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Investigating the Role of Social Support, Cardiovascular Reactivity, and Self-Regulation Skills Training in Response to Thermal Stimuli

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INVESTIGATING THE ROLE OF SOCIAL SUPPORT, CARDIOVASCULAR REACTIVITY, AND SELF-REGULATION SKILLS TRAINING IN RESPONSE TO THERMAL STIMULI

DISSERTATION

A dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
at the University of Kentucky

By
Tracey Christine Kniffin

Lexington, Kentucky

Director: Dr. Charles R. Carlson, Professor of Psychology

Lexington, Kentucky

2016

ABSTRACT OF DISSERTATION

INVESTIGATING THE ROLE OF SOCIAL SUPPORT, CARDIOVASCULAR REACTIVITY, AND SELF-REGULATION SKILLS TRAINING IN RESPONSE TO THERMAL STIMULI

Persistent pain conditions are a major health problem throughout the world and are one of the primary reasons that people seek medical treatment (Gureje, Von Korff, Simon, & Gater, 1998; Verhaak, Kerssens, Dekker, Sorbi, & Bensing, 1998). These conditions are characterized by complex interactions between cognitive, emotional, and physiological disturbances and are often associated with comorbid psychological disorders (Gatchel, 2004). Though previous studies have examined the effect of interventions targeting persistent pain, such as physical self-regulation interventions, few studies have examined the complex interaction between such interventions and other variables such as psychological and physiological functioning and presence of social support. The current study was designed to evaluate the effect of a physical self-regulation intervention (i.e. diaphragmatic breathing entrainment) on response to a brief physical stressor (i.e., mild thermal stimulation) as well as to evaluate whether presence or absence of a supportive partner influenced this relationship. Participant response was measured via self-report of pain intensity and unpleasantness and via physiological measures of respiration rate, blood pressure, heart rate, and heart rate variability. The study consisted of 154 female participants who participated in pairs (i.e., 77 pairs). Each participant was randomly assigned to training in diaphragmatic breathing or a control condition as well as being randomly assigned to complete the study with or without their supportive partner present. Analyses revealed that breathing entrainment resulted in significantly slower breathing rate during the thermal stressor task ($p < .01$). Presence of a supportive partner interacted with breathing entrainment to influence heart rate during the thermal stressor task ($p < .05$) such that participants who completed the study with a support person present had a lower heart rate when trained in diaphragmatic breathing than when trained in a control protocol and participants who did not have a support person present showed the opposite effect. Presence of a supportive partner also interacted with breathing entrainment to influence ratings of task unpleasantness ($p < .05$) such that participants who were trained in diaphragmatic breathing rated the task similarly regardless of presence or absence of a supportive partner, whereas participants who were trained in a control protocol rated the task as more unpleasant when accompanied by a supportive partner. In conclusion, the

present study demonstrates the impact of training in diaphragmatic breathing and presence of social support on response to thermal stimuli as measured by both self-report (i.e., ratings of task unpleasantness) and physiological (i.e., respiration rate and heart rate) measures. This study highlights the usefulness of implementing a self-regulatory training strategy for treatment of pain and in considering the efficacy of incorporating a supportive partner into such training.

KEYWORDS: Social Support, Cardiovascular Reactivity, Self-Regulation, Persistent Pain, Diaphragmatic Breathing

Tracey Christine Kniffin

June 15, 2016

Date

INVESTIGATING THE ROLE OF SOCIAL SUPPORT, CARDIOVASCULAR REACTIVITY, AND SELF-REGULATION SKILLS IN TRAINING RESPONSE TO THERMAL STIMULI

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Chapter One: Introduction

1.1 Biopsychosocial Model

In 1977, Dr. George Engel suggested that the medical field was facing a crisis due to overreliance on the biomedical model of disease (Engel, 1977). The biomedical model assumes that disease can be fully explained by measurable, biological variables and does not highlight the importance of considering other factors during treatment. As an alternative, he proposed a biopsychosocial model of disease that describes disease as the result of a complex and dynamic interaction among physiological, psychological, and social factors. The biopsychosocial model states that the specifics of each patient (i.e., his or her social context, psychological make-up, etc.) must be considered if one wishes to provide effective healthcare (Engel, 1977; Engel, 1980). The biopsychosocial model is widely lauded as advantageous in conceptualizing the reality of disease; however, professionals involved in both research and healthcare have faced challenges in adapting their approaches to be congruent with this theory (Suls & Rothman, 2004).

1.2 Persistent Pain

The experience of pain, and in particular persistent pain conditions, is one area in which the value of the biopsychosocial model is easily visible. Our understanding of pain has evolved, with early theories focused on tissue damage and purely physiological theories of disease etiology and maintenance. However, over time researchers and clinicians came to see that pain is related to complex interactions between physical, psychological, and social systems. In fact, the International Association for the Study of Pain (IASP) includes these components in their definition of pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (Merskey & Bogduk, 1994). Consistent with the biopsychosocial model, patients with pain also tend to report variability in their experience due to the range and interaction of physiological, psychological, and social factors that affect their interpretation of symptoms (Gatchel, 2004); for a full review of the evolution of pain models, see (Gatchel, Howard, Haggard, Contrada, & Baum, 2011; Gatchel, 2004).

1.2.1 Acute and Persistent Pain Conditions

Acute pain is typically understood as being short in duration, having an identifiable cause, and having adaptive function as a protective mechanism that prevents against potential tissue damage (Beecher, 1959; Merskey, 1986; Millan, 1999; Renn & Dorsey, 2005; Turk, 1987). Clinically, acute pain is typically understood as a symptom rather than a disease unto itself and tends to have a good to excellent prognosis (Renn & Dorsey, 2005). Conversely, persistent pain is defined as continuous, long-term pain lasting for a period of greater than three months or longer than the typical tissue healing time (Harstall & Ospina, 2003). Persistent pain is a major health problem in the United States and throughout the world and is one of the primary reasons that people seek medical treatment (Gureje et al., 1998; Verhaak et al., 1998). Further, beyond the profound effect that these disorders have on patients and their families, persistent pain conditions are estimated to cost billions of dollars each year in patients' interactions with the healthcare system and an additional $61.2 billion in lost productive time (Stewart, Ricci, Chee, & Morganstein, 2003). Thus, it is important that clinicians and scientists work to develop more effective treatment strategies for persistent pain conditions.

1.2.2 Treatment of Persistent Pain

One example of the integration of the biopsychosocial model into healthcare is the development of comprehensive, interdisciplinary models for treating persistent pain conditions (Gatchel & Okifuji, 2006; Gatchel, Peng, Peters, Fuchs, & Turk, 2007; Turk, Monarch, & Williams, 2002). Dr. John Bonica initially developed the idea for such an approach after observing inadequacies in the management of pain conditions for World War II soldiers injured in combat; and put his idea into practice after learning of the multidisciplinary pain service established by Drs. Bill Fordyce and John Loeser at the University of Washington (Bonica, 1977; Gatchel, McGeary, McGeary, & Lippe, 2014; Meldrum, 2007). Further support for the use of such an approach in the treatment of persistent pain is found in research demonstrating that typical biomedical interventions alone, such as pharmacological treatment with opiate medications and surgical interventions, may not be sufficient to produce long-term benefits (Gatchel et al., 2014). However, despite evidence demonstrating that an integrated, interdisciplinary approach is

both clinically effective and cost-efficient, such treatment is still not widely available for many chronic pain conditions (Kress et al., 2015).

Biopsychosocial treatment programs for the management of persistent orofacial pain conditions have a strong research tradition supporting the basic underlying principles for their use as well as addressing their clinical effectiveness with well-controlled randomized clinical trials. One of the most well supported mechanisms of pain discussed in previous literature is the role of the autonomic nervous system, specifically the sympathetic nervous system, in the etiology and maintenance of persistent pain conditions (Wall, Melzack, & Bonica, 1994) (Carlson et al., 1993b; Maixner, Greenspan, et al., 2011; Schmidt & Carlson, 2009; Solberg Nes, Carlson, Crofford, De Leeuw, & Segerstrom, 2010)(Hallman & Lyskov, 2012; Kang, Chen, Chen, & Jaw, 2012; Solberg Nes, Carlson, Crofford, De Leeuw, & Segerstrom, 2010). In particular, sympathetic nervous system activity is consistently tied to cardiovascular response to pain and other physical and psychological stressors; and, thus, addressing changes in cardiovascular response is a critical component of biopsychosocial interventions for persistent orofacial pain conditions.

1.3 Cardiovascular Response to Pain

Extensive previous research has investigated the connection between the experience of pain and autonomic nervous system response. The autonomic nervous system is composed of three major divisions, known as the sympathetic, parasympathetic, and enteric nervous system (Dodd & Role, 1991). The sympathetic nervous system is responsible for the stress response, or fight or flight mechanism, whereas the parasympathetic nervous system is responsible for returning the physiological system to homeostasis after sympathetic tone has been elevated, sometimes referred to as the rest and digest mechanism. The enteric nervous system is responsible for maintaining homeostasis in the body and works in concert with the central nervous system to control the digestive system in the context of physiological demands. (Dodd & Role, 1991).

Although the sympathetic response is necessary for survival, the presence of severe, prolonged, or chronic stressors can result in maladaptive physiological responses and greater allostatic load on the body (Goldstein & McEwen, 2002; McEwen, 2006; Purdy, 2013; Sapolsky, 2004). Over time, chronic stress results in up-regulation of the

sympathetic nervous system and makes one more susceptible to persistent pain conditions (Kendall-Tackett, 2010; Purdy, 2013). Sympathetic activity linked to acute pain conditions maintains vasoconstriction and may be related to the transition from acute to persistent pain (Nijs & Van Houdenhove, 2009). Patients with persistent pain exhibit sympathetic up-regulation in a variety of ways. For example, patients with persistent myofascial, orofacial, and arthritic pain all exhibit higher resting heart rates than pain-free controls (Brody et al., 1997; Carlson et al., 1993a; Maixner, Diatchenko, et al., 2011; Nilsson, Kandell-Collen, & Andersson, 1997; Perry, Heller, Kamiya, & Levine, 1989). Additionally, persistent pain has been reliably associated with lower high-frequency heart rate variability (HRV); heart rate variability refers to variation in interbeat intervals and is a measure of parasympathetic nervous system activity (Hallman & Lyskov, 2012; Kang, Chen, Chen, & Jaw, 2012; Solberg Nes et al., 2010).

Previous work has also revealed a high rate of comorbidity between persistent pain and heart disease, a condition that may also be caused by dysregulation of the autonomic nervous system (Fredrikson & Matthews, 1990; Kendall-Tackett, 2010; Light, 1981; Purdy, 2013). For example, in a study of patients with temporomandibular conditions, over 30 percent of patients were found to have cardiovascular conditions and over 19 percent to have hypertension (Burris, Evans, & Carlson, 2010). Interestingly, heightened response to stress and poor recovery following exposure to an acute stressor have been shown to occur in both individuals with persistent pain conditions as well as in individuals with hypertension and normotensive individuals with a family history of hypertension (Fredrikson & Matthews, 1990; Hastrup, Light, & Obrist, 1982; Hocking Schuler & O'Brien, 1997; Jorgensen & Houston, 1981; Manuck, Kamarck, Kasprowicz, & Waldstein, 1993; O'Brien, Haynes, & Mumby, 1998; Pierce, Grim, & King, 2005; Schneider, Jacobs, Gevirtz, & O'Connor, 2003; Wright, O'Donnell, Brydon, Wardle, & Steptoe, 2007).

Changes in autonomic variables have also been linked specifically to persistent orofacial pain conditions (Carlson et al., 1993b; Maixner, Greenspan, et al., 2011; Schmidt & Carlson, 2009; Solberg Nes et al., 2010). For example, the Orofacial Pain: Prospective Evaluation and Risk Assessment (OPPERA) project assessed profiles of individuals diagnosed with temporomandibular disorder (TMD) compared to individuals who were

not found to have TMD and compared autonomic variables as measured under resting conditions and in response to a physical stressor and psychological stressor task (Maixner, Greenspan, et al., 2011). Data from this study revealed that individuals diagnosed with TMD displayed dysfunction in autonomic activity as characterized by lower HRV at rest and in response to both physical and psychological stressors (Maixner, Greenspan, et al., 2011). They also found that individuals with TMD had higher heart rates in response to both physical and psychological stressors (Maixner, Greenspan, et al., 2011). Given these previous findings, it is important that treatments for persistent pain, and specifically persistent orofacial pain conditions, address cardiovascular response to stress. One such intervention is training in physical self-regulation.

1.4 Physical Self-Regulation

Self-regulation involves the capacity to exert control over cognition, emotion, physiology, and behavior and is defined as one's ability to alter his/her own responses by overriding one response in favor of a less common but more desired response (Baumeister, 1999; Baumeister, Schmeichel, DeWall, & Vohs, 2007; Baumeister, Vohs, & Tice, 2007; Carver & Scheier, 2001; Higgins, 1996; Solberg Nes, Roach, & Segerstrom, 2009). Self-regulation is also related to executive functioning, including the ability to make choices, such that repeated demands may lead to self-regulatory fatigue which may in turn impact executive functioning (Schmeichel, 2007; Schmeichel, Vohs, & Baumeister, 2003; Solberg Nes et al., 2009). Physical self-regulation refers specifically to the ability to exert control over physical processes such as through control of muscle tension (for example, clenching masseter muscles) or breathing pattern (for example, respiration rate and use of diaphragmatic breathing) (Carlson, Bertrand, Ehrlich, Maxwell, & Burton, 2001b).

1.4.1 Physical Self-Regulation and Pain

Since the etiology and maintenance of persistent pain is influenced by both physiological and psychological variables, successful interventions for pain management should have mechanisms of action that influence both physiological and psychological factors. One such intervention is training in physical self-regulation strategies including diaphragmatic breathing. For example, diaphragmatic breathing has been successfully

used for the treatment of insomnia, asthma, anxiety, depression, and a number of other psychological and stress-related medical conditions (Brown, Gerbarg, & Muench, 2013). As research has consistently found a high rate of comorbidity between persistent pain conditions and other physical and psychological conditions, this intervention may be uniquely suited for treatment of persistent pain (Burris et al., 2010; Tunks, Weir, & Crook, 2008).

Further, management of persistent pain conditions inherently require the use of self-regulatory strategies as patients must adhere to treatment regimens, engage in positive coping strategies, maintain relationships, and manage negative emotional experiences (Crombez, Vlaeyen, Heuts, & Lysens, 1999; Kabat-Zinn, Lipworth, & Burney, 1985; Solberg Nes et al., 2009). Despite the importance of self-regulatory ability in the management of persistent pain conditions, previous research has shown that persistent pain itself may interfere with the ability to self-regulate (Nes, Carlson, Crofford, De Leeuw, & Segerstrom, 2010). For example, one study found that patients with persistent pain conditions had less capacity to persist on a task following an initial self-regulation task than did persons without such pain conditions (Nes et al., 2010).

