre variables differed only in Tension across conditions and gender. The subsequent analyses were, therefore, initially performed with Gender as a between-
subjects factor. However, no differences in gender were detected, so the factor was removed and all main analyses were rerun without Gender.

**Hypothesis 1: Changes in Psychological Variables across Time and Condition**

Performing the ANOVA on state anxiety revealed a Time x Condition interaction effect \( (F(4, 31)=4.235, p<.01, \eta^2=.120) \). Post-hoc ANCOVA results for BF showed a main effect for Time \( (F(2, 31)=9.895, p<.001, \eta^2=.268) \) on state anxiety. The effect size for BF Pre to Post0 was \( d=-.049 \) and Pre to Post15 was \( d=-0.39 \). This indicates that BF successfully reduced anxiety, but EX did not. See Figure 3 for changes in state anxiety across time and condition, Table 2 for means, standard deviation and effect sizes.

Performing the ANOVA on Energy revealed a Time x Condition interaction effect \( (F(4, 30)=3.588, p<.01, \eta^2=.107) \), a main effect for condition \( (F(2, 30)=9.148, p<.001, \eta^2=.234) \), and a main effect for time \( (F(2, 30)=5.883, p<.01, \eta^2=.164) \). Post-hoc ANCOVA results for EX showed a main effect for Time \( (F(2, 30)=7.745, p<.01, \eta^2=.230) \) on Energy. The effect size for EX Pre to Post0 was \( d=.68 \) and Pre to Post15 was \( d=0.04 \).

Performing the ANOVA on Tiredness revealed no significant results. Performing the ANOVA on Tension revealed a main effect for condition \( (F(2, 30)=7.190, p<.01, \eta^2=.193) \). Tension scores were higher for QS condition in general due to a previously reported Gender x Time effect at baseline. The standard deviation in the QS condition was also higher than the other conditions, which may have influenced the results and lack of condition x time interactions. Performing the ANOVA on Calmness revealed a Time x Condition interaction effect \( (F(4, 30)=5.100, p<.01, \eta^2=0.145) \) and a main effect for condition \( (F(2, 30)=10.141, p<.001, \eta^2=.253) \). Post-hoc ANCOVA results for BF
revealed a non-significant main effect for Time ($F(2, 31)=4.341, p<.05$). See Figures 4-7 for changes in affect, Energy, Tiredness, Tension, and Calmness and Tables 3-6 for changes in means, standard deviation, and effect sizes.

![Graph showing State Anxiety Inventory (min 0 - max 60) across time (Pre, Post0, Post15) by Condition (exercise, biofeedback, and quiet study).]

**Figure 3.** Anxiety: Mean change across time (Pre, Post0, Post15) by Condition (exercise, biofeedback, and quiet study)

**Table 2**

*Anxiety: Means, standard deviations, and effect sizes between time points and across conditions (exercise, biofeedback, and quiet study)*

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ES=Cohen’s $d$ effect size; Interaction effect for Time x Condition ($p<.01$)
Figure 4. Energy: Mean change across time (Pre, Post0, Post15) by Condition (exercise, biofeedback, and quiet study)

Table 3

*Energy: Means, standard deviations, and effect sizes between time points and across conditions (exercise, biofeedback, and quiet study)*

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</table>

ES=Cohen’s $d$ effect size; Main effect for Condition ($p<.001$) and Time ($p<.01$), Interaction effect for Time x Condition ($p<.01$)
Figure 5. Tiredness: Mean change across time (Pre, Post0, Post15) by Condition (exercise, biofeedback, and quiet study)

Table 4

Tiredness: Means, standard deviations, and effect sizes between time points and across conditions (exercise, biofeedback, and quiet study)

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<td>12.8</td>
<td>4.3</td>
<td>12.2</td>
</tr>
</tbody>
</table>

ES=Cohen’s $d$ effect size
Figure 6. Tension: Mean change across time (Pre, Post0, Post15) by Condition (exercise, biofeedback, and quiet study)

Table 5

Tension: Means, standard deviations, and effect sizes between time points and across conditions (exercise, biofeedback, and quiet study)

<table>
<thead>
<tr>
<th></th>
<th>EX</th>
<th>BF</th>
<th>QS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>ES differences</td>
</tr>
<tr>
<td>Post0</td>
<td>8.5</td>
<td>2.7</td>
<td>-.1</td>
</tr>
<tr>
<td>Post15</td>
<td>7.3</td>
<td>2.9</td>
<td>-.23</td>
</tr>
</tbody>
</table>

ES=Cohen’s d effect size; Main effect for Condition (p<.05).
Figure 7. Calmness: Mean change across time (Pre, Post0, Post15) by Condition (exercise, biofeedback, and quiet study)

Table 6

Calmness: Means, standard deviations, and effect sizes between time points and across conditions (exercise, biofeedback, and quiet study)

