Pain and Stress Processes: The Role of the Transactional Model of Stress and Mindfulness in Acute Pain

by

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ACTH	Adrenocorticotropic Hormone
BP	Blood Pressure
CNS	Central Nervous System
CPT	Cold Pressor Task
CRF	Corticotropic Releasing Factors
DBP	Diastolic Blood Pressure
FFMQ	Five Facet Mindfulness Questionnaire
HPA	Hypothalamic-pituitary-adrenocortical
HR	Heart Rate
MAAS	Mindfulness Attention Awareness Scale
MAP	Mean Arterial Pressure
PCS	Pain Catastrophizing Scale
SAM	Sympathetic-adrenomedullary system
SAM 1 & 2	Stress Appraisal Measure
SBP	Systolic Blood Pressure
SNS	Sympathetic Nervous System

Abstract

Chronic Pain has been found to be a critical factor contributing to disability and life dissatisfaction, comorbid mental disorders, and the socioeconomic cost among suffers and for society. From the biopsychosocial approach, pain experience has been understood as a complex phenomenon of objective and subjective experiences that account for sensory experiences as well as emotions and cognitions. Stress has been found to impact acute and chronic pain experiences. While there are several models of stress, the transactional model of stress serves a framework to explain the individual differences in stress responses. In particular, threat appraisals (primary appraisal) and pain catastrophizing (secondary appraisal) have been found to be associated with poorer pain-related outcomes. On the other hand, mindfulness has been found to be beneficial to stress responses and pain-related outcomes. Therefore, this study examined how cognitive stress appraisals, pain catastrophizing, and their interaction influence the pain experience in terms of pain ratings and pain tolerance as well as physiological reactivity of cardiovascular function and cortisol to an induced acute pain. The study also examined how trait mindfulness could influence these relations. Ninety-three undergraduate participants at the University of Michigan-Dearborn engaged in a cold pressor task and completed several self-reported measures such as the Stress Appraisal Measure (SAM), the Pain Catastrophizing Scale, the Mindfulness Attention Awareness Scale, and the Five Facet Mindfulness Questionnaire. Threat appraisals using the SAM were measured before and after the task. Also, blood pressure, heart rate, and cortisol reactivity data were collected as well as pain ratings, pain threshold, and pain tolerance. The results show that, in general, psychological predictor variables were associated with psychological outcome variables; however, psychological factors across the board did not predict pain tolerance or physiological reactivity. The study partially supported the transactional model of stress when considering the effects of psychological predictor variables of cognitive stress appraisals and pain catastrophizing over subjective pain ratings of an acute pain stimulus. It also supported that mindfulness could be beneficial to the cognitive stress appraisal processes and pain catastrophizing. The lack of general support for pain tolerance and physiological reactivity is considered within the context of social desirability and an allostatic model of stress examining differential contribution of cognitive and homeostatically driven physiological changes respectively. Future study to further investigate the associations between these psychological factors and physiological stress reactivity or pain tolerance may shed an additional light on our understanding in stress processes and pain-related outcomes.

Keywords: Threat appraisals, Pain catastrophizing, Mindfulness, Stress, Pain experience

Chapter I

Introduction

Chronic pain (non-cancer) has been identified as one of the major factors that can lead to disability and cause overall life dissatisfaction among sufferers (Jensen et al., 2002). Chronic pain can significantly impact the daily lives of those who suffer from it, restricting them from participating in their daily physical activities, which leads to lower satisfaction in their everyday lives. Such physical limitations may impact the quality of interpersonal relationships or social relationships, as the over-reliance of some sufferers on their partners can lead to interpersonal problems or the sufferer's withdrawal from social activities, which in turn can lead to social isolation (Mort & Philip, 2014). Moreover, chronic pain has been found to be associated with negative emotions, potentially leading to comorbid mental disorders such as depression, anxiety, and substance abuse (Demyttenaere et al. 2007). Patients with chronic pain often experience frustrations that the pain does not go away no matter what they do, disappointments that they cannot engage in normal life activities as before, anger that they have toward the cause of the pain, medical professionals, and themselves, and/or stresses that bring to their lives because of pain (Trost, Vangronsveld, Linton, Quartana, & Sullivan, 2012). These negative emotions overtime can increase a risk for development of mental disorders.