Fortunately, previous research has shown that regular "exercise" of self-regulatory skills can improve future capacity for self-regulation (Gailliot, Plant, Butz, & Baumeister, 2007; Muraven, Baumeister, & Tice, 1999; Oaten & Cheng, 2007). For example, participants who practiced daily self-regulatory tasks demonstrated better self-regulatory ability at follow-up than did those who did not engage in practice (Muraven et al., 1999). Training in diaphragmatic breathing, as well as subsequent practice of this skill, requires that patients engage in self-regulation as they must alter the dominant learned response of inattention to breathing habits and less adaptive breathing patterns. Thus, engaging in training and daily practice of diaphragmatic breathing may increase self-regulatory ability, which in turn may improve patients' ability to manage symptoms of persistent pain.

As expected, previous laboratory studies have found an effect of diaphragmatic breathing on measures of pain. One study trained a group of patients with persistent pain in diaphragmatic breathing and had patients practice this breathing in 10-minute increments, three times per day. After two weeks of daily practice, participants returned to

the laboratory to complete a cold pressor test. Results of this study demonstrated that participants who practiced at least 25 minutes per day had significantly improved pain tolerance and reduced pain sensitivity during the cold pressor task as compared to those who did not practice the recommended amount of time (Schmidt, Joyner, Tonyan, Reid, & Hooten, 2012).

Further, there is ample evidence that diaphragmatic breathing is successful in addressing persistent pain conditions in clinical populations (Brown et al., 2013). For example, a randomized, controlled trial of breathing entrainment compared to physical therapy for patients with chronic lower back pain found that patients who received training in diaphragmatic breathing improved more in self-reported ratings of pain, physical well-being, and emotional well-being than did patients who received just physical therapy (Mehling, Hamel, Acree, Byl, & Hecht, 2005). A different study found that a diaphragmatic breathing intervention utilizing biofeedback reduced the recurrence of migraine headaches more effectively than medication, an effect which was maintained at six and twelve month follow-ups (Kaushik, Kaushik, Mahajan, & Rajesh, 2005). Finally, in patients with chronic orofacial pain, training in diaphragmatic breathing along with other self-regulation skills reduced self-reported pain intensity and pain interference, a result which was maintained at 26-week follow-up (Carlson et al., 2001b).

1.4.2 Mechanisms of Action

The existing literature has examined possible mechanisms of action to explain the effect of diaphragmatic breathing in treatment of persistent pain. Some of these mechanisms focus on psychological changes, such as increasing self-regulatory capacity as discussed in the section above, while others focus on physiological changes. Several of the major physiological mechanisms that have been proposed are discussed below; however, it is likely the case that none of these mechanisms fully drives the effect seen from such an intervention and rather that all may complement one another.

As mentioned previously, persistent pain conditions have been consistently linked with changes in autonomic nervous system activity and with changes in the cardiovascular system such as reduced HRV (Hallman & Lyskov, 2012; Kang et al., 2012; Solberg Nes et al., 2010). Diaphragmatic breathing training may target persistent pain via increasing high

frequency HRV (Lehrer et al., 2003; Schmidt, Naranjo, et al., 2012; Vaschillo, Vaschillo, & Lehrer, 2006). This increase in HRV is interpreted as an increase in parasympathetic nervous system activity, which may counter the typical pattern of sympathetic nervous system activation seen in patients with persistent pain conditions. Thus, entrainment in diaphragmatic breathing may allow for a better balance between the sympathetic and parasympathetic nervous systems, reducing problematic sympathetic activity associated with persistent pain conditions (Carlson, Bertrand, Ehrlich, Maxwell, & Burton, 2001a).

A second way in which breathing entrainment is proposed to be beneficial in individuals with persistent pain conditions is through neuronal activity. Persistent pain conditions are linked to changes in the firing pattern of sensory neurons and may cause hyperexcitability in neurons in sensory pathways (Rogawski & Löscher, 2004). This hyperexcitability may contribute to increases in pain through a cycle of abnormal nociception (Nordin, Nyström, Wallin, & Hagbarth, 1984; Ochoa & Torebjörk, 1989). Though the exact mechanism of action is unknown, anti-epileptic drugs such as gabapentin and carbamazepine which are often prescribed to treat persistent pain may be exerting influence by inhibiting neuronal hyperactivity along these pain pathways (Rogawski & Löscher, 2004; Yogeeswari, Ragavendran, & Sriram, 2007).

Respiration parameters can also affect neuronal firing thresholds, and thus training in diaphragmatic breathing is one potential non-pharmacological intervention that may be used to diminish neuronal activity. During inhalation, depolarization of transmembrane voltage allows sodium (Na^+) ions to flow inward and rapid influx of Na^+ produces action potentials. Conversely, hyperpolarization occurs during exhalation (Monteau & Hilaire, 1991). Hypocapnea, defined as a state of reduced CO_2 resulting from hyperventilation, can increase neuronal firing during the low frequency portion of the respiratory cycle (Fried, 1993). On the other hand, when respiratory drive is low, the incidence of neuronal firing also decreases (Chen, Eldridge, & Wagner, 1991). Taken together, the evidence suggests that training in diaphragmatic breathing could potentially affect neuronal firing thresholds and quiet the hyperexcitability of sensory neurons to produce a reduction in pain (Glynn, Lloyd, & Folkhard, 1981).

A third proposed mechanism of action deals with the effect of respiration on blood chemistry and muscle fatigue. Respiration is directly tied to blood chemistry through the

control of oxygen (O_2) and carbon dioxide (CO_2) levels that regulate the pH of the blood, also known as the Bohr Effect (Bohr, Hasselbalch, & Krogh, 1904); for a review of this system, see (Hall & Guyton, 2011). Briefly, low levels of CO_2 in the blood, a condition which may be triggered by over-breathing, results in a change of blood pH in the alkaline direction. When blood pH becomes too alkaline, the ability of O_2 to dissociate from hemoglobin is decreased and body tissues are not adequately oxygenated, leading to muscle fatigue and increased pain perception (Fried, 1993; Hall & Guyton, 2011; Hilpert, Fleischmann, Kempe, & Bartels, 1963; Laffey & Kavanagh, 2002; Litchfield, 2003). Although the direction of the relationship is unclear, the comorbidity of muscle fatigue and persistent pain conditions has been well-documented in the literature (De Becker, Roeykens, Reynders, McGregor, & De Meirleir, 2000; Maquet, Croisier, Renard, & Crielaard, 2002; Meeus, Nijs, & Meirleir, 2007). For example, pain has been shown to persist following muscle fatigue even after allowing for rest (Svensson, Burgaard, & Schlosser, 2001; Torisu et al., 2006).

Diaphragmatic breathing can be adaptive and lead to maintaining O_2 and CO_2 levels and ensuring a normal (7.4) blood pH; and thus keeping tissues adequately oxygenated by the timely release of oxygen from hemoglobin (Litchfield, 2003). Further, previous work has demonstrated that diaphragmatic breathing reduces muscle activity and tension, particularly in the neck and shoulder regions (Lehrer, Sargunaraj, & Hochron, 1992; Ritz, von Leupoldt, & Dahme, 2006; Schwartz, 1995). Thus, by promoting healthy oxygenation of muscle tissues and reducing muscle activity and fatigue, diaphragmatic breathing may reduce pain levels.

1.4.3 Breathing Entrainment

Clinicians and researchers have taken a variety of approaches to training patients and study participants in the skill of diaphragmatic breathing. Naturally, this has led to efforts to determine the most effective protocol for training. For example, previous research has demonstrated the integration of diaphragm movement with a breath rate of 3-7 breaths per minute reliably improves HRV (Lehrer, Vaschillo, & Vaschillo, 2000; Vaschillo, Lehrer, Rishe, & Konstantinov, 2002; Vaschillo et al., 2006). However, until recently, previous literature was limited to examining the relationship between HRV and

respiration rate using a two-phased rhythmic breathing pattern with equal periods for inhalation and exhalation (Henriques, Keffer, Abrahamson, & Horst, 2011; Lehrer et al., 2000; Lin et al., 2012; Patron et al., 2013; Rosalba Courtney ND, 2011; Whited, Larkin, & Whited, 2014).

Our laboratory recently examined whether a breathing pattern including a rest phase within the traditional inhale-exhale cycle better altered HRV. As a result of this study, we have optimized our breathing entrainment protocol and found that a pause between exhalation and inhalation creates the optimal breathing rate as indexed by increased HRV (Russell, Under review). Further, this study demonstrated that an automated training protocol, utilizing audio recordings paired with a video prompt, may be used to complete training in the diaphragmatic breathing protocol. An ongoing goal in our laboratory is to refine and enhance our breathing entrainment protocol, and thus we have been thoughtful about modifications that may improve delivery and utilization of training. Thus, we seek to answer the question of whether integration of a patients' social support network into the training protocol may lead to further positive outcomes.

1.5 Social Support

Social relationships are a pervasive part of life and fulfil a variety of important functions across the lifespan (Uchino, Cacioppo, & Kiecolt-Glaser, 1996a). In particular, previous research has demonstrated that social relationships may lead to beneficial health effects through the buffering properties they may provide in the presence of stress and this discovery led to the use of the label "social support" (Cassel, 1976; Cobb, 1976; House, Umberson, & Landis, 1988). Despite this origin, the term "social support" is not always used consistently and the literature contains no clear consensus as to what constitutes social support (Dean & Lin, 1977; Pearson, 1986). However, in general social support seems to refer to both qualitative, such as the perceived meanings and expressive values of social relationships, and quantitative, such as length and complexity of relationships, ease of access to others, and number of relationships, properties (Adams, 1967; Berkman & Syme, 1979; Kaplan, Cassel, & Gore, 1977; Lowenthal & Haven, 1968; Pearson, 1986; Thoits, 1982; Tolsdorf, 1976). Both aspects of social support appear important in explaining the connection with well-being and health, with qualitative dimensions indicating the client's perception of what is supportive and the quantitative dimensions

indicating the presence of relationships available to the individual (Pearson, 1986; Tolsdorf, 1976; Wilcox, 1981).

1.5.1 Social Support and Health Outcomes

Despite differences in definition, one reliable finding in the literature is the relationship between social support and health outcomes (Eisenberger, 2013; Gottlieb, 1983). Compared to individuals with little social support (typically measured with self-report questionnaires), individuals who are socially integrated tend to live longer, have better mental health outcomes, and have higher resistance to a variety of medical conditions including cardiovascular disease and cancer (Berkman & Syme, 1979; Chida, Hamer, Wardle, & Steptoe, 2008; Eisenberger, 2013; House, Landis, & Umberson, 1988; Miller, Chen, & Cole, 2009; Seeman, 1996; Smith, Holt-Lunstad, & Layton, 2010; Uchino, 2006). Several mechanisms have been proposed to explain the effect of social support on health. For example, previous research has linked social support to altered neural and endocrine system activity which may affect disease pathophysiology via the sympathetic nervous system and the hypothalamus-pituitary-adrenal (HPA) axis (Bosch et al., 2009; Eisenberger, 2013; Uchino, Cacioppo, & Kiecolt-Glaser, 1996b). Additionally, previous work has revealed a positive link between social support and self-management of chronic illnesses such as diabetes (Gallant, 2003).

1.5.2 Social Support and Pain

Given the role of social support in chronic illness, it is not surprising that social support has also been implicated as having significant effects on the experience of pain in human populations. Research in clinical populations has found that perceived level of social support is associated with a wide range of outcomes in patients with persistent pain conditions including pain intensity, pain disability, activity interference, coping strategies, pain catastrophizing, and depression (Buenaver, Edwards, & Haythornthwaite, 2007; Cano, Leong, Heller, & Lutz, 2009; Cho, Zunin, Chao, Heiby, & McKoy, 2012; Evers, Kraaimaat, Geene, Jacobs, & Bijlsma, 2003; Holtzman, Newth, & Delongis, 2004; Jamison & Virts, 1990; López-Martínez, Esteve-Zarazaga, & Ramírez-Maestre, 2008; Stroud, Turner, Jensen, & Cardenas, 2006; Trief, Carnrike, & Drudge, 1995). Furthermore, the presence of a supportive person has been shown to reduce reported level

of pain in the cold pressor task and to have positive effects during childbirth (Brown, Sheffield, Leary, & Robinson, 2003; Chalmers, Wolman, Nikodem, Gulmezoglu, & Hofmeyer, 1995; Cogan & Spinnato, 1988; Niven, 1985). However, despite the documented importance of social support in pain conditions, no study to our knowledge has examined the effects of integrating a patient's social support system directly into interventions for pain management.

1.5.3 Social Support and Cardiovascular Response

Social support has also been implicated as playing a role in cardiovascular response to stress. For example, one experiment found that presence of a friend during a psychological stressor significantly reduced heart rate reactivity as compared to a group that underwent the task alone (Kamarck, Manuck, & Jennings, 1990). A separate study examined the effect of having one's opinions supported or not supported during a debate and found that participants in the support condition reacted with less than half the increase in blood pressure seen in participants in the "no support" condition (Gerin, Pieper, Levy, & Pickering, 1992). Previous work has also found that receiving support from a friend produced a greater reduction in cardiovascular reactivity than did receiving support from a stranger (Christenfeld et al., 1997). For a complete review of the literature connecting social support and cardiovascular reactivity, see (Christenfeld & Gerin, 2000).

1.6 Current Study

The current study was designed to evaluate the effect of a physical self-regulation intervention (i.e. breathing entrainment) on the response of participants to a brief physical stressor (i.e., mild thermal stimulation). Outcomes measured included subjective self-report measures (i.e. rating of pain intensity and unpleasantness) as well as physiological measures of respiration rate, heart rate, heart rate variability (HRV), and blood pressure. Paper and pencil measures of general perception of social support, symptoms of depression and pain-related anxiety, and personality factors were also collected. Additionally, the proposed study evaluated whether inclusion of a support person during breathing entrainment and administration of the brief physical stressor affects participants' outcomes as well as whether this effect is altered by the participant's perception of the quality of their social support. Finally, exploratory analyses were conducted to examine

the possible contribution of other psychological factors, such as depression, pain-related anxiety, social desirability, and personality factors, to participants' reaction to the thermal stressor task. Thus this study had two main foci. First, this study examined the effectiveness of our breathing protocol in reducing physiologic reactivity to and self-report ratings of pain and unpleasantness in response to a brief physical stressor (i.e., thermal stimulation). Second, this study examined the effect of including a social support person in the breathing entrainment protocol and on outcome measures during and following the brief stressor.

Chapter Two: Methodology

2.1 Overview and Study Design

All procedures were approved by the university's internal review board and all participants agreed to the study via an informed consent protocol. The present study consisted of a between-subjects design to investigate the impact of social support and breathing entrainment on responses to a thermal stressor task. Participants with a family history of hypertension were recruited in order to ensure cardiovascular response to the thermal stressor task (and therefore to improve likelihood of measuring a change in reactivity following intervention) and were asked to attend the study with a support person. Participants attended one study session that lasted approximately 1.5 hours and were randomly assigned to complete the study procedures with or without their support person present. Participants were also randomly assigned to receive training in a diaphragmatic breathing protocol or an attention control protocol. Additional measures were completed to obtain information about perceived social support, social desirability, symptoms of depression and pain-related anxiety, and personality factors. Physiological measures including respiration rate, heart rate, HRV, and blood pressure were also collected. No deception was involved in the study procedure.