<table>
<thead>
<tr>
<th></th>
<th>EX</th>
<th></th>
<th></th>
<th>BF</th>
<th></th>
<th></th>
<th>QS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>ES differences</td>
<td>M</td>
<td>SD</td>
<td>ES differences</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>Post0</td>
<td>Post15</td>
<td></td>
<td>Post0</td>
<td>Post15</td>
<td></td>
<td>Post0</td>
<td>Post15</td>
</tr>
<tr>
<td>Calmness</td>
<td>14.3</td>
<td>3.1</td>
<td>-.48</td>
<td>-0.08</td>
<td>14.6</td>
<td>3.3</td>
<td>.5</td>
<td>15.4</td>
</tr>
<tr>
<td>Pre</td>
<td>12.9</td>
<td>3</td>
<td>.4</td>
<td>16.1</td>
<td>2.8</td>
<td>.32</td>
<td>14.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Post15</td>
<td>14.1</td>
<td>3.1</td>
<td></td>
<td>15.2</td>
<td>3.1</td>
<td></td>
<td>14.8</td>
<td>3.2</td>
</tr>
</tbody>
</table>

ES=Cohen’s $d$ effect size; Main effect for Condition ($p<.001$), Interaction effect for Time x Condition ($p<.01$)
Hypothesis 2: Physiological Changes as covariates of Psychological Changes

The QS condition did not appear to induce changes in psychological variables; therefore, it was not included in the follow-up analyses. To determine if changes in HRV variables across time were associated with changes in any of the psychometric variables within the EX and BF conditions, several ANCOVAs were performed. Specifically, separate analyses for EX and BF were conducted, with Time (3) repeated measures, and change in HRV variables (ΔRMSSD, ΔpNN50, ΔHFnu, and ΔLFHF) included as covariates. These analyses were performed on State Anxiety, Energy, Tiredness, Tension, and Calmness. Trends were discovered for the BF condition and Calmness with a main effect for Time ($F(2, 31)=4.341, p<.05$) and a Time x ΔpNN50 interaction ($F(2, 31)=4.331, p<.05$). No other interactions between time and HRV variables were observed. To further explore the effect of the interventions on heart rate variability, Condition (3) x Time (2) mixed-factor ANOVAs were run on RMSSD, pNN50, HFnu, and LFHF. Performing the ANOVA on pNN50 revealed a main effect for time ($F(1, 31)=8.203, p<.01, \eta^2=.209$). Performing the ANOVA on RMSSD, HFnu and LFHF Ratio revealed no significant effects.
CHAPTER 5

DISCUSSION

Stress is a helpful way for the body to activate physiologic systems that deal with stressors and changes in the environment, but chronic stress can place the body in a state of over-activation. This can lead to serious negative outcomes. University students are a particularly high-risk population, as illustrated by recent surveys (Downs & Eisenberg, 2012; Keyes, et al., 2012) showing increasing prevalence of mental health issues and demand for counseling services at universities. Therefore, it is important to present effective and accessible strategies for students to deal with stress to avoid the negative outcomes of chronic activation of the body from stress.

In this study, two acute interventions were evaluated with high-stress university students. A 10-minute self-paced walk (EX) and 10 minutes of paced-breathing with biofeedback (BF) were compared to a quiet study (QS) control condition to evaluate changes in anxiety and affect, which were measured by collecting questionnaire responses before and after each intervention. Heart rate variability (HRV) was also recorded before and after the intervention to determine if physiological changes accompanied potential changes in state anxiety and affect. It was hypothesized that both EX and BF would be more effective than QS in reducing state anxiety and improving affect. The second hypothesis was that changes in HRV would predict changes in state anxiety and affect.

The results demonstrate that the first hypothesis was only partially supported.
Specifically, the present study found that a 10-minute bout paced-breathing with biofeedback reduced anxiety, but self-paced walking did not appear to change anxiety significantly (Pre to Post15 effect sizes: $d=-.39$ for BF, $d=-.21$ for EX). This non-significant result for exercise contrasts somewhat to most other research on the effect of exercise on anxiety, yet the effect size found in the present study was comparable to that seen in other studies. In a recent systematic review on patients’ anxiety symptoms, chronic exercise training of 10 to 30 minutes reduced anxiety (over half of the 75 studies reviewed involved aerobic training), with a mean effect size of -.22 (Herring, O’Connor, & Dishman, 2010). Ekkekakis, Hall, Van Landuyt & Petruzzello (2000) also showed reduced state anxiety in 26 people after a 10-minute self-paced walk ($d=-.3$). Thus, it is plausible that the sample size in the present study was too small to find a significant effect of exercise on anxiety.

In contrast, the results from the BF condition did support the first hypothesis. State anxiety was significantly reduced immediately after the intervention ($d=-.49$) as well as 15 minutes after the intervention ($d=-.39$). These results are consistent with Prinsloo et al. (2011). After 10 minutes of training with a portable Respiratory Sinus Arrhythmia Biofeedback device they found significant reductions in state anxiety ($d=1.4$, $n=9$). They also found an effect in the control group participants who used a dummy device and were instructed to release stressful thoughts ($d=0.8$, $n=9$). The reduced anxiety seen in their control group could have been due to some placebo effect, which may suggest that a placebo condition may be warranted in biofeedback studies. However, the small sample size is a limitation of Prinsloo et al. (2011), so the conclusions
should be viewed with some caution. More research on this topic should be done to help establish a more standard experimental design. The present study sought to implement a practical control of quiet study to allow a realistic comparison between conditions.