Chronic pain can also impact individuals' socioeconomic status, as these individuals may become unproductive because of absence from work, frequent visits to medical centers, and reduced work capacity. Such societal costs of chronic pain take a considerable proportion of the total costs of chronic pain (Patel et al. 2010). Chronic pain has also been identified as one of the most significant health problems facing the public and healthcare providers. Considering that almost 100 million American adults suffer from chronic pain, chronic pain is a major health care problem (Gatchel, MaGeary, McGeary, & Lippe, 2014). Additionally, at least $560-$635 billion is annually spent on chronic pain in the United States, which amounts to between $261-$300 billion for the incremental cost of health care and to between $297-$336 billion for the cost of lost productivity (Institute of Medicine, 2011). In addition, the Institute of Medicine (2011) has indicated that problems related with chronic pain (e.g., severity, disability) increase with age. Accordingly, as the baby boomer population gets older, those aged 65 years or older is going to be almost doubled by 2050 (Gatchel et al., 2014). As these problems associated with chronic pain increase, so too will the costs of addressing chronic pain and treating it.

Considering all of these factors, it is clear that chronic pain can directly or indirectly impact the quality of lives of the individuals as well as our society. Therefore, it would be beneficial to understand the nature of chronic pain and potential mechanisms that may prevent and/or mitigate chronic pain.

Pain Experience and Chronic Pain

Pain experience is commonly understood as a sensory experience signaling us that there is actual or potential tissue damage (Kerns, Sellinger, & Goodin, 2010; Merksey & Bogduk, 1994). However, this sensory signal or nociceptive experience is interpreted by the individual, and that interpretation creates the person’s unique pain experience. Because such experience is partly subjective in nature, it is influenced not only by biological factors (e.g., pathophysiology, genetics) but also by psychosocial factors (e.g., memories, emotions, beliefs, attitudes, expectations, the social and environmental context) (Turk & Okifuji, 2002). These factors can contribute to individual’s subjective interpretation of pain and influence his/her behavioral responses. Thus, pain experience can be considered as a complex phenomenon of objective and subjective experiences (Tracey & Mantyh, 2007).

Chronic pain refers to pain that is persistent for more than three to six months adversely affecting individual's life (American Chronic Pain Associations, 2016). Chronic pain may cause disability in daily life activity by influencing all aspects of a person's functioning, emotionally, interpersonally, and physically (Turk & Okifuji, 2002). Disability refers to the restrictions or limitations on daily activities that lead to physical or mental impairment (Turk & Okifuji, 2002). Disability may cause impaired social functioning and reciprocally lead to possible further impairment in physical or mental functioning (Rohrbaugh, Kogan, & Shoham, 2012). The levels of physical, mental, and social functioning that individuals achieve are often influenced by how they interpret their pain experience. Therefore, chronic pain can be defined as a condition in which "cognitive, affective, biological, and behavioral variables interact to form a 'chronic pain experience' characterized by pain, distress, and disability" (Hoffman, Papas, Chatkoff, & Kerns, 2007, p. 1).

Historical approaches to understanding pain: theories of pain.

While chronic pain is a significant health care issue for patients and the public, the complex biopsychosocial nature of chronic pain creates additional challenges to understanding it and to developing effective treatments (Banks & Kerns, 1996). Historically, the pain experience has been theorized in different ways. Initially, pain was viewed from a traditional biomedical reductionist philosophy. This philosophy held that the mind and body function separately, and therefore view pain simply as a symptom arising from the stimulation of nociceptive nerves caused by the presence of tissue damage. More recently, theories of pain have adopted more complex biopsychosocial models, which consider pain as a subjective experience involves the interpretation of sensory input. Thus, the pain experience is considered as the process influenced by the various biopsychosocial factors such as one's genetic composition, emotions, cognitive process, behavioral learning, interpersonal relationships, and cultural factors (Gatchel et al., 2007). A few representative models of pain are discussed briefly in the following sections.

Specificity theory of pain (nociception). The specificity theory of pain is a model of nociceptive processes of pain proposed by Max von Frey (Mendell, 2014). This theory states that there are unique pathways that specific painful information from the peripheral nerves gets transmitted to the central nerves of the spinal cord and the brain (Gatchel et al., 2007). The process of nociception is an ascending pain pathway projecting from the peripheral nerves to the cortex through the spinal cord, brain stem, and thalamus (Mendell, 2014). The basic process can be illustrated by the fact that when there is an injury or pain stimulus in the cutaneous sensory area, the injury stimulates the nociceptor (afferent sensory nerve fiber), firing signals that travel to the dorsal horn of the spinal cord where a pain neurotransmitter (e.g., substance P) is released into the synaptic cleft, and then transmitted to the polysynaptic interneuron (second order neuron). Once transduction occurs, the interneuron sends the pain signals through the spinothalamic track to the brain stem and then to the thalamus. The thalamus sends the pain information to cortical regions, such as the somatosensory cortex, which help the body identify which part of the body is potentially damaged, then to the prefrontal cortex to identify the extent of the pain the individual is experiencing. Pain information is also transmitted to the limbic system, a process that instigates an emotional and motivational response to the pain, such as fear and surprise (Simons et al., 2014). A criticism of this theory is a unidimensional sensory and affective model that views pain experience as the result of a linear, bottom-up process and fails to explain the fact that sometimes an individual does not feel pain immediately after an initial injury.