2.2 Participants

Participants were 154 female undergraduate students who were enrolled at a public university in the east south-central region of the United States. In order to participate in the study, each participant was instructed to bring a female support person with her to the study session. Thus, the total sample size of 154 participants consisted of 77 main participants and 77 support persons. Participants were recruited for a study titled "Examining the Effect of Breathing and Social Support on Response to Thermal Stimuli" through flyers placed around campus and through an introductory psychology course subject pool. Participants who were eligible to receive course credit (i.e., those enrolled in certain psychology courses at the time of the study) received two course credits and $5.00 for their participation. Participants who were not eligible to receive course credit received $10.00 for their participation.

In order to participate in the study, all participants had to be between the age of 18 and 65 years old and identify as female. Additionally, the main participant was required to have a family history of hypertension; this criterion was selected to identify persons who might be more sensitive to the value of a self-regulation strategy. Main participants were also screened out prior to participation in the study if they had medical conditions affecting breathing such as asthma or pre-existing skin conditions such as psoriasis or rosacea and if they were taking any prescription pain medications. Main participants were also asked to abstain from use of over-the-counter pain medications, alcohol, and nicotine products for 24 hours prior to participation in the study. All participants were randomly assigned to complete study procedures alone or with their study partner and to receive training in diaphragmatic breathing or in an attention control protocol.

2.3 Recruitment Methods

Participants were recruited from undergraduate students participating in an introductory psychology course subject pool and by flyers placed on campus. Research participants were able to sign up for the study via email, phone, or through an online system. A brief description of the study that was used on recruitment materials is as follows:

> Friends between the age of 18 and 65 are invited to participate in a project entitled "Examining the Effect of Breathing and Social Support on Response to Thermal Stimuli." To participate in this study you must be female and between the ages of 18 and 65 with a family history of high blood pressure and you cannot have any conditions affecting breathing such as asthma, pre-existing skin conditions such as psoriasis or rosacea, or currently be taking any prescription pain medications (such as medications for migraines or other pain disorders). You must bring a female friend with you to the study session. The project will study how training in self-control procedures and being accompanied by a friend influence a person's perception of a brief heat stimulus. This study requires 1.5 hours (90 minutes) of time to complete. You may only participate in this study one time.

Participants who signed up for the study online or via email were called prior to their study appointment to screen for inclusion and exclusion criteria. During this contact, the following script was used:

> Hello, is this [participant name]? My name is [experimenter name] and I am calling you to schedule an appointment for you to participate in our study entitled, "Examining the Effect of Breathing and Social Support on Response to Thermal Stimuli." To participate in the study you must have a family history of high blood pressure and you cannot have any medical conditions that affect your breathing such as asthma, pre-existing skin conditions such as psoriasis or rosacea, or currently be taking any prescription pain medications (such as medications for migraines or other pain disorders). Would you still be interested in participating? (If the individual is not interested, politely end the conversation with "Thank you very much for taking the time to speak with me and have a good day.") Since you are still interested, I would like to schedule you to come to Room 119 of Kastle Hall on [date/time]. There is a small waiting area just inside the door and I will meet you there on [date/time]. Also, please know that you must bring a female friend with you on the day of your study and that you will both participate in this study together. Do you have a friend in mind? Also, please know that the experiment requires you to refrain from drinking alcohol, smoking, or taking any over-the-counter pain medication such as Advil, Tylenol, or Aspirin for at least 24 hours before your scheduled appointment.

Informed consent was obtained from both the main and support participant at the beginning of the study session. Inclusion and exclusion criteria were reviewed and the researcher explained that participants may stop the study anytime without penalty. Each participant was also given an informed consent form to read and sign before beginning any experimental procedures.

2.4 Design Overview

After arriving at the laboratory on the day of their appointment, all participants were reminded of inclusion and exclusion criteria and asked if they were still willing to participate in the study. All participants were additionally asked if they followed directions on abstaining from tobacco, alcohol, and over-the-counter pain medications for at least 24 hours prior to their appointment. All participants indicated that they had followed these directions prior to their study session. Participants then completed informed consent and received monetary compensation for their participation. Participant pairs were next randomly assigned to complete the study alone or with their support person present and to receive training in a diaphragmatic breathing protocol or an attention control protocol. At this time, participants randomly assigned to complete the study procedure alone were separated into two private rooms while those assigned to complete the study procedure together remained in the same room.

2.4.1 Design Overview for Paired Training

After obtaining informed consent, both participants completed paper and pencil measures. The main participant was then oriented to the thermal stimuli and underwent determination of their individualized temperature for the stressor task. Next, baseline physiological measurements were obtained for the main participants and then both participants watched a video of the diaphragmatic breathing protocol or an attention control protocol. Following this video, the main participant completed a brief physical stressor task during which she was exposed to a mild thermal stimulus. During completion of this task, the main participant was told to continue practicing the technique learned during the video and her support person was instructed to "provide verbal support and encouragement during the task." Physiological data for the main participant were collected during and after the stressor task. Both the main participant and the support participant remained together in the same testing room for the duration of the experiment. Thus, the order of research activities with estimated time for each task was as follows:

1. Complete informed consent (5 min)
2. Complete paper and pencil measures (30-45 min)
3. Determination of temperature for stressor task (5 min)

4. Attach sensors and physiologic baseline (10 min)
5. Breathing training and practice (10 min)
6. Brief physical stressor task (7 min)
7. Post-stressor physiological measurements (5 min)
8. Debriefing and exit (3 min)

2.4.2 Design Overview for Training Alone

Participants randomly assigned to training alone were separated into two private testing rooms after completing informed consent and remained in separate rooms for the duration of the experiment. Both participants were first given paper and pencil measures to complete. The main participant was then oriented to the thermal stimuli, completed baseline physiological measures, and watched a video with instructions on breathing training or a control protocol. Following this video, main participants completed the thermal stressor task with physiological data collected during and after this task. Time estimates remain consistent with those provided above for participants who underwent training together.

2.5 Paper and Pencil Measures

2.5.1 Demographics Form

The brief demographics form included questions about common demographic information (age, race, etc.), questions about current pain level, medications, and smoking status, and questions about the nature and duration of each participant's relationship with their study partner. Forms were filled out privately, so that presence of the support person did not impact ratings of the relationship quality. See Appendix A for a copy of the demographics form used.

2.5.2 Paulhus Balanced Inventory of Desirable Responses (BIDR)

The Paulhus Balanced Inventory of Desirable Responses (BIDR) is a 40-item measure that assesses for two facets, impression management and self-deceptive enhancement, of social desirability (Paulhus, 1984, 1986, 1994). While both scales assess for socially conforming responses, the impression management scale assesses conscious deception while the self-deceptive enhancement scale assesses unconscious

deception (Lanyon & Carle, 2007; Paulhus, 1994). The BIDR has been shown to have high internal consistency (coefficient alpha = 0.83) and moderate test-retest reliability (0.65 and 0.69 for impression management and self-deceptive enhancement, respectively) (Paulhus, 1994).

2.5.3 Center for Epidemiological Studies – Depression (CES-D)

The Center for Epidemiological Studies – Depression scale (CES-D) is a 20-item, unidimensional self-report scale designed to assess the presence and severity of depressive symptoms in the general population over the previous week (Brenner, 2011; Radloff, 1977). It includes symptoms encompassing four domains: depressive affect, somatic symptoms, positive affect, and interpersonal relationships (Radloff, 1977). Higher scores indicate greater frequency of symptoms with scores above 16 indicating the possibility of a depressive disorder (Brenner, 2011; Radloff, 1977). The CES-D has also been shown to have high internal consistency (coefficient alpha = 0.85) and moderate test-retest reliability (ranging from 0.45 to 0.70) (Radloff, 1977).

2.5.4 Pain Anxiety Symptoms Scale (PASS)

The Pain Anxiety Symptoms Scale (PASS) is a 53-item, self-report instrument designed to measure pain-related fear and anxiety across four domains (McCracken, Zayfert, & Gross, 1992). The PASS produces scores on four subscales including somatic anxiety, cognitive anxiety, fear, and escape/avoidance (McCracken et al., 1992). The somatic anxiety subscale assesses symptoms of physiological arousal related to the experience of pain. The cognitive anxiety subscale assesses cognitive symptoms related to the experience of pain such as racing thoughts or impaired concentration. The fear subscale measures fearful thoughts related to the experience of pain or the anticipated negative consequences of pain. Finally, the escape/avoidance subscale assesses maladaptive behavioral responses to pain. Internal consistency was high for all four scales (coefficient alpha ranged from 0.81 to 0.94) (McCracken et al., 1992).

2.5.5 NEO Five-Factor Inventory (NEO-FFI)

The Neo Five-Factor Inventory (NEO-FFI) is a shortened form of the NEO-PI-R that uses 60 items to assess personality traits across the five domains of personality

(neuroticism, extraversion, openness, agreeableness, and conscientiousness) (Costa, McCrea, & Psychological Assessment Resources Inc., 1992). Items are rated on a five point scale from 1 ("strongly disagree") to 5 ("strongly agree"). Internal consistency ranges from 0.68 to 0.86 for the NEO-FFI and test retest reliability ranges from 0.86 to 0.90 (Costa & McCrae, 1989; Robins, Fraley, Roberts, & Trzesniewski, 2001). The five factors of personality may be best understood as follows. Neuroticism is the tendency to experience unpleasant emotions or psychological distress. Extraversion refers to a variety of traits such as tendency to experience positive emotions, sociability, and the tendency to seek company of others. Openness is associated with appreciation of or willingness to engage in or consider new experiences or ideas. Conscientiousness refers to a tendency to be organized, dutiful, and reliable. Finally, agreeableness may be thought of as a tendency to be compassionate and trusting towards others.

2.5.6 Interpersonal Support Evaluation List (ISEL)

The Interpersonal Support Evaluation List (ISEL) is a 40-item measure that assesses perceived availability of interpersonal support across four domains: tangible support, appraisal support, self-esteem support, and belonging support (Brookings & Bolton, 1988; Cohen, Hoberman, Kamarck, & Mermelstein, 1983). The tangible support subscale measures the perceived availability of material support. The appraisal support subscale evaluates the perceived availability of someone with whom to have discussions about personal issues. The self-esteem support sub-scale measures the perceived presence of someone with whom the individual feels he/she compares favorably. Finally, the belonging support subscale assesses for the perception that there is a group of people within which a person can identify and socialize. The ISEL has high internal consistency (coefficient alpha estimated between 0.77 and 0.90) and high test-retest reliability (estimated between 0.71 and 0.87) (Heitzmann & Kaplan, 1988).

2.6 Physiological Measures

Blood pressure was recorded using a standard blood pressure cuff placed on the non-dominant arm at four time points during the study (immediately before baseline heart rate and breathing data are collected, immediately before the brief physical stressor, immediately following the physical stressor, and at the end of the post-stressor collection

of heart rate and breathing rate). Heart rate, HRV, and breathing rate were collected for five minutes before breathing entrainment, during exposure to the brief physical stressor, and for five minutes following the brief physical stressor. To collect heart rate, HRV, and breathing rate, the experimenter attached physiological sensors to the participants (only after receiving permission to do so) in accord with standard clinical protocol (Carlson et al., 2001a). Heart function was recorded using three Ag/AgCl electrodes using shielded leads connected to a BioPac ECG100C electrocardiogram amplifier module and respiration rate was recorded using the respiration module for the BioPac MP100 system. All data were collected at a sampling rate of 2000 samples/second.

2.7 Breathing Entrainment

An experimenter explained to participants that they would be given instructions on a breathing pattern, be asked to demonstrate the pattern correctly, and then be asked to perform this pattern of breathing during the physical stressor task. Participants were randomly assigned to receive either diaphragmatic mechanics training with instructions to follow a 4-2-4 breathing pattern at a rate of 5-6 breaths per minute or, alternatively, were given no instructions on diaphragmatic breathing mechanics and instructed to breath at a pattern of 12-14 breaths per minute. Instructions were given via audio recording with an accompanying visual aid. An in-room computer displayed the video for breathing training; the video's visual cue consisted of an oval that expands, contracts, and remains still at each breathing conditions' specified rate. The breathing videos included a soft tone corresponding with the inhalation period and preceding the oval beginning to expand as a guide to the breathing rate. After watching the training video, participants were given an opportunity to ask questions and practice their breathing.

2.7.1 Diaphragmatic Breathing Training Script

The following script was used in combination with the video described above for participants randomly assigned to receive training in diaphragmatic breathing.

> We are very interested in understanding your responses to the study procedures. Breathing so that the stomach is moving in and out rather than breathing with your chest can help relax you. This stomach breathing, or

diaphragmatic breathing, can help you relax and maintain calmness in today's study experience.

Please remember the rule: you should do nothing to increase your sense of discomfort while you are practicing the breathing. To start breathing with your stomach, or diaphragm, you should rest in a comfortable position with your head centered, supported and in the midline of your body; your eyes are closed, with smooth eyelids; and smooth forehead; your mouth is relaxed: with lips apart, teeth apart, and tongue relaxed; there's no throat movement; your shoulders are sloped and even; elbows bent; your hands will be in a curled, relaxed position, not touching one another; knees are apart; and feet are pointing away from one another at a 45-90 degree angle.

Then, place your right hand just below your rib cage on top of your stomach. Just exhale first to release air from your body—it should be a complete, relaxed release where there is no holding, controlling, or forcing of the release—it is like a balloon collapsing as you let your air go from your body. When you are ready to take your next breath of air in; let the stomach gently rise as if you are pushing your stomach up with the column of air coming in. After you take in a comfortable, normal breath, release your muscles and let the air go just as you did at first when you started the exercise...there is no controlled, gradual release, just let go all at once and have the air move naturally out of your body. Then, pause and rest for a few moments before you take air in again to start another breath cycle. The rest period between breaths is the deepest point of your relaxation when everything is quiet and you relax before taking air in again. (Pause for 10 seconds)

From the beginning of this training, you should breathe at a pace that makes you feel comfortable. (Pause for 5 seconds) You also want to breathe naturally and not too deeply in order to avoid over breathing or hyperventilation. If you were to feel light-headed or dizzy, chances are you

are taking in too much air with each breath…take a little less air in on your next breath and the breaths that follow. (Pause 10 seconds) Most people find that counting to 4 while air is coming into your lungs may set a natural, relaxed pace. Once the air is released, the rest period is typically the time it takes to count from 1 to 4. So, a starting pace for you can be counted as "air in-2-3-4; release; and rest-2-3-4." (Repeat this phrasing 2 times)

Repeat this breathing pattern for several minutes to establish a comfortable, relaxed rhythm to your breathing. (Pause for 5 seconds) Let your stomach rise as air enters, then let the stomach fall as you release the air, and let everything rest until taking in your next breath of air. (Pause for 10 seconds) Your breathing rate will likely be somewhere between 5-6 breaths per minute as you practice diaphragmatic breathing. Let your breathing be slow and relaxed as your stomach moves up and down. Please use this diaphragmatic breathing method throughout your remaining time in the laboratory.

2.7.2 Attention Control Training Script

The following script was used in combination with the video described above for participants randomly assigned to the control condition.

We are very interested in understanding your responses to the study procedures. Since we all have our own ways of responding to what happens to us, we are interested in following your responses carefully. The purpose of our project is to better understand the ways in which individuals such as yourself respond to the application of the laboratory procedures.