In accordance with the first hypothesis, the QS condition did not appear to change state anxiety or affective variables. In contrast, EX significantly improved Energy \((d =.68)\) before returning to baseline and in the BF condition a trend revealed a temporary increase in Calmness \((d=.5)\). Ekkekakis et al. (2000) also reported short-lived energizing effects, decreases in Tension, and increases in Calmness during the recovery period after a short bout of self-paced exercise. Thayer (1987) compared the effects of self-paced walks to eating a sugar snack on affect and found that participants generally experienced an increase in Energy and decrease in Tension up to two hours after a 10-minute walk. Thus, the effects of the EX condition on affect in this study confirm previous research. The BF results are unique to this research because no previous studies were found that measured acute changes in affect in response to acute respiration biofeedback training.

Overall, these changes in state anxiety and affect show that students can have a positive influence over their stress-related emotions with acute bouts of BF or EX. The present results suggest, however, that exercise and biofeedback may serve slightly different psychological purposes. The findings can be summarized by highlighting that BF and EX changed affect in terms of the level of arousal. ES boosted arousal (increased Energy) and BF reduced arousal (increased Calmness), but both kept valence positive. Some students may prefer to decrease state anxiety and increase Calmness, and should
therefore choose BF over self-paced walking as an acute intervention. Others may prefer to feel more alert and stimulated and choose EX to feel more energetic.

The differences between the effect of BF and EX on affect and anxiety may be explained by differences in how EX and BF affect the autonomic nervous system. The result of exercise is a stimulation of the sympathetic nervous system, whereas the result of respiration biofeedback is parasympathetic nervous system activation. The second objective of the study addressed this issue, and it was hypothesized that HRV would predict changes in state anxiety and affect. Overall, this hypothesis was not supported by the results but, a trend was found linking the increase in calmness to a change in pNN50 in the BF condition. This indicates that further research should be done to evaluate whether or not improvement in Calmness and pNN50 in response to BF are associated. This relationship only appeared in the BF condition and not the EX condition. This may be explained by the participant associating increased parasympathetic activity (indicated by increased HRV) during BF with feelings of Calmness. Respiration Biofeedback has been shown to increase parasympathetic activity (Hayano et al., 1994), improve the baroreflex (Lehrer et al., 2003), which controls blood pressure, improves HRV, and decreases the stress response (Schipke, Pelzer, & Arnold, 1999). A study with a larger sample size may reveal a stronger relationship between increased Calmness and improved pNN50. The return of HRV to baseline levels after exercise may take more than 15 minutes (Barak et al., 2010) and is also a function of fitness (Seiler, Haugen, & Kuffel, 2007). EX may not produce significant results as the HRV measures may not have returned to baseline only 10 minutes after exercising (an activity that would be
expected to increase sympathetic activity, and thus, reduce HRV).

The inclusion of HRV variables was intended to explore a possible physiological mechanism by which the interventions improved state anxiety and affect, namely by influencing the autonomic nervous system (ANS) through reduced sympathetic activity or increased parasympathetic activity. Unfortunately, in this study no significant interactions between psychological variables and changes in HRV supported the second hypothesis, nor were Condition x Time interactions detected in the mixed-factor ANOVAs run on HRV variables. A Condition x Time interaction would mean that the interventions had differing effects on HRV. On the contrary, the results indicate that the interventions did not affect HRV differently. According to the second hypothesis, it was expected that improvements in state anxiety and affect would be explained by the HRV variables through parasympathetic nervous system activation or improved vagal nerve tone. This expected activation would have increased the respiratory sinus arrhythmia, in turn increasing variability in the beat-to-beat changes in heart rate resulting in greater HRV variable changes. It may be that: 1) the ANS is not the mechanism causing the observed changes in state anxiety and affect; 2) our sample group was not large enough; or 3) the duration of the interventions needed to be longer. In addition, comparing different scales between psychological measures and physiological measures may make finding differences more challenging or the measures were not sensitive enough.

The study had number of limitations that need to be acknowledged in order to effectively interpret these findings. Highly anxious students may have found learning a new skill (such as respiration biofeedback) to be stressful even if they appear to be doing
well. They may feel an expectation to master the skill immediately, even though they were told new skills take some time to learn and improve upon. They may think they are being evaluated by the researcher despite the space they were given during the practice time. Overall, five participants were dropped from the final sample because they were unable to produce smooth sign waves during breathing and a 50% coherence between heart rate and respiration rate, which were criteria included to assure that participants had learned effective paced-breathing. The challenge of learning a new skill, having a reduced respiratory sinus arrhythmia, or having a resonant breathing frequency outside of the normal 0.1 Hz (6bpm) range may explain their inability to meet the criteria. Acute biofeedback studies run the risk of missing the additional benefits, such as significantly greater HRV increases relative to relaxation techniques (Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009), of chronic biofeedback programs (Wells, Outhred, Heathers, Quintana, & Kemp, 2012).