Gate control theory of pain. Melzack and Wall (1965) sought to address the phenomenon of an individual not feeling pain immediately after an injury. They explained such a phenomenon by recognizing a certain degree of the nociception process and at the same time acknowledging the significant role of emotions and cognitive evaluations (Gatchel et al., 2007). According to the gate control theory (Melzack & Wall, 1965), the experience of pain depends on a complex interplay of ascending and descending systems. The ascending pathways, as the specificity theory of pain, start with the neural signals from the primary afferent nerves after aversive stimulations and those signals are transmitted to the substantia gelatinosa (SG), the dorsal column, the transmission cells within the spinal cord, and the brain. However, the authors proposed additional pathways that also influence the signal transmissions from the spinal cord to the brain. The additional pathways are the descending pathways which signals are sent from the brain to sensory nerves through the spinal cord.

The authors proposed that the SG in the dorsal horn acts as a gate control system, which regulates the synaptic transmission of nerve stimulations from peripheral cells to central cells (Melzack & Wall, 1965). The gate control system is determined by the balance of the activity between the large and small diameter fibers, which the large fibers carry the information about nonpainful tactile stimulations and the small fibers carry the nociceptive information. The activity of the large fibers inhibits the gate opening, whereas the activity of the small fibers facilitates the gate opening (Moayedi & Davis, 2013). The balance of the activity between these fibers projects to the SG in the dorsal horn and the first central transmission cells, which controls whether the gate opens or closes, leading to the strength of the signals leaving the spinal cord.

In addition to the ascending pathways, the gate control theory of pain highlights how the descending pathways can also affect the balance of activity between the large and small fibers.

Central activities such as psychological factors can activate the descending pathways, which may open or close the gate. When nociceptive information, the balance of large and small fiber activities, exceeds a threshold of the transmission cells, it opens the gate and activates the ascending pathways that lead to the experience of pain (Moayedi & Davis, 2013). On the other hand, the greater activities of the large inhibitory fibers activated by the stimulation of the central nervous system can lead to closing of the gate. For instance, psychological factors (e.g., distraction) can increase the activities of the larger inhibitory fibers by triggering the release of neurotransmitters such as endorphins into the periaqueductal gray (PAG), which stimulates the neurons in the raphe nuclei to release 5-HT (serotonin). This activates the interneurons in the dorsal horn of the spinal cord, which releases Enkephalin (endogenous opioid neurotransmitters) into the synaptic gap, where the pain is transmitted to the next interneuron on the ascending pain pathway of nociception to the brain (Basbaum & Fields, 1978). Enkephalin works as an antagonist for the pain neurotransmitter, so it inhibits the signal from being transmitted to the next neuron, which blocks the ascending pathway to the brain. This process results in closing the gate. Thus, gate control theory accounts not only for the somatic sensation of the pain process but also psychological and social factors in the pain experience.