First of all, it is important to remember the rule that you should do nothing to increase your sense of discomfort. Take a few moments to notice your surroundings and let yourself get comfortable and settle in. We would like for you to sit quietly during the procedure and let your attention be directed

to the activities going on around you. You should be observing yourself and your environment as you undergo the laboratory experience. Please remain aware of your surroundings and what is happening at any given moment. Take a few minutes now to let yourself be aware of what is happening. (Pause for 5 seconds)

Next, we would like you to focus on the pace of your breathing. To start breathing, you should rest in a comfortable position. Just exhale first to release air from your body. When you are ready to take your next breath of air in; let the lungs fill as you count to three. After you take in a breath, let the air go just as you did at first when you started the exercise. From the beginning of this training, you should breathe at a pace that makes you feel comfortable. (Pause for 5 seconds) You also want to breathe naturally and not too deeply in order to avoid over breathing or hyperventilation. If you were to feel light-headed or dizzy, chances are you are taking in too much air with each breath…take a little less air in on your next breath and the breaths that follow. (Pause 10 seconds)

Most people find that counting to 3 while air is coming into your lungs may set a natural, relaxed pace. Then, once the air is released, you begin the next breathe cycle. So, a starting pace for you can be counted as "air in-2-3 and release." (Repeat this phrasing 2 times, read "release" slowly) Repeat this breathing pattern for several minutes to establish a comfortable, relaxed rhythm to your breathing. (Pause for 5 seconds) Your breathing rate will likely be somewhere between 12-14 breaths per minute as you practice. We will want you to use this breathing pace and let yourself be aware of what is happening around you throughout your remaining time in the laboratory.

2.8 Thermal Stimuli

The brief physical stressor task occurred immediately following breathing entrainment. The stressor consisted of unilateral, intermittent heat stimulation to structures innervated by the mandibular branch of the trigeminal nerve on the side of the

non-dominant hand. Prior to breathing entrainment, each participant was familiarized with the thermal stimulation equipment and the temperature necessary to achieve a "7 out of 10 pain" level was determined. After breathing entrainment, the thermal stimulus was delivered as a stressor while participants were instructed to practice breathing as per their training. If randomly assigned to complete the study with their support partner present, the support partner was asked to "provide verbal support and encouragement during the task." Physiological recordings of heart rate, HRV, and respiration rate were made continuously during the stressful task. The total stressor time was about 7 minutes, allowing for 5 repetitions.

2.8.1 Determination of Temperature

On the day of the study, the participant was familiarized with the thermal stimulation equipment. Temperature-evoked stimuli were applied through a Peltier thermode (TSAII, Medoc, Ramat Yishai, Israel) of size 30 by 30 (mm). It was anticipated that most participants would experience a 39.5°C stimulus as a non-painful warm stimulus, and 47°C as a painful hot stimulus. However, to account for individual differences in perceived pain intensity, for each participant the temperature needed to achieve a "7 out of 10 pain" on scale where "0" represents "no pain" and "10" represents "the most extreme pain" was determined. To do this, the participant held the thermode securely to the lower part on one side of the face, against the skin overlying the masseter muscle. With the other hand the participant held a controlling device. The "7 out of 10" pain supra-thresholds were determined with the method of limits. Starting from a baseline of 32ºC, the temperature of the thermode increased by 0.5ºC every second up to a maximum of 50ºC. Each participant was instructed to stop the heat by pressing the button on the controlling device as soon as the temperature was perceived as a "7 out of 10". This procedure was repeated 5 times to obtain an average suprathreshold. After 30 seconds this sequence was repeated for measurement consistency and reliability purposes. The average of the temperatures was used as the stressor temperature. The stimulus temperatures are well below the limits of potentially tissue damaging temperature ranges. However, as a safety feature, the thermal analyzer automatically returned to the baseline temperature upon reaching 50ºC.

2.8.2 Thermal Stressor Task

During the stressor task, a repetitive cycle consisting of a 25 second period of a 32°C baseline temperature, followed by a 25 second period of warm (39.5°C) non-painful stimulation, followed by 5 pulses of painful heat (individually adjusted to reach a "7 out of 10" pain) was delivered during a period of approximately 30-35 seconds. The total stressor time was about 7 minutes, allowing for 5 repetitions. Immediately following the stressor task, participants were asked to provide a rating of pain unpleasantness on a scale from 0 to 10 where 0 is "not at all unpleasant" and 10 is "the most unpleasant sensation possible." Participants were also asked to rate the painfulness of the physical stressor task on a scale from 0 to 10 where 0 is "no pain" and 10 is "the most extreme pain." Additionally, physiological data were collected before, during, and after the thermal stressor task.

2.9 Hypotheses and Planned Data Analyses

2.9.1 Hypotheses

The current study examined the following hypotheses:

1. Compared to participants trained in the control breathing protocol, participants trained in the diaphragmatic breathing protocol will:
    a. have a lower respiration rate during and following the thermal stressor task.
    b. have an improved physiological reaction during and following the thermal stressor task (i.e., lower blood pressure, lower heart rate, and increased HRV).
    c. rate the thermal stressor task as less painful and as a less unpleasant experience than those in the other conditions.
2. Presence of a social support person during the study session will increase the positive effects of training in the diaphragmatic breathing protocol.
3. The effect of having a social support person present will be influenced by the quality of the relationship participants have with their study partner.
4. A portion of the variance in significant relationships will be accounted for by perceived social support, depression, anxiety, and personality variables.

2.9.2 Power Analysis

An a priori power analysis was conducted using G*Power software and was used to calculate the necessary sample size to achieve 80% power (Faul, Erdfelder, Buchner, & Lang, 2009). Sample size was estimated using an estimated medium effect size, 80% power, and an alpha level of 0.05. Power analysis was conducted with an estimated medium effect size based on the results of previous studies that demonstrated a medium effect size for change in heart rate variability and a large effect size for change in breaths per minute (Russell, Under review). This analysis revealed that a total sample size of at least 64 participants was needed to detect medium effects.

2.9.3 Planned Statistical Analyses

First, results were analyzed with multivariate analyses of variance (MANOVA) tests to check for baseline differences in demographic variables, psychological self-report measures, and physiological measures. Next, the effect of training in diaphragmatic breathing versus a control breathing protocol and of the presence of absence of a support person on physiological measures (i.e., heart rate, HRV, respiration rate, and blood pressure) during and following the thermal stressor task and on pain and unpleasantness ratings was examined with multivariate analyses of covariance (MANCOVA) tests. Analyses were repeated with measures of social support (specific to the relationship between study partners as well as a general measure of perceived social support) entered as covariates. Finally, significant findings were evaluated with hierarchical regression to examine the effects of psychological variables.

Chapter Three: Results

3.1 Participant Demographics

The study sample consisted of 154 female participants who participated in pairs. Thus there were 77 main participants and 77 support participants. Participants were randomly assigned to receive training in paced diaphragmatic breathing or training in a control protocol and to complete the experiment with or without a support person present. Thus, participants were randomly assigned into one of four experimental groups. In total, 20 participants were assigned to training in breathing without a support person present, 19 were assigned to control training without a support person present, 19 were assigned to training in breathing with a support person present, and 19 were assigned to control training with a support person present.

3.1.1 Main Participants

The average age of main participants was 18.65 (standard deviation (SD) = .82). The sample of main participants was predominantly White/Caucasian (n = 60, 77.9%); 11 (14.3%) participants were African American, 2 (2.6%) participants were Asian American, 1 (1.3%) participant was Hispanic, 1 (1.3%) participant was Middle Eastern, 1 (1.3%) participant was multi-racial, and 1 (1.3%) participant identified as "other." All of the main participants indicated that they were currently single and never married.

The majority of main participants denied experiencing pain (n = 61, 79.2%). Of those who did report experiencing pain (n = 16, 20.8%), 10 (13.0%) reported pain in one location and 6 (7.8%) reported pain in two locations. Those who reported pain estimated that their pain had been present for between 15 and 192 months (mean = 56.07, SD = 50.18) and rated their current pain level between 1 and 7 (mean = 2.87, SD = 2.10) on a scale from 0 to 10 (with 10 equal to the worst pain imaginable). Only three main participants (3.9%) reported taking pain medication and all of those participants stated that they were taking these medications as needed only and had not used the medications for more than 24 hours prior to their study session. None of the main participants reported taking medication for hypertension. Only 1 main participant (1.3%) reported using nicotine. This participant reported smoking 1.5 packs of cigarettes per day.

3.1.2 Support Participants

The average age of support participants was 19.08 (standard deviation = 3.78). The majority of support participants identified as female (98.70%) with one support participant identifying as transgendered (1.3%). Support participants predominately identified themselves as White/Caucasian (n = 56, 72.7%); 13 (16.90%) were African American, 5 (6.5%) were multi-racial, 2 (2.6%) were Hispanic, and 1 (1.3%) was Asian American. The majority of support participants (n = 75, 97.4%) were single and 2 (2.6%) were married.

The majority of support participants denied experiencing pain (n = 55, 71.4%). Of those who did report experiencing pain (n = 22, 28.6%), 12 participants (15.6%) reported pain in one location, 7 participants (9.1%) reported pain in two locations, 2 participants (2.6%) reported pain in three locations, and 1 participant (1.3%) reported pain in four locations. Those who reported pain estimated that their pain had been present for between 2 and 84 months (mean = 15.95, SD = 32.89) and rated their current pain level between 0 and 5 (mean = 1.05, SD = 2.13) on a scale from 0 to 10 (with 10 equal to the worst pain imaginable). Only two support participants (2.6%) reported taking pain medications and one (1.3%) reported taking medicine for hypertension. Only three support participants (3.9%) reported using nicotine and all three declined to report their average level of use. See Table 1 for a summary of demographic characteristics for main and support participants.

3.1.3 Supportive Relationships

All participants were asked to provide information about the nature, duration, and quality of their relationship with their study partner. The majority of participants (n = 70, 90.9%) were accompanied by a friend; 2 (2.6%) participants were accompanied by roommates, 2 (2.6%) participants were accompanied by a sibling, 2 (2.6%) participants were accompanied by cousins, and 1 (1.3%) participant was accompanied by her mother. The average duration of the relationships was 44.80 months (standard deviation = 61.43) with a minimum length of 1 month and a maximum length of 240 months.

Participants were asked to rate the quality of their relationship on a scale from 0 to 10, with 10 indicating the best possible quality. The mean rating for main participants was 8.66 (SD = 1.55) with a minimum rating of 4 and a maximum rating of 10. The mean

rating for support participants was 8.78 (SD = 1.43) with a minimum rating of 5 and a maximum rating of 10. Participants were also asked to rate the quality of support they receive from their partner on a scale from 0 to 10, with 10 indicating the best possible support. The mean rating for main participants was 8.99 (SD = 1.45) with a minimum rating of 3 and a maximum rating of 10. The mean rating for support participants was 9.00 (SD = 1.35) with a minimum rating of 4 and a maximum rating of 10. The majority of participants rated the quality of their relationship as 10/10 (n = 36 for main participants and n = 34 for support persons) and the quality of support from their partner as 10/10 (n = 44 for pain participants and n = 42 for support persons). See Table 2 for a summary of data on support relationships.

3.2 Baseline Analyses

3.2.1 Baseline Analyses for Demographic Variables

Two-way MANOVA tests were conducted to examine differences between groups (e.g., breathing training condition and social support condition) for demographic variables (e.g., age, gender, race, relationship status, employment status, household income, current pain, use of pain medication, and use of nicotine). For main participants, results from this two-way MANOVA found no significant multivariate effect for breathing training condition (Wilks' Lambda: $F(7,65) = 1.27$, $p = .28$), for social support condition (Wilks' Lambda: $F(7.65) = .87$, $p = .53$), nor for the interaction of these variables (Wilks' Lambda: $F(7,65) = 1.06$, $p = .40$).

For support participants, results from this two-way MANOVA found no significant multivariate effect for breathing training condition (Wilks' Lambda: $F(9,63) = .90$, $p = .53$) nor for social support condition (Wilks' Lambda: $F(9,63) = 1.35$, $p = .23$). A significant multivariate effect was observed for the interaction of these two variables (Wilks' Lambda: $F(9,63) = 2.27$, $p < .05$). Follow-up univariate analyses revealed a significant effect for race ($F(1,75) = 8.25$, $p < .01$, $\eta^2 = .10$) and thus this variable was controlled for in all analyses of the hypotheses. Results for all other univariate analyses were not significant (all p values > .05).

Two-way MANOVA tests were also conducted to examine differences between groups for type, length, and quality of the supportive relationship between study partners.

Results from this two-way MANOVA found no significant multivariate effect for breathing training condition (Wilks' Lambda: $F(6,65) = .31$, $p = .93$), for social support condition (Wilks' Lambda: $F(6,65) = .76$, $p = .61$), nor for the interaction of these variables (Wilks' Lambda: $F(6,65) = 2.23$, $p = .05$).

3.2.2 Baseline Analyses for Psychological Measures

Two-way MANOVA tests were conducted to examine differences between groups for psychological self-report measures (e.g., CES-D, PASS, PBIDR, ISEL, and NEO-FFI). For main participants, results from this two-way MANOVA found no significant multivariate effect for breathing training condition (Wilks' Lambda: $F(16,43) = .69$, $p = .79$), for social support condition (Wilks' Lambda: $F(16,43) = 1.45$, $p = .17$), nor for the interaction of these variables (Wilks' Lambda: $F(16,43) = .74$, $p = .74$). For support participants, results from the two-way MANOVA found no significant multivariate effect for breathing training condition (Wilks' Lambda: $F(16,53) = .73$, $p = .75$), for social support condition (Wilks' Lambda: $F(16,53) = .64$, $p = .84$), nor for the interaction of these variables (Wilks' Lambda: $F(16,53) = 1.12$, $p = .37$). See Table 3 for a summary of psychological measures completed by main and support participants.

3.2.3 Baseline Analyses for Physiological Measures

Finally, two-way MANOVA tests were conducted to examine differences between groups for baseline physiological measures (e.g., respiration rate, systolic and diastolic blood pressure, heart rate, and HRV) in main participants. Results of this two-way MANOVA found no significant multivariate effect for breathing training condition (Wilks' Lambda: $F(5,68) = .19$, $p = .97$), for social support condition (Wilks' Lambda: $F(5,68) = 1.24$, $p = .30$), nor for the interaction of these variables (Wilks' Lambda: $F(5,68) = 2.06$, $p = .08$).

Analyses were also conducted to examine differences between groups for characteristics of the thermal stressor task (e.g., 7/10 temperature and length of stressor task). Results of this analysis found no significant multivariate effect for breathing training condition (Wilks' Lambda: $F(2,69) = .43$, $p = .65$), for social support condition (Wilks' Lambda: $F(2,69) = .05$, $p = .95$), nor for the interaction of these variables (Wilks' Lambda: $F(2,69) = 2.12$, $p = .13$). Thus there were no significant differences between

groups for length of exposure to the thermal stressor task, nor for the temperature determined to represent a 7 out of 10 pain level for main participants. On average the thermal stressor task lasted for 555.56 seconds (SD = 49.93) and participants indicated that a temperature of 45.71 (SD = 2.78) represented a 7 out of 10 pain. See Table 4 for a summary of baseline physiological measures and specifics of the thermal stressor task.