Altogether, the five participants who were removed reduced the sample size by 13.5%, thereby increasing the possibility of Type II errors. A larger sample size would reduce possible Type II errors. Despite the small sample size and possibility of Type II errors, finding results in a small sample indicate that the interventions did cause significant differences in the dependent variables.

Many participants in the study were recruited from Kinesiology core classes. These students may have had some understanding of research and experimental design in exercise psychology and exercise physiology from exposure to this kind of research in various classes. This prior knowledge could have led to some expectancy of the desired
outcomes for the study. For example, they may expect that exercise would reduce anxiety, which may influence their survey results. Finally, it may have been obvious to some participants that the QS condition was a control condition and not an intervention.

This study was novel in its attempt to connect research questions that had been previously unlinked in the literature: could changes in HRV explain changes in state anxiety and affect seen as a result of self-paced exercise and respiration biofeedback? Although, the question was not fully answered, the trend between Calmness and pNN50 seen in the BF condition warrants further research. To sufficiently answer this question more studies on acute interventions and HRV should be conducted. To detect the expected acute changes in HRV, BF may require immediate post-intervention HRV recording. EX may require greater than 15 minutes before the post-intervention HRV recording.

There are several ways for this research to be continued. A larger study of a similar design could be performed to see if the results can be replicated and more conclusively determine whether the interventions can produce significant changes in HRV variables that differ between conditions. If HRV is affected differently by the interventions then covariance may be found between state anxiety/affect and the changes in HRV. If the alternative is true, that the ANS is not responsible for affecting changes in state anxiety and affect, research may need to be done to explore cognitive rather than physiological mediators of state anxiety and affect. It would also be useful to test the efficacy of biofeedback after the participant has learned the skill. A protocol where participants learn paced-breathing with biofeedback in the first session and then returned
for another session of paced-breathing without biofeedback may allow researchers to
determine how well the skill was learned and if students could be taught effective paced-
breathing in a single biofeedback session. Because Wells et al. (2012) were able to find
significant changes in HRV variables after a 30-minute intervention, it may be possible to
alter HRV after only an acute intervention but a longer duration may be required to see
the same result. The baselines for HFnu and LF/HF ratio variables in Wells et al.’s study
reflected more sympathetic activity than the current sample; therefore it may have been
easier to detect a change in their sample. Evaluating self-paced exercise and biofeedback
in a chronic training protocol could show the comparative effect of self-paced walking
and respiration biofeedback on state anxiety and affect over time.

To conclude, acute bouts of respiration biofeedback decreased anxiety and
increased Calmness. In addition, self-paced walking temporarily improved Energy. The
research also suggests that taking a 10-minute break to do one of these activities is likely
to have a more positive psychological effect on high-stress students than studying for
those 10 minutes. This study demonstrates that self-paced exercise and respiration
biofeedback can be recommended to stressed-out students to effectively, inexpensively,
and quickly improve their emotional state.
REFERENCES


### APPENDIX A: AD-ACL

**AD-ACL, 1989**

**Self-Assessment Inventory**

**INSTRUCTIONS:** Following are some adjectives that describe people’s feelings. Please, read each of the adjectives and then indicate how you are feeling at this particular moment, by circling the appropriate response. There are no right or wrong answers, so do not spend too much time on any one item. Check to make sure you have responded to all the items.

<table>
<thead>
<tr>
<th>Adjective</th>
<th>Definitely feel</th>
<th>Feel slightly</th>
<th>Cannot decide</th>
<th>Definitely do not feel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Active</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>2. Placid</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>3. Sleepy</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>4. Jittery</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>5. Energetic</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>6. Intense</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>7. Calm</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>8. Tired</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>9. Vigorous</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>10. At rest</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>11. Drowsy</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>12. Fearful</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>13. Lively</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>14. Still</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>15. Wide-awake</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>16. Clutched-up</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>17. Quiet</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>18. Full-of-pep</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>19. Tense</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
<tr>
<td>20. Wakeful</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>no</td>
</tr>
</tbody>
</table>

*Thayer (1989)*
## APPENDIX B: RPE

### Borg's Scale of Perceived Exertion

**Instructions**
During your exercise session we want you to listen to your body and pay close attention to how hard you feel the work is. The feelings you report should be your total amount of exertion and fatigue, combining all feelings of physical stress, effort and fatigue. Do not concern yourself with any one factor, e.g. leg pain, or shortness of breath, but try and concentrate on your inner feeling or effort. Try not to under or over estimate, be as accurate as you can (Borg, 1998).

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>very, very light</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>very light</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>fairly light</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>somewhat hard</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>hard</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>17</td>
<td>very hard</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>19</td>
<td>very, very hard</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>
APPENDIX C: STAI

State Anxiety Inventory-Y

INSTRUCTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and circle an answer to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement, but give the answer which seems to describe your present feelings best.