Operant conditioning and social learning theory of pain. While biological and psychological factors influence the pain experience, social factors are another important element to consider in an individual's pain experience. Although social support has been viewed as a beneficial factor in reducing distress from the pain experience and improving treatment adherence, adaptation, and rehabilitation of patients with chronic pain, there have been suggestions that certain types of social supports can facilitate dependency and maintain inappropriate responses by patients, leading to maladaptive behaviors (Meichenbaum & Turk, 1987; Turk, Kerns, & Rosenberg, 1992; Wallston et al., 1983; Wortman & Conway, 1985). The operant conditioning model of chronic pain (Fordyce, 1976) emphasizes that overt pain behaviors can be selectively reinforced by the presence of social supports (Turk et al., 1992). Patients may develop maladaptive pain-related behaviors by seeking continuous social supports. Pain behaviors are influenced by consequences and may be maintained by means of positive reinforcement. Primary care-givers, who tend to be family members and offer social supports, often condition patients' maladaptive behaviors of expressing their pain by providing discriminative cues and selective reinforcement (Fordyce, 1976). Several studies suggest that certain form of attention from spouses and solicitousness in relation to patients' pain behaviors may lead not only to increased overt pain behaviors, but also higher severity of pain (Flor, Kerns, & Turk, 1987; Boothby, Thorn, Overduin, & Charles, 2004; Giardino, Jensen, Turner, Ehde, & Cardenas, 2003). For example, a solicitous spouse may provide overly attentive sympathy for the patient's expression of pain and allow him/her to avoid unwanted responsibilities or undesirable activities. He/she may continuously seek attention and sympathy from his/her spouse for their pain. Over time, such solicitousness unwittingly contributes to maladaptive and avoidant pain-related behaviors (Turk et al., 1992). In that sense, maladaptive pain behaviors can be reinforced through operant conditioning and can lead to deleterious consequences such as pain, distress, and disability.

As seen in learning behaviors from modeling (Bandura, 1965), pain-related experience can be learned from observing other's behaviors (Goubert, Vlaeyen, Crombez, & Craig, 2011). For example, children may learn how to react to the experience of pain by observing how their parents react to painful stimuli. The experiment conducted by Goodman and McGrath (2003) showed that children demonstrated a lower pain threshold when they observe their mothers voluntarily display an exaggerated pain expression during a cold pressor task (CPT). Similarly, pain-related fear can also be learned through observations (Olsson, Nearing, & Phelps, 2007). Some evidences from fMRI suggest that the amygdala is involved with observational learning and expressing of the learned fear (Ochsner et al., 2008; Olsson, Nearing, & Phelps, 2007). Therefore, pain-related experience, particularly behavioral and emotional responses, can be learned in social context through operant conditioning and observations.

Neuromatrix theory of pain. Even though the gate control theory of pain accounts for psychological factor in the experience of somatic sensation, it still does not explain why an individual feels pain when there is no actual tissue damage, as in the case of phantom limb pain or post-traumatic stress disorder (Melzack, 2005). The neuromatrix theory of pain proposes that individual's pain experience depends on his/her unique neurosignature. Melzack (2005) called it a body-self neuromatrix, which is a widely distributed brain neural network. In short, the neural network system integrates the information of sensory-discriminative, cognitive-evaluative, and motivational-affective components and produces an individual's pain perception, pain behaviors, and physiological reactivity (e.g., hormone level, immune system activity) (Melzack & Casey, 1968; Melzeck, 2001). Therefore, the neuromatrix theory of pain takes into account all biopsychosocial factors that can influence the neural network system, such as individual's genetic compositions, cognitive processes, emotions, prior experiences, memory, interpersonal relationships, socio-economic environments, etc.

The flashback pain experience of patients with PTSD can also be explained by the neuromatrix theory of pain. Even though there is not an actual physical threat or stimuli, the neural network system can be triggered to create the actual pain experience in that patient (Melzack, 2005). In addition, this explains the experience of pain in the phantom limb. Individuals who lose a limb will often continue to experience the presence of the missing limb or the pain in that area (Gatchel et al., 2007). This phenomenon can also be explained by activating the neural network system.

According to the neuromatrix theory of pain, multiple factors determine the multidimensional experience of pain (Melzeck, 2001). For instance, a negative affective component of pain, such as emotional distress, has also been identified as a significant factor in chronic pain patients. Emotional distress may chronically activate the neural network, which may serve as a modulator that amplifies or inhibits the intensity of pain experience. In fact, emotional distress can contribute to persistent pain experience (Gatchel et al., 2007). In particular, anxiety, depression, and anger have received considerable attention as significant emotions in chronic pain. Anxiety or fear driven by the anticipation of pain may trigger the neural network system of pain, and may contribute to avoidance behavior, inactivity, and greater functional disability (Boersma & Linton, 2006). Continuous vigilance of noxious stimulation and the belief that it makes disease progression worse may increase and reinforce avoidance behavior by the temporal reduction of suffering (McCracken et al., 1993). Furthermore, although depression and chronic pain have been strongly associated, the temporal order of the causality between depression and chronic pain is not clear (Banks & Kerns, 1996; Gatchel et al., 2007). However, it is clear that there is a reciprocal relationship between them. One study suggests that patients with depression were 2.3 times more likely to report back pain than those without depression (Jarvik et al., 2005). Some studies suggest that pain causes individuals to develop depression (Brown, 1990). Furthermore, anger has also been observed among chronic pain patients (Schwartz et al., 1991).