3.3 Hypothesis 1: Effect of Diaphragmatic Breathing Training

3.3.1 Effect on Respiration Rate

A one-way MANCOVA test was conducted to test the hypothesis that participants trained in paced diaphragmatic breathing would have a lower respiration rate during and following the thermal stressor task compared to other participants. In this analysis, breathing training condition was entered as the independent variable and respiration rate during and following the thermal stressor task were entered as dependent variables. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results from this analysis revealed a significant multivariate effect of breathing condition (Wilks' Lambda: $F(2,67) = 3.88$, $p < .05$, $\eta^2 = .10$) Follow-up univariate analyses supported the hypothesis that training in diaphragmatic breathing reduces respiration rate during the thermal stressor task ($F(1,71) = 7.46$, $p < .01$, $\eta^2 = .10$), but did not support the hypothesis that training would also reduce respiration rate during the recovery period after the thermal stressor task ($F(1,71) = .55$, $p = .50$). On average during the thermal stressor task, participants trained in diaphragmatic breathing breathed at a rate of 10.10 breaths per minute (SD = 3.40) compared to 12.23 breaths per minute (SD = 3.04) for participants trained in the control protocol.

3.3.2 Effect on Physiological Response to Thermal Stressor

Two one-way MANCOVA tests were conducted to test the hypothesis that participants trained in the diaphragmatic breathing protocol would have an improved physiological reaction (measured as lower systolic and diastolic blood pressure, lower heart rate, and increased HRV) during and following the thermal stressor task as compared to participants trained in the control protocol. First, a one-way MANCOVA test was conducted with breathing training condition entered as the independent variable

and physiological measures collected during the thermal stressor task entered as dependent variables. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results of this analysis found no significant multivariate effect (Wilks' Lambda: $F(4,65) = 1.30$, $p = .28$). To test specific *a priori* hypotheses, univariate analyses were further examined and no significant effects of training in diaphragmatic breathing were found for systolic or diastolic blood pressure, heart rate, nor HRV during the thermal stressor task (all p values > .05). Thus, the hypothesis that training in diaphragmatic breathing would improve physiological reactions during the thermal stressor task was not supported.

A second one-way MANCOVA test was conducted with breathing training condition entered as the independent variable and physiological measures collected during the recovery period following the thermal stressor task entered as dependent variables. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results of this analysis found no significant multivariate effect (Wilks' Lambda: $F(4,70) = .06$, $p = .99$). To test specific *a priori* hypotheses, univariate analyses were further examined and no significant effects were found for systolic or diastolic blood pressure, heart rate, nor HRV following the thermal stressor task (all p values > .05). Thus, the hypothesis that training in diaphragmatic breathing would improve physiological reactions during the recovery period following the thermal stressor task was not supported.

3.3.3 Effect on Participant Ratings of Pain and Unpleasantness

A one-way MANCOVA test was conducted to test the hypothesis that participants trained in the diaphragmatic breathing protocol would rate the thermal stressor task as less painful and less unpleasant compared to participants trained in the control protocol. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results of this analysis found no significant multivariate effect (Wilks' Lambda: $F(2,73) = .16$, $p = .85$). To test specific *a priori* hypotheses, univariate analyses were further examined and no significant effects were found for participant ratings of pain nor unpleasantness (all p values > .05). Thus, the hypothesis that training in diaphragmatic breathing would reduce participants' ratings of pain and unpleasantness during the thermal stressor task was not supported.

3.4 Hypothesis 2: Effect of Presence of a Social Support Person

3.4.1 Effect on Respiration Rate

Results were next examined with two-way MANCOVA tests to examine the hypothesis that presence of a social support person would increase the effectiveness of training in diaphragmatic breathing in reducing respiration rate during and in the recovery period following the thermal stressor task. First, a two-way MANCOVA test was conducted with breathing training condition and social support condition entered as independent variables and respiration rate during and following the thermal stressor task entered as dependent variables. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results of this analysis revealed a significant multivariate effect of breathing condition (Wilks' Lambda: $F(2,65) = 3.73$, $p < .05$, $\eta^2 = .10$). No significant multivariate effect was found for social support condition (Wilks' Lambda: $F(2,65) = .29$, $p = .75$) nor for the interaction of these variables (Wilks' Lambda: $F(2,65) = 2.21$, $p = .12$). Thus, the hypothesis that presence of a social support person would further reduce respiration rate during and following the thermal stressor task was not supported. Follow-up univariate analyses confirmed the previous finding that training in diaphragmatic breathing significantly reduced respiration rate during the thermal stressor task ($F(1,71) = 7.18$, $p < .01$, $\eta^2 = .10$) but not during the recovery period following the thermal stressor task ($F(1,71) = .52$, $p = .47$).

3.4.2 Effect on Physiological Response to Thermal Stressor

Next, results were analyzed to examine the hypothesis that presence of a social support person would increase the effectiveness of training in diaphragmatic breathing in improving physiological response during and in the recovery period following the thermal stressor task. A two-way MANCOVA test was conducted with breathing training condition and social support condition entered as independent variables and systolic and diastolic blood pressure, heart rate, and HRV during the thermal stressor task entered as dependent variables. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results of this analysis did not reveal a significant multivariate effect for breathing condition (Wilks' Lambda: $F(4,63) = 1.25$, $p = .30$), for social support condition (Wilks' Lambda: $F(4,63) = .44$, $p = .78$), nor for the

interaction of these variables (Wilks' Lambda: $F(4,63) = 1.94$, $p = .12$). To test specific *a priori* hypotheses, univariate analyses were further examined and no significant effects of training in diaphragmatic breathing were found for systolic or diastolic blood pressure, heart rate, nor HRV during the thermal stressor task (all p values > .05). Thus, the hypothesis that presence of a support person would influence the effect of training in diaphragmatic breathing on physiological reactions during the thermal stressor task was not supported.

A two-way MANCOVA test was also conducted with breathing training condition and social support condition entered as independent variables and physiological measures (systolic and diastolic blood pressure, heart rate, and HRV) during the recovery period following the thermal stressor task entered as dependent variables. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results of this analysis did not reveal a significant multivariate effect for breathing condition (Wilks' Lambda: $F(4,68) = .05$, $p = .99$), for social support condition (Wilks' Lambda: $F(4,68) = .55$, $p = .70$), nor for the interaction of these variables (Wilks' Lambda: $F(4,68) = 1.89$, $p = .12$). To test specific *a priori* hypotheses, univariate analyses were further examined and no significant effects were found (all p values > .05). Thus the hypothesis that presence of a social support person would enhance the positive effects of training in diaphragmatic breathing during the recovery period following the thermal stressor task was not supported.

3.4.3 Effect on Participant Ratings of Pain and Unpleasantness

Results were next examined with two-way MANCOVA tests to examine the hypothesis that presence of a social support person would reduce participants' ratings of pain and unpleasantness during the thermal stressor task. In this analysis, breathing training condition and social support condition were entered as independent variables and participants' ratings of pain and task unpleasantness were entered as dependent variables. Race of the social support person was entered as a covariate to control for baseline differences between groups. Results revealed a significant multivariate effect for the interaction between the independent variables (Wilks' Lambda: $F(2,71) = 3.44$, $p < .05$, $\eta^2 = .09$). Analyses did not reveal significant multivariate effects for the breathing condition (Wilks' Lambda: $F(2,71) = .16$, $p = .85$) nor for the social support condition

(Wilks' Lambda: $F(2,71) = .83$, $p = .44$) alone. Follow-up univariate analyses did not reveal any significant effects of breathing training condition, social support condition, nor the interaction of these variables on ratings of painfulness nor task unpleasantness (all p values > .05). Thus, the hypothesis that presence of a social support person would enhance the positive effects of training in diaphragmatic breathing on participants' ratings of pain and unpleasantness during the thermal stressor task was not supported.

3.5 Hypothesis 3: Quality of the Supportive Relationship

To test the hypothesis that the effect of having a social support person present would be influenced by the quality of support, two-way MANCOVA tests were repeated with measures of quality entered as covariates. Information on type and quality of social support was collected in two ways. First, participants were asked to rate the quality of their relationship with and the quality of the support received from their study partner. Second, participants completed the ISEL, a measure of participants' general perception of social support.

3.5.1 Controlling for Quality of the Supportive Relationship

First, a two-way MANCOVA test was conducted with the breathing training condition and social support condition entered as independent variables, physiological measures (e.g., respiration rate, systolic and diastolic blood pressure, heart rate, and HRV) during the thermal stressor task entered as dependent variables, and participants' ratings of the quality of their relationship with their study partner and the quality of support they receive from their partner entered as covariates. Race of the social support person was also entered as a covariate to control for baseline differences between groups. Results of this analysis revealed a significant multivariate effect of breathing training condition (Wilks' Lambda: $F(5,60) = 3.55$, $p < .01$, $\eta^2 = .23$). Analyses did not reveal significant multivariate effects for social support condition (Wilks' Lambda: $F(5,60) = .75$, $p = .59$) nor for the interaction of these variables (Wilks' Lambda: $F(5,61) = 2.27$, $p = .06$). Follow-up univariate analyses revealed a significant effect of breathing training condition on respiration rate during the thermal stressor task ($F(1,71) = 7.45$, $p < .001$, $\eta^2 = .10$). Thus, the previous finding that training in diaphragmatic breathing results in

slower respiration rate during the thermal stressor task was confirmed after controlling for participants' ratings of the quality of the supportive relationship.

A significant effect was also found for the interaction between breathing training condition and social support condition for heart rate during the thermal stressor task ($F(1,71) = 4.99$, $p < .05$, $\eta^2 = .07$). Specifically, participants who completed the study with a support person present had a lower heart rate when trained in diaphragmatic breathing (mean = 76.53, SD = 12.17) than trained in a control protocol (mean = 81.12, SD = 8.57) whereas participants who completed the study without a support person present had a higher heart rate when trained in diaphragmatic breathing (mean = 79.97, SD = 12.18) than when trained in a control protocol (mean = 77.40, SD = 8.68; see Figure 1). Thus, the hypothesis that the effect of having a support person present would be influenced by the quality of the support was supported for heart rate during the thermal stressor task. No other significant effects were found (all p values > .05).

Next, a two-way MANCOVA test was conducted with the breathing training condition and social support condition entered as independent variables, physiological measures (e.g., respiration rate, systolic and diastolic blood pressure, heart rate, and HRV) during the recovery period following the thermal stressor task entered as dependent variables, and participants' ratings of the quality of their relationship with their study partner and the quality of support they receive from their partner entered as covariates. Race of the social support person was also entered as a covariate to control for baseline differences between groups. Results of this analysis did not reveal a significant multivariate effect for breathing training condition (Wilks' Lambda: $F(5,65) = .22$, $p = .96$), for social support condition (Wilks' Lambda: $F(5,65) = .56$, $p = .73$), nor for the interaction of these variables (Wilks' Lambda: $F(5,65) = 1.79$, $p = .13$). To test specific *a priori* hypotheses, univariate analyses were further examined and no significant effects were found (all p values > .05). Thus, the hypothesis that the effect of having a support person present would be influenced by the quality of support was not supported for physiological measurements during the recovery period following the thermal stressor task.

Finally, a two-way MANCOVA test was conducted with the breathing training condition and social support condition entered as independent variables, participants'

ratings of pain and task unpleasantness entered as dependent variables, and participants' ratings of the quality of their relationship with their study partner and the quality of support they receive from their partner entered as covariates. Race of the social support person was also entered as a covariate to control for baseline differences between groups. Results of this analysis revealed a significant multivariate effect for the interaction between breathing training condition and social support condition (Wilks' Lambda: $F(2,69) = 3.80$, $p < .05$, $\eta^2 = .10$). There were not significant multivariate effects for breathing training condition (Wilks' Lambda: $F(2,69) = .23$, $p = .80$) nor for social support condition (Wilks' Lambda: $F(2,69) = 1.41$, $p = .25$) alone. Follow-up univariate analyses revealed a significant effect of the interaction between independent variables for participants' ratings of task unpleasantness ($F(1,77) = 4.83$, $p < .05$, $\eta^2 = .07$). Specifically, participants who completed the study with a support person present rated the task as less unpleasant when trained in diaphragmatic breathing (mean = 4.68, SD = 1.67) than when trained in a control protocol (mean = 5.18, SD = 1.26) whereas participants who completed the study without a support person present rated the task as more unpleasant when trained in diaphragmatic breathing (mean = 4.83, SD = 1.86) than when trained in a control protocol (mean = 3.84, SD = 2.34; see Figure 2). No other significant effects were found (all p values > .05). Thus, the hypothesis that the effect of having a support person present would be influenced by the quality of support was supported for participants' ratings of task unpleasantness, but not for ratings of pain.

3.5.2 Controlling for General Perception of Social Support

Next, two-way MANCOVA tests were conducted with participants' general perception of social support (measured by subscale scores on the ISEL) entered as covariates. First, a two-way MANCOVA test was conducted with the breathing training condition and social support condition entered as independent variables, physiological measures (e.g., respiration rate, systolic and diastolic blood pressure, heart rate, and HRV) during the thermal stressor task entered as dependent variables, and ISEL subscale scores entered as covariates. Race of the social support person was also entered as a covariate to control for baseline differences between groups. This analysis revealed a significant multivariate effect for breathing training condition (Wilks' Lambda: $F(5,55) = 3.59$, $p < .01$, $\eta^2 = .25$). No significant multivariate effects were found for social support

condition (Wilks' Lambda: $F(5,55) = .41$, $p = .84$) nor for the interaction between independent variables (Wilks' Lambda: $F(5,55) = 2.00$, $p = .09$). Follow-up univariate analyses revealed a significant effect of breathing training condition on respiration rate during the thermal stressor task ($F(1,68) = 11.22$, $p < .01$, $\eta^2 = .16$). Thus, the previous finding that training in diaphragmatic breathing results in slower respiration rate during the thermal stressor task was confirmed after controlling for participants' general perception of social support. No other significant effects were found (all p values > .05).

Next, a two-way MANCOVA test was conducted with the breathing training condition and social support condition entered as independent variables, physiological measures (e.g., respiration rate, systolic and diastolic blood pressure, heart rate, and HRV) during the recovery period following the thermal stressor task entered as dependent variables, and ISEL subscale scores entered as covariates. Race of the social support person was also entered as a covariate to control for baseline differences between groups. This analysis revealed no significant multivariate effects for breathing training condition (Wilks' Lambda: $F(5,60) = .28$, $p = .93$), for social support condition (Wilks' Lambda: $F(5,60) = .39$, $p = .86$), nor for the interaction of these variables (Wilks' Lambda: $F(5,60) = 1.60$, $p = .17$). To test specific *a priori* hypotheses, univariate analyses were further examined and no significant effects were found (all p values > .05). Thus, this finding does not lend support to the hypothesis that the effect of having a support person present would be influenced by quality of support for physiological variables during the recovery period following the thermal stressor task.

Finally, a two-way MANCOVA test was conducted with the breathing training condition and social support condition entered as independent variables, participant ratings of painfulness and task unpleasantness entered as dependent variables, and ISEL subscale scores entered as covariates. Race of the social support person was also entered as a covariate to control for baseline differences between groups. This analysis revealed a significant multivariate effect of the interaction between independent variables (Wilks' Lambda: $F(2,64) = 4.05$, $p < .05$, $\eta^2 = .11$). No significant multivariate effects were found for the breathing training condition (Wilks' Lambda: $F(2,64) = .42$, $p = .66$) nor for the social support condition (Wilks' Lambda: $F(2,64) = .87$, $p = .43$) alone. Follow-up univariate analyses did not reveal any significant effects of breathing training condition,

social support condition, nor the interaction of these variables on ratings of painfulness nor task unpleasantness (all p values > .05). Thus, this finding does not lend support to the hypothesis that the effect of having a support person present would be influenced by quality of support for ratings of task unpleasantness and pain.