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Somewhat</th>
<th>Moderately so</th>
<th>Very Much so</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I feel calm</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2. I feel secure</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. I am tense</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. I feel strained</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. I feel at ease</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. I feel upset</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. I am presently worrying over possible misfortunes</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8. I feel satisfied</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9. I feel frightened</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10. I feel comfortable</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11. I feel self-confident</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12. I feel nervous</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13. I am jittery</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14. I feel indecisive</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15. I am relaxed</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16. I feel content</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17. I am worried</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18. I feel confused</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19. I feel steady</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20. I feel pleasant</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
## APPENDIX D: TAI-Y

### Trait Anxiety Inventory-Y

**INSTRUCTIONS:** A number of statements which people have used to describe themselves are given below. Read each statement and then circle an answer sheet to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement, but give the answer which seems to describe how you generally feel.

<table>
<thead>
<tr>
<th></th>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Often</th>
<th>Almost Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>I feel pleasant</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>I feel nervous and restless</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>I feel satisfied with myself</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>I wish I could be as happy as others seem to be</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>I feel like a failure</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6.</td>
<td>I feel rested</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7.</td>
<td>I am &quot;calm, cool, and collected&quot;</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8.</td>
<td>I feel that difficulties are piling up so that I cannot overcome them</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9.</td>
<td>I worry too much over something that really doesn't matter</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10.</td>
<td>I am happy</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>11.</td>
<td>I have disturbing thoughts</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>12.</td>
<td>I lack self-confidence</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>13.</td>
<td>I feel secure</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>14.</td>
<td>I make decisions easily</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>15.</td>
<td>I feel inadequate</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>16.</td>
<td>I am content</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>17.</td>
<td>Some unimportant thought runs through my mind and bothers me</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>18.</td>
<td>I take disappointments so keenly that I can't put them out of my mind</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>19.</td>
<td>I am a steady person</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>20.</td>
<td>I get in a state of tension or turmoil as I think about my recent concerns and interests</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
APPENDIX E: STAI SCORING

State Anxiety Inventory:
Add up all items to give one state anxiety score. Note that the following items should be reverse scored (i.e., 0=3; 1=2; 2=1; 3=0):
1, 2, 5, 8, 10, 11, 15, 16, 19, 20.

Trait Anxiety Inventory:
Add up all items to give one trait anxiety score. Note that the following items should be reverse scored (i.e., 0=3; 1=2; 2=1; 3=0):
1, 3, 6, 7, 10, 13, 14, 16, 19.
PERCEIVED STRESS SCALE

Sheldon Cohen

The Perceived Stress Scale (PSS) is the most widely used psychological instrument for measuring the perception of stress. It is a measure of the degree to which situations in one’s life are appraised as stressful. Items were designed to tap how unpredictable, uncontrollable, and overloaded respondents find their lives. The scale also includes a number of direct queries about current levels of experienced stress. The PSS was designed for use in community samples with at least a junior high school education. The items are easy to understand, and the response alternatives are simple to grasp. Moreover, the questions are of a general nature and hence are relatively free of content specific to any subpopulation group. The questions in the PSS ask about feelings and thoughts during the last month. In each case, respondents are asked how often they felt a certain way.

Evidence for Validity: Higher PSS scores were associated with (for example):

- failure to quit smoking
- failure among diabetics to control blood sugar levels
- greater vulnerability to stressful life-event-elicited depressive symptoms
- more colds


Temporal Nature: Because levels of appraised stress should be influenced by daily hassles, major events, and changes in coping resources, predictive validity of the PSS is expected to fall off rapidly after four to eight weeks.

Scoring: PSS scores are obtained by reversing responses (e.g., 0=4, 1=3, 2=2, 3=1 & 4=0) to the four positively stated items (items 4, 5, 7, & 8) and then summing across all scale items. A short 4 item scale can be made from questions 2, 4, 5 and 10 of the PSS 10 item scale.

Norm Groups: L. Harris Poll gathered information on 2,387 respondents in the U.S.

Norm Table for the PSS 10 item inventory

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>926</td>
<td>12.1</td>
<td>5.9</td>
</tr>
<tr>
<td>Female</td>
<td>1406</td>
<td>13.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-29</td>
<td>645</td>
<td>14.2</td>
<td>6.2</td>
</tr>
<tr>
<td>30-44</td>
<td>750</td>
<td>13.0</td>
<td>6.2</td>
</tr>
<tr>
<td>45-54</td>
<td>285</td>
<td>12.6</td>
<td>6.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>55-64</td>
<td>282</td>
<td>11.9</td>
<td>6.9</td>
</tr>
<tr>
<td>65 &amp; older</td>
<td>296</td>
<td>12.0</td>
<td>6.3</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>white</td>
<td>1924</td>
<td>12.8</td>
<td>6.2</td>
</tr>
<tr>
<td>Hispanic</td>
<td>98</td>
<td>14.0</td>
<td>6.9</td>
</tr>
<tr>
<td>black</td>
<td>176</td>
<td>14.7</td>
<td>7.2</td>
</tr>
<tr>
<td>other minority</td>
<td>50</td>
<td>14.1</td>
<td>5.0</td>
</tr>
</tbody>
</table>
APPENDIX G: PERCEIVED STRESS SCALE

The questions in this scale ask you about your feelings and thoughts during the last month. In each case, you will be asked to indicate by circling how often you felt or thought a certain way.