Such anger can be the result of frustrations that he/she experiences due to persistent pain and repeated treatment failure, and that the information of the etiology is limited. In addition, frustration with others (e.g., insurance company, the health care system, family members) and toward themselves can lead to anger (Okifuji et al., 1999). Such anger and frustration may activate the neural network and exacerbate pain (Burns et al., 1996).

Stress and cognition in particular can play a crucial role in an individual's experience of chronic pain. Psychological and physiological stress may produce muscle tensions or negative emotions and trigger the neural network, contributing to neurosignature patterns that eventually exacerbate the pain experience (Melzeck, 2001). As the diathesis-stress model of pain proposed by Turk (2002) suggests, the interaction of various vulnerabilities and stress can play a role in the development and perpetuation of chronic pain. Such interaction may influence the neural network of pain.

Stress, considered as the product of perceived cognitive process, may also play a huge role in how an individual perceives the pain experience. As a result, the role of cognitive stress appraisals is believed to be important in chronic pain. As the study by Turk, Okifuji, and Scharff (1995) suggested, patients' appraisals of how pain will affect their lives and whether they have any control over their pain can mediate the relationship between pain and depression. Therefore, of particular interest in this paper, and within the context of chronic pain being a complex multimodal phenomenon is the additional role of stress and cognitive appraisal in the chronic pain experience.

Stress and the Experience of Chronic Pain

Stress has been identified as a critical component that may contribute to physiological or psychological pathologies. While acute stress can sometimes be adaptive, chronic stress can have a detrimental impact on our mind and body. Chronic stress has been found to be associated with depression, post-traumatic disorder, anxiety disorder, and other psychological disorders (Banks & Kerns, 1996; Blackburn-Munro & Blackburn-Munro, 2001; Otis et al., 2003; McEwen et al., 2012). Furthermore, chronic stress accelerates aging by shortening telomeres, genetic structures that protect the ends of our chromosomes from fraying (Simon et al., 2006; Oliveira et al., 2006). Chronic stress has also been known to be associated with chronic pain experienced in chronic fatigue syndrome, fibromyalgia, irritable bowel syndrome, chronic headache, dysmenorrhea, and temporomandibular disorder (Harris et al., 2008; Harris et al., 2009; Clifford & Demitrack, 1996; Crofford et al., 2004). Because the particular interest of this paper is stress within the context of chronic pain, the subsequent sections provide background information on four models of stress, as well as their implications for physiological and psychological responses that may lead to health problems such as chronic pain.

Models of stress.

Cannon: fight-or-flight and homeostasis. Walter Cannon, an early pioneer in stress research, built on the work of Claude Bernard and coined the term “homeostasis” (Cannon, 1929), which describes the biological processing system that maintains physiological variables such as blood pressure and body temperature within fixed ranges through feedback regulation (Goldstein & Kopin, 2006). He also coined the term “fight-or-flight” to describe acute changes in adrenal gland secretion and in the sympathetic nervous system (SNS) (Cannon, 1929). It is generally recognized that stressful circumstances evoke arousals or feelings of anxiety or anger, with accompanying activation of the autonomic nervous system leading to fight-or-flight responses (Spielberger, 1979).

His model of stress describes unitary biological pathways to explain the “fight-or-flight” response from a threat to “homeostasis.” He suggested there are two pathways in our bodies to respond to a “fight-or- flight” situation. The first pathway is that a stimulus (a threat to homeostasis) stimulates the reticular formation that activates the SNS, which in turn activates the adrenal medulla, releasing epinephrine or norepinephrine (adrenaline, noradrenaline respectively). These neurotransmitters, epinephrine or norepinephrine, contribute to regulating the various physiological systems related with survival (e.g., cardiovascular function, digestion). This pathway is called the peripheral sympathetic-adrenomedullary system (SAM).

The second pathway is activated when the reticular formation sends signals to the thalamus, which then sends the message to the hypothalamus, which generates corticotropic releasing factors (CRF). The CRF activates the pituitary glands to release adrenocorticotropic hormone (ACTH). This pathway is called the hypothalamic-pituitary-adrenocortical (HPA) system. The HPA system regulates the cardiovascular system, the metabolic system, the immune system, the reproductive system, and the central nervous system to maintain homeostasis in the body (Goldstein & Kopin, 2006).