3.6 Hypothesis 4: Examining the Influence of Other Psychological Variables

The final hypothesis was that psychological variables, such as symptoms of depression, pain-related anxiety, social desirability, and personality factors, would account for a portion of the variance in the significant relationships found between training in diaphragmatic breathing, presence and quality of social support, and response to the thermal stressor task. To examine this hypothesis, bivariate correlations were examined between significant findings (e.g., respiration rate and heart rate during the thermal stressor task and rating of task unpleasantness) and these psychological variables. This analysis revealed a significant positive correlation between heart rate during the thermal stressor task and the Escape/Avoidance subscale of the PASS such that higher scores on this subscale were associated with higher heart rate during the thermal stressor task. It also revealed significant positive correlations between ratings of unpleasantness and the Escape/Avoidance subscale of the PASS and the Openness scale of the NEO-FFI such that higher scores on these subscales were associated with higher ratings of task unpleasantness. No significant correlations were found between psychological variables and respiration rate during the thermal stressor task (see Table 5 for a summary of bivariate correlations).

Given these correlations, two hierarchical regression analyses were conducted to examine how these factors may be contributing to the dependent variables of heart rate during the thermal stressor task and ratings of task unpleasantness. First, a hierarchical regression model was analyzed for the dependent variable of heart rate during the thermal stressor task. Covariates (e.g., race of the support person and ratings of the quality of the relationship and quality of support received from the study partner) were entered into the first level of the model, followed by the Escape/Avoidance subscale of the PASS at level two, the two independent variables (e.g., breathing training condition and social support condition) entered at level three, and the interaction of the independent variables entered

at level four. Results of this analysis revealed that the model was not significantly predictive of heart rate during the thermal stressor task at any level (see Table 6).

A second hierarchical regression model was conducted with unpleasantness rating as the dependent variable. Covariates (e.g., race of the support person and ratings of quality of the relationship and quality of support received from the study partner) were entered into the first level of the model, followed by the Escape/Avoidance subscale of the PASS and the Openness subscale of the NEO-FFI entered at level two, the two independent variables (e.g., breathing training condition and social support condition) entered at level three, and the interaction of the independent variables entered at level four. At the first level, the model was not significantly predictive of participants' ratings of task unpleasantness ($F(3,69) = .80$, $p = .50$) and explained only 3.36% of the variance. Adding psychological variables resulted in a significant change in R^2 values ($\Delta R^2 = .26$, $p < .001$). This model was significantly predictive of participants' ratings of task unpleasantness ($F(5,67) = 5.47$, $p < .001$) and accounted for 29.00% of the variance. Introducing the two independent variables did not result in a significant change in R^2 value ($\Delta R^2 = .00$, $p = .91$). However, the model was still significantly predictive of participants' ratings of task unpleasantness ($F(5,65) = 3.83$, $p < .01$) and accounted for 29.20% of the variance. Finally, introducing the interaction variable did not result in a significant change in R^2 value ($\Delta R^2 = .04$, $p = .07$). However, the overall model was significantly predictive of participants' ratings of task unpleasantness ($F(5,64) = 3.89$, $p < .01$) and accounted for 32.70% of the variance. The predictors that most significantly contributed the variance in the final model were participant scores on the Escape/Avoidance subscale of the PASS and on the Openness subscale of the NEO-FFI (see Table 7).

Table 1

Demographic Characteristics for Main and Support Participants

	Main Participants			Support Participants		
Demographic Variable	Mean	SD	%	Mean	SD	%
Age	18.65	.82		19.08	3.78	
Gender						
Female			100.0%			98.7%
Transgender			0.0%			1.3%
Race						
Caucasian or White			77.9%			72.7%
African American			14.3%			16.9%
Hispanic or Latino			1.3%			2.6%
Asian American			2.6%			1.3%
Middle Eastern			1.3%			0.0%
Bi-/Multi-Racial			1.3%			6.5%
Other			1.3%			0.0%
Relationship Status						
Single, never married			100.0%			97.4%
Married			0.0%			2.6%
Employment Status						
Unemployed			68.8%			71.4%
Employed Part-time			28.6%			24.7%
Employed Full-time			2.6%			3.9%
Household Income						
< $20,000			24.0%			21.3%
$20,000 - $39,999			5.3%			1.3%
$40,000 - $59,999			8.0%			12.0%
$60,000 - $79,999			16.0%			14.7%
$80,000 – $99,999			9.3%			4.0%
$100,000 - $149,999			18.7%			22.7%
>$150,000			18.7%			24.0%
Presence of Pain						
No pain			79.2%			71.4%
One location			13.0%			15.6%
Two locations			7.8%			9.1%
Three locations			0.0%			2.6%
Four locations			0.0%			1.3%

Table Continued on Next Page

Demographic Characteristics for Main and Support Participants (continued)

	Main Participants			Support Participants		
Demographic Variable	Mean	SD	%	Mean	SD	%
Pain Description [a]						
Current Pain Rating	2.87	2.10		1.05	2.13	
Pain Length (months)	56.07	50.18		15.95	32.89	
Medication Use						
Pain			3.9%			2.6%
Hypertension			0.0%			1.3%
Nicotine Use						
Reported use			1.3%			3.9%
Denied use			98.7%			96.1%

Note. SD = standard deviation, [a] Pain description values describe only those participants who reported that they were currently experiencing pain

Table 2

Description of Supportive Relationships

Variable Name	Mean	SD	%
Type of Relationship			
Friend			90.9%
Sibling (Sister)			2.6%
Roommate			2.6%
Cousin			2.6%
Parent (Mother)			1.3%
Duration of Relationship (months)	44.80	61.43	
Quality of Relationship			
Main Participant	8.66	1.55	
Support Person	8.78	1.43	
Quality of Support			
Main Participant	8.99	1.45	
Support Person	9.00	1.35	

Note. SD = standard deviation

Table 3

Psychological Measurements for Main and Support Participants

Variable Name	Diaphragmatic Breathing Training Condition		Attention Control Training Condition	
	Support Absent	Support Present	Support Absent	Support Present
	Main Participants			
CES-D	9.88 (7.48)	16.20 (12.25)	13.64 (13.45)	11.69 (8.66)
PASS				
Cognitive Anxiety	25.18 (9.86)	28.20 (7.43)	26.21 (11.00)	26.06 (8.16)
Fearful Appraisal	16.65 (9.96)	18.80 (7.69)	18.57 (11.27)	16.88 (7.07)
Escape/Avoidance	24.82 (8.41)	26.73 (5.59)	25.43 (9.84)	25.13 (6.39)
Physiological Anxiety	23.76 (9.08)	23.20 (9.94)	23.43 (10.51)	24.81 (10.63)
PBIDR				
Self-deceptive Enhancement	6.47 (3.02)	4.80 (2.18)	5.64 (3.13)	6.50 (3.52)
Impression Management	6.76 (3.77)	6.00 (3.85)	5.79 (3.64)	5.63 (2.99)
ISEL				
Appraisal	26.47 (3.06)	24.73 (5.22)	24.57 (4.01)	25.56 (5.38)
Tangible	26.88 (2.83)	26.80 (5.60)	22.50 (6.28)	25.44 (5.03)
Self-esteem	23.47 (3.64)	20.67 (4.08)	22.36 (3.05)	21.13 (3.18)
Belonging	26.06 (3.86)	24.40 (3.50)	24.21 (3.79)	24.50 (4.70)
NEO-FFI				
Neuroticism	19.00 (12.47)	27.87 (6.81)	22.64 (7.98)	24.69 (8.08)
Extraversion	37.35 (9.37)	32.93 (7.10)	31.50 (5.50)	33.94 (8.40)
Openness	26.06 (4.75)	28.67 (7.64)	22.79 (8.71)	28.38 (8.46)
Agreeableness	31.29 (6.23)	27.20 (10.02)	28.14 (4.93)	28.88 (5.56)
Conscientiousness	38.47 (11.85)	33.80 (8.90)	38.43 (12.71)	34.88 (14.30)

Table Continued on Next Page

Psychological Measurements for Main and Support Participants (continued)

Variable Name	Diaphragmatic Breathing Training Condition		Attention Control Training Condition	
	Support Absent	Support Present	Support Absent	Support Present
	Support Participants			
CES-D	12.11 (10.86)	12.76 (11.46)	10.21 (13.77)	13.17 (9.76)
PASS				
Cognitive Anxiety	27.11 (13.02)	24.18 (9.20)	28.63 (8.73)	30.06 (7.32)
Fearful Appraisal	15.94 (9.30)	16.35 (7.78)	20.63 (7.99)	19.56 (9.11)
Escape/Avoidance	23.67 (8.14)	22.18 (8.91)	27.74 (8.38)	25.11 (8.28)
Physiological Anxiety	20.97 (10.91)	19.41 (9.63)	23.95 (9.91)	23.67 (10.15)
PBIDR				
Self-deceptive Enhancement	5.72 (2.67)	5.65 (2.67)	6.26 (2.96)	4.39 (3.18)
Impression Management	6.00 (2.72)	6.71 (2.95)	7.79 (2.68)	7.56 (3.54)
ISEL				
Appraisal	26.72 (5.44)	23.94 (6.31)	27.32 (11.04)	26.00 (2.61)
Tangible	25.72 (5.71)	25.12 (2.74)	24.00 (4.93)	26.22 (3.25)
Self-esteem	21.89 (4.03)	20.35 (3.71)	21.16 (4.65)	20.83 (3.47)
Belonging	25.44 (4.90)	24.53 (3.54)	24.11 (4.95)	25.61 (3.01)
NEO-FFI				
Neuroticism	27.50 (7.47)	25.35 (6.77)	24.26 (9.02)	29.00 (6.58)
Extraversion	32.17 (4.66)	35.06 (15.09)	30.68 (9.09)	31.44 (7.82)
Openness	30.06 (15.39)	22.18 (11.98)	27.53 (6.77)	23.72 (14.12)
Agreeableness	28.67 (5.94)	27.65 (11.26)	33.37 (16.53)	27.94 (16.83)
Conscientiousness	32.00 (7.54)	31.12 (9.13)	33.21 (14.82)	32.61 (9.02)

Note. Data presented as mean (standard deviation).

Table 4

Physiological Measurements and Ratings of Thermal Stressor Task

Variable Name	Diaphragmatic Breathing Training Condition		Attention Control Training Condition	
	Support Absent	Support Present	Support Absent	Support Present
Baseline Physiological Measures				
Respiration Rate	16.79 (3.05)	14.17 (2.43)	15.17 (2.63)	15.82 (3.66)
Systolic Blood Pressure	106.80 (11.47)	110.37 (13.59)	111.89 (8.32)	109.16 (11.14)
Diastolic Blood Pressure	73.10 (7.20)	73.79 (9.93)	73.16 (6.93)	74.63 (9.21)
Heart Rate	81.21 (13.64)	76.87 (13.28)	79.12 (10.16)	77.58 (12.07)
Heart Rate Variability	6.35 (1.19)	6.94 (1.36)	6.91 (1.41)	6.59 (1.49)
Physiological Measures During the Thermal Stressor Task				
Respiration Rate	10.68 (3.53)	9.46 (3.24)	11.17 (2.31)	13.11 (3.35)
Systolic Blood Pressure	103.85 (10.74)	106.05 (15.09)	106.89 (7.91)	107.95 (10.17)
Diastolic Blood Pressure	70.40 (8.04)	74.89 (9.39)	74.05 (8.50)	76.11 (9.20)
Heart Rate	79.97 (12.18)	76.53 (12.17)	77.40 (8.68)	81.12 (8.57)
Heart Rate Variability	6.93 (.98)	7.34 (1.07)	7.36 (.93)	7.37 (2.03)
Physiological Measures Following the Thermal Stressor Task				
Respiration Rate	13.92 (4.97)	13.16 (3.67)	13.83 (2.84)	14.63 (5.91)
Systolic Blood Pressure	107.55 (7.82)	109.32 (11.45)	108.32 (9.41)	109.11 (9.35)
Diastolic Blood Pressure	75.85 (6.12)	71.68 (15.65)	72.63 (7.16)	75.79 (7.60)
Heart Rate	79.93 (14.42)	75.43 (10.52)	75.99 (9.15)	78.45 (10.18)
Heart Rate Variability	6.61 (1.45)	7.06 (.99)	6.87 (1.44)	7.00 (1.89)
Ratings of Painfulness and Unpleasantness of the Thermal Stressor Task				
Unpleasantness Rating	4.83 (1.86)	4.68 (1.67)	3.84 (2.34)	5.18 (1.26)
Pain Rating	4.55 (2.01)	4.79 (1.81)	4.26 (2.13)	4.66 (2.20)

Note. Data presented as mean (standard deviation).