Date _________ Age ________ Gender (Circle): M F

0=Never 1=Almost Never 2=Sometimes 3=Fairly Often 4=Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?  
   0 1 2 3 4

2. In the last month, how often have you felt that you were unable to control the important things in your life?  
   0 1 2 3 4

3. In the last month, how often have you felt nervous and “stressed”?  
   0 1 2 3 4

4. In the last month, how often have you felt confident about your ability to handle your personal problems?  
   0 1 2 3 4

5. In the last month, how often have you felt that things were going your way?  
   0 1 2 3 4

6. In the last month, how often have you found that you could not cope with all the things that you had to do?  
   0 1 2 3 4

7. In the last month, how often have you been able to control irritations in your life?  
   0 1 2 3 4

8. In the last month, how often have you felt that you were on top of things?  
   0 1 2 3 4

9. In the last month, how often have you been angered because of things that were outside of your control?  
   0 1 2 3 4

10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?  
    0 1 2 3 4

Please feel free to use the Perceived Stress Scale for your research. The PSS Manual is in the process of development; please let us know if you are interested in contributing.
Mind Garden, Inc.
1690 Woodside Road, Suite #202
Redwood City, CA 94061 USA
Phone: (650) 261-3500 Fax: (650) 261-3505
e-mail: mindgarden@msn.com
www.mindgarden.com

References
APPENDIX H: DEMOGRAPHIC INFORMATION

Gender:  Male ☐  Female ☐

Age: ________  Height: _______________  Weight: _______________

Birthday (month/day/year): _____/_______/___

Are you currently taking any prescription medications? Yes ☐  No ☐

Stages of Change Questionnaire

<table>
<thead>
<tr>
<th>True</th>
<th>False</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I currently do not exercise ☐ ☐</td>
<td></td>
</tr>
<tr>
<td>2. I intend to exercise in the next 6 months ☐ ☐</td>
<td></td>
</tr>
<tr>
<td>3. I currently exercise regularly* ☐ ☐</td>
<td></td>
</tr>
<tr>
<td>4. I have exercised regularly* for the past 6 months ☐ ☐</td>
<td></td>
</tr>
<tr>
<td>5. I have exercised regularly* in the past for at least 3 months, but I am not doing so currently ☐ ☐</td>
<td></td>
</tr>
</tbody>
</table>

7-Day Physical Activity Recall Interview Questionnaire

Now we would like to know about your physical activity during the past 7 days. And also let me ask you about your sleep habits.

1. On the average, how many hours did you sleep each night during the last 5 weekday nights (Sunday through Thursday)? (Record to the nearest quarter-hour)
   ☐ ☐ ☐ Hours

2. On the average, how many hours did you sleep each night last Friday and Saturday nights?
   ☐ ☐ ☐ Hours
3. Now about your physical activities, let’s first consider moderate activities. What activities did you do and how many total hours did you spend during the last 5 weekdays doing these moderate activities or others like them? Please tell me to the nearest half-hour.

☐ ☐ Hours

4. Last Saturday and Sunday, how many hours did you spend on moderate activities and what did you do? (Probe: Can you think of any other sport, job, or household activities that would fit into this category?)

☐ ☐ Hours

5. Now let’s look at hard activities. What activities did you do and how many total hours did you spend during the last 5 weekdays doing these hard activities or others like them? Please tell me to the nearest half-hour.

☐ ☐ Hours

6. Last Saturday and Sunday, how many hours did you spend on hard activities and what did you do? (Probe: Can you think of any other sport, job, or household activities that would fit into this category?)

☐ ☐ Hours

7. Now let’s look at very hard activities. What activities did you do and how many total hours did you spend during the last 5 weekdays doing these hard activities or others like them? Please tell me to the nearest half-hour.

☐ ☐ Hours

8. Last Saturday and Sunday, how many hours did you spend on very hard activities and what did you do? (Probe: Can you think of any other sport, job, or household activities that would fit into this category?)

☐ ☐ Hours

Reminders for participants:
1. Do NOT smoke, drink caffeinated beverages, exercise or eat a heavy meal for 2 hours before testing time.
2. Come in comfortable clothes/shoes to exercise in.
3. Bring reading glasses if you need them for the surveys.
APPENDIX I: EMAILS TO PARTICIPANTS

RECRUITMENT FIRST E-MAIL

Subject title: Research Participants Needed

Are you feeling stressed? Do you want to know what your current stress level is and learn some ways to combat stress? We need male and female students, 18 and older, to participate in a research study. The study will involve three visits to a laboratory in the Forker Building at Iowa State University. You will get a free individualized stress profile using biofeedback equipment and you will learn several stress-reduction strategies. All participants will be entered into a raffle in which they will have a chance to win one of three cash prizes.