The HPA pathway also influences the SAM pathway. The ACTH released from pituitary glands also activates the SAM pathway, leading to activation of the adrenal medulla. Thus, when a stimulus activates the reticular formation, the body produces the compensatory and anticipatory adjustments to enhance the likelihood of survival by regulating the SAM and the HPA pathways (Goldstein & Kopin, 2006). This model suggests that our bodies are constantly adjusting our physiological processes to maintain homeostasis from a threat through the feedforward and feedback mechanisms of these pathways. In the context of chronic pain, physiological arousals to painful stimuli, through these mechanisms, can cause patients to avoid a situation or stimulus that may evoke such arousal.

Selye: general adaptation syndrome. Hans Selye (1956) defined and popularized the term "stress" as being the "nonspecific response of the body to any demand upon it" (Selye, 1974, p. 20), where the term "nonspecific" represents a set of general physiological responses to the different nature of the stressor (Goldstein & Kopin, 2006). He introduced the General Adaptation Syndrome (GAS) to describe the short-term and long-term nonspecific physiological responses to stressors. Such responses adapt to the stressor by modifying various homeostatic systems at the level of the adrenals, the digestive tract, and the immune system (Huether, 1996). The GAS has three stages of coping with a stressor: first, an initial "alarm reaction," which is basically Cannon's fight-or-flight response; second, "stage of resistance," during which the body adapts to the stressor by activating the neuroendocrine system; and third, a "stage of exhaustion," which is the gradual decline of stress resistance, eventually resulting in physiological damage and organismic death (diseases) if continued (Goldstein & Kopin, 2006; Huether, 1996). For example, adrenal hypertrophy, gastrointestinal ulceration, and thymic and lymphoid shrinkage can be caused by the stress-related exhaustions of the adrenal functioning, the digestive tract, and the immune system respectively.

Selye proposed that the body adapts or modulates the immune system to prolonged stress through the activation of the adrenal cortex by ACTH, with the resultant release of glucocorticoid steroids such as cortisol, which then modulate the immune system (Goldstein & Kopin, 2006; Huether, 1996). When cortisol levels rise in the system, the hypothalamus is triggered to slow down or stop the manufacturing process through a negative feedback mechanism of the HPA axis. However, when stress is prolonged, the adaptive responses of the

HPA axis are disrupted and become maladaptive (Blackburn-Munro & Blackburn-Munro, 2001). In other words, the thalamus is unable to regulate the hypothalamus to stop producing CRF even though there is a signal indicating cortisol level is too high. Thus, prolonged stress can lead to dysregulation of the HPA pathways and modulation of the immune system, potentially leading to increased risk for physiological diseases.

Lazarus & Folkman's transactional model of stress. Cannon explains stress by unitary pathways and Selye explains stress by the general adaptation processes, but their models do not account for individual differences such as emotional, social, and psychological factors. Lazarus and Folkman's (1984) transactional model of stress explains stress by accounting for all of these factors. To be specific, the transactional model of stress explains why some people respond to the same stressor differently. Lazarus and Folkman defined stress as "constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person" (Lazarus & Folkman, 1984, p. 141). This model proposes that stress occurs when a person encounters an environmental demand, and the stress response depends on his/her cognitive appraisal, which refers to an interpretation of the stressor based on his or her ability to cope with it. When an individual interprets the demands of the situation to exceed his/her ability to meet those demands, he/she will experience a stress response. Thus, the appraisal process is subjective and highly personal and depends on a person's evaluation of his or her own ability to cope with the stressor. In addition, the authors suggested that the appraisal process is not necessarily a conscious process, but rather an automatic process influenced by the person's previous experiences.

This model suggests three types of cognitive appraisal: primary appraisal, secondary appraisal, and reappraisal (Lazarus & Folkman, 1984). Primary appraisal is the individual's judgement of what is at stake, and consists of irrelevant, benign-positive, and stressful appraisals. Irrelevant appraisal can be made when the situation does not have any implications for one's well-being. Benign-positive appraisal can occur if the outcome of an encounter is considered positive, while stressful appraisal, the particular interest of the present study, includes harm/loss, threat, and challenge. Harm/loss refers to damage that has already occurred to an individual, such as the loss of a loved one; threat refers to anticipation of harm or losses; and challenge refers to events from which an individual can improve or obtain gain (Lazarus & Folkman, 1984). Lazarus and Folkman point out that threat and challenge are separate constructs but not necessarily mutually exclusive. In a given situation, threat and challenge appraisals can occur simultaneously and this relationship can also change based on the nature of stress (Lazarus & Folkman, 1984). In terms of pain, an appraisal of threat about potential injury or pain may result in a maladaptive pain experience such as pain avoidance behaviors. On the other hand, an appraisal of challenge may lead to a more adaptive pain experience because an individual can be more positive about a demanding encounter, leading to greater morale, better quality of overall functioning, and better physical health (Lazarus & Folkman, 1984).