Table 5

Bivariate Correlations of Psychological Variables and Significant Findings

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Respiration Rate [a]														
2. Heart Rate [a]	.08													
3. Unpleasantness	-.01	.11												
4. CES-D	.06	-.11	.03											
5. PASS – CA	.02	.04	.14	.23										
6. PASS – FA	.09	.18	.05	.13	.73**									
7. PASS – EA	.15	.27*	.35**	.01	.60**	.47**								
8. PASS – PA	.01	.22	.13	.13	.75**	.60**	.52**							
9. PBIDR – SDE	.12	.20	-.03	-.17	-.26*	-.15	-.07	-.16						
10. PBIDR – IM	.06	.05	-.16	-.04	-.07	-.07	.00	-.15	.44**					
11. NEO-FFI – N	-.04	-.01	.02	.46**	.52**	.28*	.14	.38**	.52**	-.19				
12. NEO-FFI – E	-.06	-.22	-.11	-.03	.07	.08	.02	-.05	-.05	-.09	.03			
13. NEO-FFI – O	-.17	.13	.39**	.26*	.01	.02	-.05	.02	.10	.00	.08	-.21		
14. NEO-FFI – A	-.10	-.07	.15	-.18	-.07	-.03	.09	.02	-.01	.19	-.16	.18	.20	
15. NEO-FFI – C	.06	.10	-.19	-.03	.05	-.07	-.09	.12	.31**	.09	-.28*	-.02	-.26*	-.09

Note. * = $p < .05$, ** = $p < .01$, *** = $p < .001$, [a] = During the thermal stressor task,
PASS: CA = Cognitive Anxiety, FA = Fearful Appraisal, EA = Escape/Avoidance, PA = Physiological Anxiety
PBIDR: SDE = Self-deceptive Enhancement, IM = Impression Management
NEO-FFI: N = Neuroticism, E = Extraversion, O = Openness, A = Agreeableness, C = Conscientiousness

Table 6

Summary of Hierarchical Regression for Heart Rate during the Thermal Stressor Task

Variable	β	*P*	R^2	ΔR^2	*P*
Step1			.04	.04	.44
Support Partner's Race	-.08	.53			
Quality of Relationship	.28	.22			
Quality of Support Received	-.26	.24			
Step 2			.12	.08	.10
Support Partner's Race	-.10	.42			
Quality of Relationship	.27	.23			
Quality of Support Received	-.28	.18			
PASS – Escape/Avoidance	.28	< .05*			
Step 3			.13	.01	.20
Support Partner's Race	-.09	.48			
Quality of Relationship	.27	.22			
Quality of Support Received	-.27	.22			
PASS – Escape/Avoidance	.27	< .05*			
Breathing Training Condition	-.05	.68			
Social Support Condition	-.10	.43			
Step 4			.18	.06	.08
Support Partner's Race	.00	.99			
Quality of Relationship	.36	.11			
Quality of Support Received	-.36	.09			
PASS – Escape/Avoidance	.28	< .05*			
Breathing Training Condition	.21	.23			
Social Support Condition	.18	.32			
Interaction – Breathing x Social Support	-.45	< .05*			

Note. * = p < .05, ** = p < .01, *** = p < .001*

Table 7

Summary of Hierarchical Regression for Unpleasantness Rating

Variable	β	*P*	R^2	ΔR^2	*P*
Step1			.03	.03	.50
Support Partner's Race	-.03	.79			
Quality of Relationship	-.12	.55			
Quality of Support Received	-.08	.65			
Step 2			.29	.26	< .001***
Support Partner's Race	-.05	.65			
Quality of Relationship	-.00	.99			
Quality of Support Received	-.10	.55			
PASS – Escape/Avoidance	.38	< .01**			
NEO-FFI – Openness	.38	< .01**			
Step 3			.29	.00	< .01**
Support Partner's Race	-.05	.63			
Quality of Relationship	-.01	.96			
Quality of Support Received	-.11	.52			
PASS – Escape/Avoidance	.37	< .01**			
NEO-FFI – Openness	.36	< .01**			
Breathing Training Condition	.00	.97			
Social Support Condition	.05	.67			
Step 4			.33	.04	< .01**
Support Partner's Race	.01	.92			
Quality of Relationship	05	.80			
Quality of Support Received	-.18	.30			
PASS – Escape/Avoidance	.36	< .01**			
NEO-FFI – Openness	.35	<.01**			
Breathing Training Condition	.20	.18			
Social Support Condition	.26	.11			
Interaction – Breathing x Social Support	-.34	.07			

Note. * = p < .05, ** = p < .01, *** = p < .001*

Figure 1. Effect of Diaphragmatic Breathing and Social Support on Heart Rate during the Thermal Stimuli Task

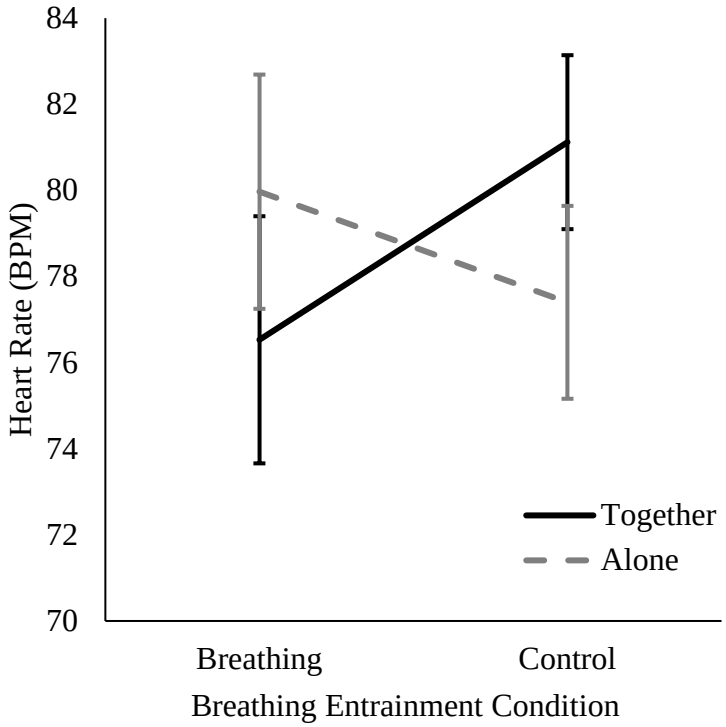
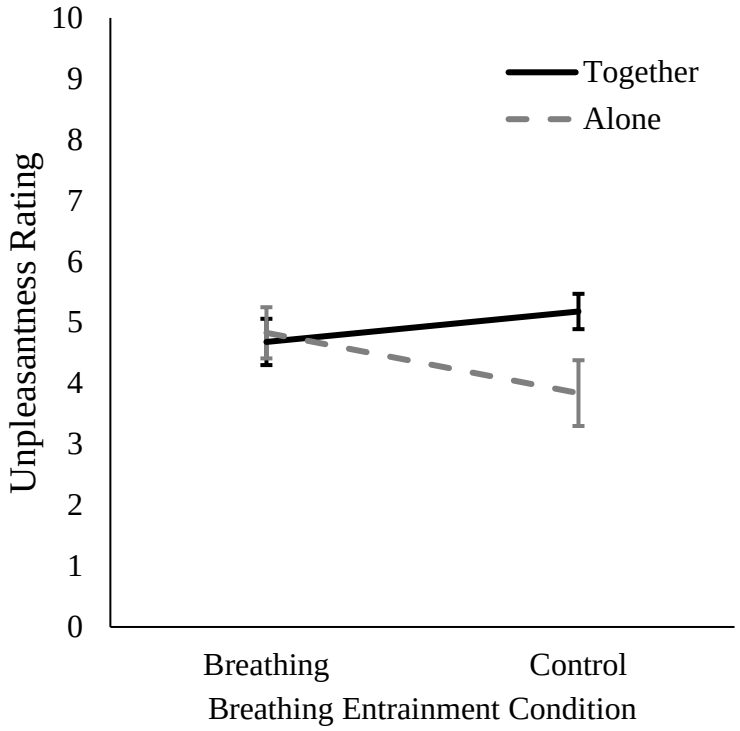


Figure 2. Effect of Diaphragmatic Breathing and Social Support on Unpleasantness Rating of the Thermal Stimuli Task



Chapter Four: Discussion and Conclusions

4.1 Overview of Results

The first hypothesis tested in the present study was that training in a diaphragmatic breathing protocol would significantly affect participants' reactions during and following a thermal stressor task as compared to participants trained in a control breathing condition. It was predicted that participants trained in diaphragmatic breathing would have lower respiration rate, blood pressure, and heart rate and higher HRV than participants trained in the control protocol. It was also predicted that participants trained in diaphragmatic breathing would rate the task as less painful and less unpleasant than would participants trained in the control condition. Results of the study provided support for the hypothesis that training in diaphragmatic breathing yields slower respiration rate during the thermal stressor task as compared to participants who complete a control training protocol. However, the data did not support the hypothesis that training in diaphragmatic breathing would positively impact participants' heart rate, HRV, or blood pressure during or following the thermal stressor task, respiration rate during the recovery period following the thermal stressor task, nor ratings of pain and unpleasantness as compared to training in a control protocol.

The second hypothesis tested was that presence of a social support person during the study session would increase the positive effects of training in diaphragmatic breathing during and following the thermal stressor task (i.e., respiration rate, blood pressure, heart rate, and HRV during and following the thermal stressor task as well as ratings of pain and task unpleasantness). Despite confirming the positive effect of training in diaphragmatic breathing on respiration rate during the thermal stressor task, results of the study did not reveal any significant interaction effects between training in diaphragmatic breathing and presence or absence of a support person. Thus, our findings do not lend support to this hypothesis.

The third hypothesis examined whether presence or absence of a support person during the study would influence outcomes after controlling for the perceived quality of social support. Results were examined with two different measures of social support (i.e., perceived quality of the relationship between study partners and general perception of

social support). Controlling for the perceived quality of the relationship between study partners provided support for this hypothesis by revealing two significant interactions.

First, after controlling for quality of the relationship, a significant interaction was found between training in diaphragmatic breathing and presence of social support on heart rate during the thermal stressor task. Specifically, participants who completed the study with a support person present had a lower heart rate when trained in diaphragmatic breathing than when trained in a control protocol whereas participants who completed the study without a support person present had a higher heart rate when trained in diaphragmatic breathing than when trained in a control protocol. Second, after controlling for quality of the relationship, a significant interaction was found between training in diaphragmatic breathing and presence of a social support person on ratings of task unpleasantness. Specifically, participants who completed the study with a support person present rated the task as less unpleasant when trained in diaphragmatic breathing than when trained in a control protocol whereas participants who completed the study without a support person present rated the task as more unpleasant when trained in diaphragmatic breathing than when trained in a control protocol.

No significant interaction effects were found after controlling for participants' general perception of social support. Thus, the results support the hypothesis that presence or absence of a support person will increase the positive effects of training in diaphragmatic breathing for heart rate during the thermal stressor task and ratings of task unpleasantness only after controlling for quality of the relationship, but not after controlling for general perception of social support. The data do not provide support for changes in other physiological measures during or following the thermal stressor task nor for ratings of pain.

The final hypothesis examined was that a portion of the variance in significant findings would be accounted for by psychological measures. A significant regression model was identified for the participants' ratings of task unpleasantness. In this model, the variables that most accounted for variance were Openness as measured by the NEO-FFI and Escape/Avoidance behaviors as measured by the PASS. Thus, the data support the hypothesis that psychological factors, specifically the willingness to engage in or appreciation of new experiences and the tendency to engage in escape and avoidance

behaviors in response to pain, account for a portion of the variance in predicting unpleasantness ratings.

4.2 Interpretation of Results

4.2.1 Effects of Breathing Entrainment

As expected, and confirming the effect of this manipulation, training in a diaphragmatic breathing protocol was associated with slower respiration rate during the thermal stressor task. Interestingly, this change in respiration rate did not carry over into the recovery period following the thermal stressor task. One explanation for this lack of effect lies in the instructions given to study participants. Specifically, participants were instructed explicitly to use the breathing strategy in which they were trained during the thermal stressor task, but were instructed to "sit quietly" during the recovery period and not reminded to continue use of the new breathing technique. Thus, it is likely that participants reverted to previous breathing patterns regardless of their training during the recovery period.

Despite changes in respiration rate, training in a diaphragmatic breathing protocol was not generally associated with any other changes in physiological response during the thermal stressor task (i.e., heart rate, HRV, blood pressure) nor during the recovery period following this task and was also not associated with participants' ratings of task painfulness or unpleasantness. This finding is inconsistent with previous literature that linked even brief training in diaphragmatic breathing to changes in HRV (Lehrer et al., 2003; Russell, Under review; Schmidt, Naranjo, et al., 2012; Vaschillo et al., 2002; Vaschillo et al., 2006). This finding was also inconsistent with previous research that showed diaphragmatic breathing training may positively impact blood pressure readings (Lee et al., 2003; Mourya, Mahajan, Singh, & Jain, 2009; Pinheiro, Medeiros, Pinheiro, & Marinho, 2007; Rosenthal, Alter, Peleg, & Gavish, 2001).

There are several possible explanations as to why, in this study, diaphragmatic breathing alone failed to affect heart rate or HRV. For example, one possible explanation is that the thermal stressor task was not an adequate physical stressor due to participants undergoing an initial exposure to this task during determination of each the "7 out of 10" temperature used during the stressor task and thus not experiencing a significant

physiological reaction to the task. This explanation is consistent with the finding that most participants rated the painfulness of the thermal stressor task as less than 7 (N = 63), despite the fact that all participants initially rated the temperature used during the stressor as a 7 on a scale from 0 to 10. A second factor that may be influencing this result is the type of stressor task utilized in the present study. A thermal stimuli applied to the masseter muscle was used in the present study, whereas most previous research has utilized the cold pressor task (a task in which participants submerge their hands in ice cold water) as an experimental manipulation of pain. The present study should be repeated with multiple types of stressors, including the cold pressor task, to determine whether diaphragmatic breathing would be more efficacious in improving cardiovascular measures in response to these tasks. Finally, results of the current study are consistent with a previous study in which diaphragmatic breathing did not change cardiovascular response to a stressful task, but rather only affected recovery following exposure to such a stressor (Kniffin et al., 2014). Thus, in the present study the lack of findings during the thermal stressor task may be consistent with this previous finding and lack of findings during the recovery period may be associated with a lack of explicit instructions given to the study participants to continue use of diaphragmatic breathing during the recovery period.

For blood pressure readings, one possible cause for the lack of effect of diaphragmatic breathing lies in the brief nature of the breathing training provided. Previous studies allowed for multiple weeks to months of practice prior to observing a change in blood pressure following breathing entrainment; and, thus, it is likely that the current study did not allow for enough time and practice for a change to be observed in this domain (Lee et al., 2003; Mourya et al., 2009; Pinheiro et al., 2007; Rosenthal et al., 2001).

4.2.1 Effects of Incorporating Social Support

Counter to the hypothesis that presence of a support person during the study would enhance the positive effects of training in diaphragmatic breathing, no such effects were found. However, investigation into the role of social support required that the quality of support be taken into account. As expected, these analyses revealed that the

quality of the relationship between the main participant and their support partner was more important in understanding responses to the thermal stressor task than was the participants' general perception of social support in their lives. Two important interactions were found after controlling for the quality of the relationship between study partners. Specifically, the interaction between presence of social support and breathing entrainment influenced heart rate during the thermal stressor task and participants' ratings of task unpleasantness.

During the thermal stressor task, participants who had a support person present had a lower heart rate when trained in diaphragmatic breathing than when trained in a control protocol whereas participants who did not have a support person present showed the opposite pattern. While this effect is consistent with our hypothesis for participants who completed the study with a partner present, it is somewhat counterintuitive for participants who completed the study without a partner. One possible reason for what may be driving this effect is that the combined stress of implementing a new breathing strategy while completing a stressful task resulted in greater demand and thus increased heart rate for participants who were trained in diaphragmatic breathing but unaccompanied during the study. Whereas participants who were trained in diaphragmatic breathing and had a support person present received support and reminders to use this strategy from their partner, thus reducing demand and lowering heart rate. Further research will be needed to more completely investigate this reaction.

Additionally, after controlling for the quality of the relationship between study partners, analyses revealed a significant interaction between presence of social support and breathing entrainment for participants' ratings of the unpleasantness of the thermal stressor task. Specifically, participants trained in the diaphragmatic breathing protocol rated the task as similarly unpleasant regardless of the presence or absence of a support person whereas participants who completed training in a control protocol rated the task as more unpleasant when accompanied by a support person than when completing the study alone. One possible explanation for this result is that the presence of a support person may have elicited increased pain behavior in main participants. This explanation is supported by research indicating that although the presence of social support is associated with better adjustment to pain, support in the form of solicitousness may be associated

with more overt pain behaviors (Boothby, Thorn, Overduin, & Ward, 2004; Cano, 2004; Flor, Kerns, & Turk, 1987; Giardino, Jensen, Turner, Ehde, & Cardenas, 2003; Romano, Jensen, Turner, Good, & Hops, 2000; Turk, Okifuji, & Scharff, 1995; Waltz, Kriegel, & Bosch, 1998).