For more information about this study please contact:

Nathan Meier
nfmeier@iastate.edu (515) 451-1643

SECOND E-MAIL, AFTER A POTENTIAL PARTICIPANT CONTACTS US

Hi (name of participant),

Thank you for showing interest in participating in our study. This e-mail is to give you more information about the study.

You will be asked to attend three sessions in the exercise psychology laboratory in the Forker Building, Iowa State University. Each session will last approximately 30 minutes or less from the time that you enter until you leave, and will be scheduled based upon your availability and our lab schedule. You will be asked to complete several surveys and do one intervention during each visit. All participants will be entered into a raffle in which they will have a chance to win one of three cash prizes.

Please click on this link [LINK TO SURVEY HERE] for more details about the study and a brief survey, which we would like you to complete if you are interested in participating in the study. Please call me at (515) 451-1643 if you have questions and/or to set up an appointment.

Thank you,

Nathan Meier
(515) 451-1643

Eligible participants (e-mail to set appointments):

Hi (name of participant),

Thank you for taking the time to fill out the informed consent document and surveys online. From the information you provided we have determined that you qualify to participate in this study. Can you let
me know when you can come in for the first session? Please, email me several possible times you are available so I can setup a visit. Each session should be about a week apart. Also, please reply with your cell phone number if it would be easier for you to correspond via phone/text rather than via email.

Thank you again,

Nathan Meier
(515) 451-1643

After they write back to you, send this e-mail to fix the time/date of the appointments

Hi _____,

Thank you for your reply.

Your research session has been scheduled for _________ at ______ am/pm. I will meet you at the West entrance to the Forker Building (the one off of the parking lot) a few minutes before the scheduled time. The testing will take place at Room #164M. If you have any questions please call me (515) 451-1643 or e-mail me at nfmeier@iastate.edu.

A few reminders: Please do NOT smoke, drink caffeinated beverages, exercise or eat a heavy meal for 2 hours before testing time. Come in comfortable clothes/shoes. Bring reading glasses if you need them for the surveys.

Thank you,

Nathan Meier
(515) 451-1643

Reminder e-mail to send after the participant comes to the first session and you have had a chance to discuss face-to-face about the two other sessions

Hi _____,

Thank you for participating in our study. We have scheduled the other two sessions on the following dates:

Session 2: ___day ___(date) ___ am/pm(time)
Session 3: ___day ___(date) ___ am/pm(time)

Please let me know whether all these times work or if you need any changes.

Thank you,

Nathan Meier
(515) 451-1643
Final e-mail to participants at the end of the study

Hi ______,

Thank you for your participation. We will be holding our raffle soon and you will be contacted if your name was drawn.

Finally, I wanted to share with you the resources ISU has available for students. Please, see the website below for full details.

http://www.public.iastate.edu/~stdtcouns/

1.) individual therapy
2.) group therapy
3.) biofeedback training
4.) online mind-body spa
5.) meditation training (groups meet 2x per week)

Regards,
Nathan Meier
(515) 451-1643

E-mail for ineligible participants

Hi,

Thank you for taking the time to fill out the survey. Unfortunately, after reviewing your information we found that you are not eligible to participate in this study. We apologize for any inconvenience caused.

If you have further questions or you would like further information please feel free to contact me by e-mail (nfmeier@iastate.edu) or by phone (515) 451-1643.

Thank you very much again for your interest and time.

Regards,
Nathan Meier
For individuals who have responded initially and have not followed back with the Demographic Information

Hi ____,

This is a reminder about the study that you showed willingness to participate in. I have attached the documents again in case you did not save them. I appreciate your time.

Thank you,

Nathan Meier
(515) 451-1643
APPENDIX J: INFORMED CONSENT (INCLUSION / EXCLUSION)

INFORMED CONSENT DOCUMENT

Title of Study: A comparative study of psychological responses to three stress regulation strategies.

Investigators: Dr. Amy Welch, Nathan Meier, Olivia Palmer, Sam Konz

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION

The purpose of this study is to compare the psychological and physiological effects of breathing exercises guided by computer software (biofeedback), a short bout of physical activity, and a short period of quiet reading.

You are being invited to participate in this study because you may be a student with high perceived stress. You should not participate if you are not a student or are taking any prescription medication.

DESCRIPTION OF PROCEDURES

If you agree to participate, you will be asked to complete the Demographic Survey, which covers some questions about you and some physical activity habits, and the Perceived Stress Scale Survey, which asks about your personal stress, which should take about 5 minutes.

RISKS

There are no foreseeable risks at this time from participating in this study.

BENEFITS

If you decide to participate in this study there will be no direct benefit to you. It is hoped that the information gained in this study will benefit society by allowing the researchers to find suitable participants for a research study.

COSTS AND COMPENSATION

You will not have any costs from participating in this study. You will not be compensated for participating in this study.

PARTICIPANT RIGHTS

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled.

CONFIDENTIALITY

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional
Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.
To ensure confidentiality to the extent permitted by law, the following measures will be taken: all paper records will be kept in the psychology lab in the Forker Building under lock and key, any electronic data will have personal identifiers removed and stored on a password protected computer or access will be limited to the researchers. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study.