Secondary appraisal is an individual's evaluation of what can be done in response to internal and/or external demands and constraints, and whether the person's coping options and resources are sufficient to meet the threat or challenge a stressor poses (Lazarus & Folkman, 1984). The authors suggest two types of coping strategies based on how an individual manages the stressor. Problem-focused coping is utilized when he/she manages or alters the problem with the environment causing distress while emotion-focused coping is employed when regulating the emotional response to the problem (Lazarus & Folkman, 1984). Coping is determined by cognitive appraisal, which is influenced by coping resources. Such resources include a variety of biological, psychological, and social mechanisms for managing the demand from the stressor (Lazarus & Folkman, 1984). Physical health and energy, positive beliefs (e.g., general beliefs about an internal locus of control, existential beliefs), problem-solving skills, social skills, social supports, and financial resources can facilitate an individual's coping efforts (Lazarus & Folkman, 1984). Within the context of chronic pain, several coping mechanisms have received considerable attention in an attempt to explain how they can exacerbate the experience of pain, including fear-avoidance, anxiety sensitivity, and pain catastrophizing.

A substantial body of research suggests that catastrophizing is linked to higher levels of disability as well as a higher risk of various health problems such as depression, cigarette smoking, insomnia, higher cholesterol levels, increased alcohol consumption, longer hospitalization, increased pain medication usage (Banks & Kerns, 1996; Bray et al., 1999; Brummett et al., 2004; Buenaver et al., 2012; Keefe et al., 1989; Keefe, Rumble, Scipio, Giordano, & Perri, 2004; Jones, Rollman, White, Hill, & Brooke, 2003; Pohorecky, 1991; Steptoe et al., 1998; Turk & Okifuji, 2002; Turner, Mancl, & Aaron, 2004). Pain catastrophizing, a particular interest in this study, has also been found to be a strong predictor of negative pain-related outcomes, including higher pain intensity, exaggerated pain behaviors, disability, and emotional distress (Forsythe, Thorn, Day, & Shelby, 2011).

Lazarus and Folkman also emphasize how secondary appraisals and primary appraisals interact with each other to create the stress responses and the emotional reaction (Lazarus & Folkman, 1984). Usually, when an individual appraises a situation as a threat/harm or loss, he/she is more likely to engage in emotion-focused forms of coping strategy, whereas when he/she appraises a situation as a challenge, he/she is more likely to engage in problem-focused forms of coping strategy. In other words, if that person feels he/she has a sense of control over the situation, a challenge appraisal will be more likely to occur and an individual will be more likely to engage in problem-focused coping. However, if the stakes are too high, a threat appraisal can occur and he/she may engage in emotion-focused coping.

Ramirez-Maestre, Esteve, and Lopez (2008) conducted a cross-sectional study with 122 patients experiencing musculoskeletal chronic pain to examine the influence of cognitive appraisals and pain outcomes. Their findings show that participants who make higher threat appraisal to their pain experience tend to engage in passive (emotion-focused) coping strategies while those with higher challenge appraisal tend to engage in active (problem-focused) coping strategies as described in the primary appraisal section of this paper. In addition, those who engaged in passive coping tend to show higher pain intensity, greater impairment, and low levels of functioning, whereas those engaged in high levels of active coping tend to have higher daily functioning. Their findings indicate that cognitive appraisals of pain may indirectly predict pain-related outcomes such as pain intensity, impairment, the level of functioning through the mediating role of active or passive coping.