4.2.1 Effects of Affect and Personality Factors

Finally, the present study sought to investigate the role of psychological variables, such as symptoms of depression, pain-related anxiety, social desirability, and personality factors, in the observed relationships between training in diaphragmatic breathing, presence or absence of a support person, and outcome variables (physiological response during and following the thermal stressor task and ratings of pain and task unpleasantness). Bivariate correlations were used to explore relationships between these variables and two hierarchical regression models were analyzed for the dependent variables of heart rate during the thermal stressor task and ratings of unpleasantness based on these correlations. No significantly predictive models were found for heart rate during the thermal stressor task. A significantly predictive model was found for participants' ratings of task unpleasantness with the two strongest predictors being the Openness subscale of the NEO-FFI and the Escape/Avoidance subscale of the PASS.

To review briefly, the Openness subscale on the NEO-FFI is interpreted as participants' willingness to engage in or appreciation of new experiences or ideas and the Escape/Avoidance subscale on the PASS assesses maladaptive behavioral responses to pain (Costa et al., 1992; McCracken et al., 1992). Interestingly, our findings reveal positive correlations between both subscales and ratings of task unpleasantness. In other words, participants who tend to respond to pain with maladaptive behavioral responses also tend to rate the thermal stressor task as more unpleasant. Additionally, participants who tend to be open to new experiences and ideas also tend to rate the thermal stressor task as more unpleasant.

The finding that links higher scores on the Escape/Avoidance subscale with higher ratings of task unpleasantness fits well with previous studies that link negative appraisal of pain, pain-related fear, and engagement in avoidance and escape behaviors (Leeuw et al., 2007; Martínez, Sánchez, Miró, Medina, & Lami, 2011; Vlaeyen & Linton,

2000). However, the finding that participants who score high in openness also tend to rate the thermal stressor task as more unpleasant is inconsistent with previous research findings that show a relationship between poor outcomes/responses to pain and low openness (Goubert, Crombez, & Van Damme, 2004; Martínez et al., 2011; Schmidt, Hooten, & Carlson, 2011). It is unclear what may be driving this effect and future research should further investigate this result.

4.3 Clinical Implications

Results from the current study may have important clinical implications for health care providers working with individuals with persistent pain conditions. Specifically, results indicate that the presence of a social support person may positively impact both physiological outcomes (i.e., heart rate) and self-reports of pain unpleasantness during treatment of pain through self-regulation protocols such as training in diaphragmatic breathing. Additionally, it is important to note that the positive effects of integrating a supportive person in treatment are dependent upon patients' perceptions of their relationship with this person. Practically, this means that it is important for providers to ask patients about the quality of support they receive from family and friends and to consider discussing with the patient her/his comfort with and willingness to bring a family member or friend with them to medical appointments.

4.4 Limitations and Future Directions

4.4.1 Limitations

The present study is not without certain limitations. First, this study only included women and thus did not investigate the role of gender on observed effects. The decision to include only women was based on the higher prevalence rate of orofacial pain conditions in women. It is important however to examine whether the observed results can be generalized to male patients and thus future studies should include both men and women to lead to a better understanding of these effects. Additionally, the present study recruited participants with a family history of hypertension to ensure that participants would have a strong cardiovascular reaction to the thermal stressor task. It is important that future studies examine the effect of breathing entrainment and presence of social

support in multiple groups of participants – normotensives, normotensives with a family history of hypertension, and hypertensives themselves. Given that the current study did not observe a change in HRV following breathing entrainment, it will also be important for future studies to examine the impact of these variables on participants' response to other stressful tasks, such as the cold pressor task. Further, it would be helpful to examine the efficacy of breathing entrainment in combination with presence of a social support person using a sample of patients with chronic pain conditions in order to further our understanding of the role of social support in behavioral training with such patients.

An additional limitation of the current study was that a cue for diaphragmatic breathing was not included during the thermal stimuli task. Thus, it is possible that change in breathing pattern was not as significant as may have been accomplished with such a cue present. Another limitation of the present study was that despite random assignment of groups, a significant difference between groups was found for race of the support partner. This difference, however, was controlled for statistically. It will be important for results of the present study to be replicated in future research given these baseline differences. Finally, given the exploratory nature of the present study, a large number of variables were included to allow for examination of the many factors affecting response to the thermal stressor task. Future studies should consider taking a more focused approach to improve power, for example, researchers may choose to exclude measures of depression, general perception of social support, and social desirability as these measures were not found to account for a statistically significant portion of the variance in models examined in the present study.

4.4.2 Future Directions

As stated above, further studies should examine the generalizability of the current findings by including men and individuals without a family history of hypertension. Additionally, it will be helpful to study the effects of diaphragmatic breathing and training with or without a support person present on response to a different painful stimuli, such as the cold pressor task. Another next step in the current research will be to examine the impact of training in diaphragmatic breathing and presence of social support on outcomes in a clinical setting with patients diagnosed with chronic pain conditions.

Findings from such a study would be invaluable in providing information to health care providers about when it may be best to incorporate support persons into a patient's treatment plan and when such support may not be as useful.

Appendix A: Demographics Questionnaire

Please do not write your name on this form. For the following items, please select the one response that is most descriptive of you or fill in the blank as appropriate.

1. Current age in years: _____

2. Gender:
_____ Female _____Male _____ Transgender _____ Other _____

3. Race/Ethnicity:
_____ Asian or Pacific Islander
_____ Black/African American
_____ Caucasian or White
_____ Hispanic or Latino
_____ Native American
_____ Bi-/Multi- racial
_____ Other: _____

4. Relationship Status:
_____ single, never married
_____ married
_____ separated
_____ divorced
_____ widowed

5. What is the highest grade in school, year in college, or post-degree work you have completed?
____ 8th grade or less
____1-3 years of high school
____ 12th grade, high school diploma
____ Vocational school/other non-college
____1-3 years of college
____College degree (e.g. B.A., B.S.)
____Master's degree (e.g. MA, MS)
____Professional degree (e.g. PhD)

6. If you are currently enrolled in college, which best represents your current year in school?
_____ 1st year in college (freshman)
_____ 2nd year in college (sophomore)
_____ 3rd year in college (junior)
_____ 4th year in college (senior)
_____ Other _____
_____ Not applicable

7. What is your current working status?

_____ Work full-time (40 + hours/week)
_____ Work part-time (1-39 hours/week)
_____ Retired
_____ On/Seeking Disability
_____ Unemployed

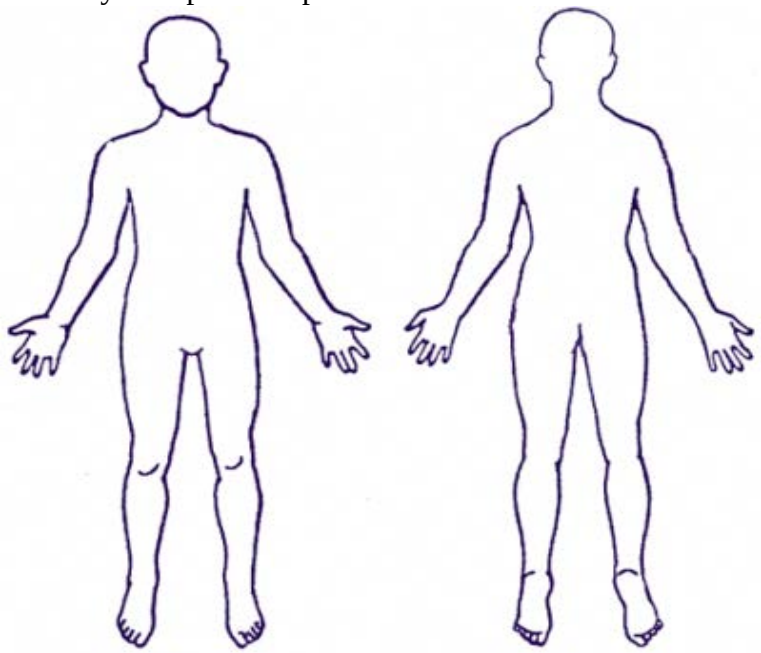
8. What is your current annual household income?

____ Less than $10,000	____ $40,000 – 49,999	____ $80,000 – 89,000
____ $10,000 – 19,999	____ $50,000 – 59,000	____ $90,000 – 99,000
____ $20,000 – 29,000	____ $60,000 – 69,000	____$100,000 – 149,000
____ $30,000 – 39,000	____ $70,000 – 79,000	____ More than $150,000

9. Where in your body do you feel pain (write "not applicable" if you do not feel any pain)?

_____
_____

10. Mark all areas that you experience pain.



11. How long have you experienced this pain?

_____ years and _____ months

12. What is your CURRENT level of pain (circle one)?

0 --- 1 --- 2 --- 3 --- 4 --- 5 --- 6 --- 7 --- 8 --- 9 --- 10

0 = No pain 10 = Worst pain imaginable

13. What is your AVERAGE level of pain (circle one)?

0 --- 1 --- 2 --- 3 --- 4 --- 5 --- 6 --- 7 --- 8 --- 9 --- 10

0 = No pain 10 = Worst pain imaginable

14. List all prescription medications you currently take and the reason you are taking these medications:

Medication:	Reason:
_____	_____
_____	_____
_____	_____
_____	_____

15. Do you smoke cigarettes and/or chew tobacco?

_____ yes _____ no

16. If you answered yes to the previous question, indicate how much tobacco you use per day.

_____ # packs of cigarettes per day
_____ # cans of tobacco per day
_____ Not applicable

17. How long have you known the person with you today?

_____ years and _____ months

18. Indicate which of the following best describes the person with you today.

_____ spouse (wife)
_____ girlfriend
_____ friend
_____ parent
_____ child
_____ sibling (sister)
_____ other (describe relationship_____)

19. How would you rate the quality of your relationship with the person with you today (circle one)?

0 --- 1 --- 2 --- 3 --- 4 --- 5 --- 6 --- 7 --- 8 --- 9 --- 10

0 = Poor 10 = Excellent

20. How supportive do you consider this person to be (circle one)?

0 --- 1 --- 2 --- 3 --- 4 --- 5 --- 6 --- 7 --- 8 --- 9 --- 10

0 = Not at all supportive 10 = Extremely supportive

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Curriculum Vitae

EDUCATION

M.S. in Clinical Psychology
University of Kentucky; Lexington, Kentucky
Date of Completion: August 2012
Thesis: Chronic orofacial pain influences self-regulation in a rodent model.

B.S. in Psychology and B.A. in English
Texas A&M University; College Station, Texas
Date of Completion: May 2010
Thesis: Impact of ghrelin and cocaine on intracranial self-stimulation in rats.

POSITIONS HELD

Clinical Experience:

08/2015 – Present	Clinical Psychology Intern VA Northern California Health Care System, Psychology Internship Program
07/2014 – 07/2015	Behavioral Medicine Trainee Cardinal Hill Rehabilitation Hospital
05/2014 – 07/2014	Clinical Psychology Trainee Chrysalis House Residential Treatment Facility
07/2013 – 07/2015	Behavioral Medicine Trainee Bluegrass Health Psychology Private Practice Clinic
08/2011 – 03/2015	Clinical Psychology Trainee Jesse G. Harris, Jr. Psychological Services Center
07/2011 – 06/2013	Behavioral Medicine Trainee University of Kentucky Orofacial Pain Center

Research Experience:

07/2010 – Present	Graduate Research Assistant (Clinical Psychology) Department of Psychology, University of Kentucky
07/2010 –07/2014	Graduate Research Assistant (Physiology) Department of Physiology, University of Kentucky
06/2009 –06/2010	Undergraduate Research Assistant (Neuroscience) Department of Psychology, Texas A&M University

01/2009 –05/2009	Undergraduate Research Assistant (English) Department of English, Texas A&M University
08/2007 –12/2007	Undergraduate Research Assistant (Social Psychology) Department of Psychology, Texas A&M University

Teaching Experience:

08 & 10/2014	Guest Lecturer for Undergraduate Independent Studies Course Department of Psychology, University of Kentucky
02/2014	Guest Lecturer for Undergraduate Scholars Course Department of Psychology, University of Kentucky
08/2011 – 12/2011	Grader for Undergraduate Developmental Psychology Course Department of Psychology, University of Kentucky

PUBLICATIONS

Lyons, D. N., Kniffin, T. C., Zhang, L., Danaher, R. J., Miller, C. S., Bocanegra, J. L., Carlson, C. R., and Westlund, K. N. (2015, June). Trigeminal inflammatory compression (TIC) injury induces chronic facial pain and susceptibility to anxiety-related behaviors. Neuroscience, 295: 126-138. doi:10.1016/j.neuroscience.2015.03.051.

Kniffin, T. C., Danaher, R. J., Westlund, K. N., Ma, F., Miller, C. S., and Carlson, C. R. (2015, April). Persistent neuropathic pain influences persistence behavior in rats. Journal of Oral & Facial Pain and Headache, 29(2): 183-192. doi:10.11607/ofph.1300.

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Kniffin, T. C., Carlson, C. R., Ellzey, A., Eisenlohr-Moul, T., Battle Beck, K., McDonald, R., and Jouriles, E. N. (2014, October). Using virtual reality to explore self-regulation in high risk settings. Trauma, Violence, and Abuse, 15(4): 310-321. doi:10.1177/1524838014521501

Boggero, I. A., Kniffin, T. C., de Leeuw, R., and Carlson, C. R. (2014, May). Fatigue mediates the relationship between pain interference and distress in persistent orofacial pain patients. Journal of Oral & Facial Pain and Headache, 28(1): 38-45. doi: 10.11607/jop.1204

Clifford, P. S., Rodriguez, J., Schul, D., Hughes, S., Kniffin, T., Hart, N., Eitan, S., Brunel, L., Fehrentz, J. A., Martinez, J. and Wellman, P. J. (2012, November). Attenuation of cocaine-induced locomotor sensitization in rats sustaining genetic or pharmacologic antagonism of ghrelin receptors. Addiction Biology, 17(6): 956–963. doi: 10.1111/j.1369-1600.2011.00339.x

GRANTS AND SCHOLARSHIPS

University of Kentucky

2010 – 2014 Research Assistant, "Gene Therapy for Orofacial Pain" (NIH/NIDCR 2P20RR020145-06), PI: Jeffrey L. Ebersole, Ph.D. (University of Kentucky)
2012 – 2013 Research Assistant, Robert H. and Anna B. Culton Award, PI: Charles R. Carlson, Ph.D. (University of Kentucky)
2010 – 2013 Recipient, Daniel R. Reedy Quality Achievement Award

Texas A&M University

2009 – 2010 Recipient, Janet Reed Schalit Scholarship
2009 Recipient, Summer Undergraduate University Research Funding
2008 – 2009 Recipient, Stewart and Anna Morgan Scholarship
2005 – 2009 Recipient, Lechner Fellowship

HONORS AND AWARDS

University of Kentucky

2015 Recipient, Excellent Clinical Performance Award
2014 Recipient, University of Kentucky Graduate School Travel Award
2012, 2014 Recipient, Department of Psychology Travel Award
2012 Recipient, Orofacial Pain Center Psychology Training Program Certificate

Texas A&M University

2010 Recipient, Summa Cum Laude
2010 Fellow, Undergraduate Research Fellow Honors Program
2010 Recipient, Foundation, University, Liberal Arts, Psychology, and English Honors
2009 Invited Member, Phi Beta Kappa
2006 – 2009 Recipient, Dean's Honor Roll