- For further information about the study contact:
  - Nathan Meier, (515) 451-1643, Forker 103C, nfmeier@iastate.edu
  - Dr. Amy Welch, (515) 294-8042

- If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

Title of Study: A comparative study of psychological responses to three stress regulation strategies.
Investigators: Dr. Amy Welch, Nathan Meier, Olivia Palmer, Sam Konz

PARTICIPANT AGREEMENT
Continuing on to the surveys indicates that you voluntarily agree to participate in this study screening process and provide information to complete the below surveys, that the study has been explained to you, that you have been given the time this read the document, and that you have no questions. You may print a copy of this informed consent for your records.
(Demographic Info, PSS, TAI will be given at this point)
APPENDIX K: INFORMED CONSENT (FULL)

INFORMED CONSENT DOCUMENT

Title of Study: A comparative study of psychological responses to three stress regulation strategies.

Investigators: Dr. Amy Welch, Nathan Meier, Olivia Palmer, Sam Konz

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION
The purpose of this study is to compare the psychological and physiological effects of breathing exercises guided by computer software (biofeedback), a short bout of physical activity, and a short period of quiet reading.

You are being invited to participate in this study because you are a student at Iowa State University who is interested in strategies to manage stress.

DESCRIPTION OF PROCEDURES
If you agree to participate, you will be asked to come for approximately 30 minutes for three sessions over the course of three weeks. Do not smoke, drink caffeinated beverages, exercise or eat a heavy meal for 2 hours before testing time. Come in comfortable clothes/shoes. Bring reading glasses if you need them for the surveys. You will be asked to fill out surveys and have your heart rate and blood pressure three times each session. The surveys will include questions about your normal emotional state and the emotions you are currently feeling. The sessions will include a quiet reading session, a short bout of exercise (walking at a preferred speed on a treadmill), and a short lesson on a breathing exercise with computerized feedback. You will complete each of the three conditions over the three sessions.

RISKS
There are no foreseeable risks at this time for participating in this study.

BENEFITS
If you decide to participate in this study there may be no direct benefit to you, though you may gain some knowledge about your own emotional state and be able to utilize the techniques you learn from participation in the study. It is hoped that the information gained in this study will benefit society by expanding our knowledge of the effects of quiet reading, biofeedback (the use of hardware and software to display physiological information from a person's body) and physical activity. We also hope to learn how these strategies may be used in peoples’ daily lives or in the medical profession to supplement
or replace other types of therapy or treatment.

**COSTS AND COMPENSATION**
You will not have any costs from participating in this study. All participants will be entered into a raffle in which they will have a chance to win one of three cash prizes.

**PARTICIPANT RIGHTS**
Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled. You can skip any questions that you do not wish to answer.

**CONFIDENTIALITY**
Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken: all paper records will be kept in the exercise psychology lab in the Forker Building under lock and key, any electronic data will have personal identifiers removed and stored on a password protected computer or access will be limited to the researchers. If the results are published, your identity will remain confidential.

**QUESTIONS OR PROBLEMS**
You are encouraged to ask questions at any time during this study.

- For further information about the study contact:
  - Nathan Meier, (515) 451-1643, Forker 103C, nfmeier@iastate.edu
  - Dr. Amy Welch, (515) 294-8042

- If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

**Title of Study:** A comparative study of psychological responses to three stress regulation strategies.

**Investigators:** Dr. Amy Welch, Nathan Meier, Olivia Palmer, Sam Konz
PARTICIPANT SIGNATURE
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant’s Name (printed)

(Participant’s Signature) (Date)
APPENDIX L: RECRUITMENT POSTER

Feeling Stressed Out?

Volunteers Needed

- Are you a student who wants to learn some new stress reduction strategies?

- We are looking for male and female participants for a research study investigating the effects of stress reduction strategies. As a volunteer you will receive introduction to some strategies that can help reduce stress and promote relaxation.

For more details and an information sheet, please contact:

- Nathan Meier: kinesiologyresearch@gmail.com; tel: 451-1643
- Dr. Amy Welch: amywelch@iastate.edu; tel: 294-8042
APPENDIX M: LIST OF ACRONYMS

AD-ACL: Activation Deactivation Adjective Checklist
ANS: Autonomic Nervous System
BPM: Breaths per minute
BF: Respiration Biofeedback intervention
EX: Self-paced walking intervention
HPA Axis: Hypothalamic-Pituitary-Adrenal Axis
HFnu: High Frequency normalized units
HRV: Heart Rate Variability
LF/HF Ratio: Low frequency High frequency Ratio
pNN50: Percent of the normal to normal waves greater than 50ms apart
PNS: Parasympathetic Nervous System
PSS: Perceived Stress Scale
QS: Quiet study intervention
RMSSD: Root mean of the square of the standard deviation
RPE: Rating of Perceived Exertion
RSA: Respiratory Sinus Arrhythmia
SAI: State Anxiety Inventory
SAM Axis: Sympathetic-Adrenal-Medullary Axis
SNS: Sympathetic Nervous System
STAI: State / Trait Anxiety Inventory
TAI: Trait Anxiety Inventory