Tertiary appraisal, reappraisal, refers to a changed appraisal. Appraisal can be changed based on new information from the environment, one's own reactions to the environment, and/or a result of cognitive coping efforts (Lazarus & Folkman, 1984). This model emphasizes that reciprocal processes between a person and the environment can be mediated by cognitive reappraisal (Lazarus & Folkman, 1984). Based on the feedback from an initial cognitive appraisal, a threat appraisal can be reappraised as irrelevant or it can be reappraised as a challenge. For instance, if a person has a pain-related disorder, he/she may engage in a threat appraisal when first experiencing pain during a certain situation/activity. However, if he/she discovers that such pain experience does not cause further injury, he/she may reappraise the same situation/activity and accept the situations as it is and be more likely to tolerate a higher level of pain and distress (Viane, et. al., 2003). Consequently, feedback from the interaction between personal and environmental factors can lead to changing emotions and appraisals. Therefore, a reappraisal modifies an earlier appraisal to the same stimulus based on external and internal factors (Lazarus & Folkman, 1984). Lazarus and Folkman do not differentiate between reappraisal and appraisal; rather, they consider that reappraisal is essentially appraisal (Lazarus & Folkman, 1984). In terms of the pain experience, changing appraisals has received considerable attention as an effective way to manage the pain experience among chronic pain patients, by turning to such strategies as cognitive-behavioral therapy (CBT) to alleviate pain (Turner, Holtzman, & Mancl, 2007; Seminowicz, 2013; Knoerl, Smith, & Weisberg, 2016).

In Lazarus & Folkman's transactional model of stress, "transaction" implies a process in which stress is not caused by personal or environmental factors; rather, it reflects a conjunction of both factors (Lazarus, 1990). This model demonstrates that the stress relationship is consistently changing because of a continual interaction between personal and environmental factors, which have a dynamic, mutually reciprocal, bidirectional relationship. It also suggests how an individual appraises the stressor as impacting social functioning as well as mental and physical health (Lazarus & Folkman, 1984). Furthermore, it implies that an individual can perceive the stressor as a threat even when the situation is not real. In addition, cognitive appraisal processes provide a common pathway through which personal and environmental variables change the psychological response, and, as a result, emotions and their biological modification follow. Thus, this model implicates a biopsychosocial model of stress.

Moreover, the transactional model of stress suggests that cognitive primary and secondary appraisals can mediate the associations between the stressor and physiological response. Although Lazarus and Folkman agree with Selye's idea that our bodies respond defensively to stressors and disturbed homeostasis, and that a sustained state of excessive arousal can lead to various diseases, they disagree with him regarding a general physiological response to the stressor. They argue that emotional responses to the same stressor can differ among people, which can lead to different physiological responses. The way people perceive a specific stressor as a threat or challenge can influence their coping patterns which, in turn, may impact their health outcomes. This is because coping can influence the neurochemical stress reactions (Lazarus & Folkman, 1984). For instance, maladaptive coping, such as the excessive use of deleterious substances (e.g., alcohol, smoking, drugs, etc.) can affect health outcomes negatively, increasing the risk of mortality and morbidity (Lazarus & Folkman, 1984).

When a person appraises the stressor as a threat, in the short-term his or her fight-or-flight response gets activated. Such a response can change our homeostasis temporarily by activating the SAM axis, which increases blood pressure, heart rate, and respiratory rate. The response can also activate the HPA axis, which increases the secretion of hormones such as glucocorticoids. This response helps individuals to adapt to personal and environmental demands; however, in the long-term, these changes caused by stress can have detrimental effects on overall well-being and health. The relationship between stress and hypertension has been studied extensively, and suggests that hypertension can lead to various cardiovascular diseases such as atherosclerosis, myocardial infarction, heart attack, ischemic stroke, angina, and congenital heart disease (Rosenthal & Alter, 2011; Steptoe & Kivimäki, 2012). The positive relationship between stress and hormonal changes, such as the production of cortisol, is of particular interest in this study. The subject has received considerable attention in the literature, which has found that prolonged hyper cortisol secretion can affect immune functioning, leading to various health problems such as those related to digestion, ulceration, reproduction, and fatigue (Segerstrom & Miller, 2004; Miller, Chen, & Zhou, 2007). In the context of pain, cortisol secretion in response to pain-related acute stress has been linked to an intensification of the pain experience (Hannibal & Bishop, 2014); furthermore, exhaustion of the HPA axis and cortisol dysfunction from chronic stress is commonly implicated in inflammation and pain without known cause (Heim, Ehlert, & Hellhammer, 2000; Edwards et al., 2008). Thus, this model accentuates how cognitive appraisal and coping processes can affect the relationship between stress and health in all its short-term and long-term physiological, psychological, and social effects.

Allostasis model of stress. While the transactional model of Lazarus and Folkman has added substantially to the work of Cannon and Selye and to the understanding and conceptualization of stress, allostasis represents a more contemporary theoretical model. While highly physiologically based, and thus not a primary model for this study, allostasis is defined as the level of activity required for an individual to achieve stability through change (McEwen & Wingfield, 2010). It is a model of how an organism maintains critical homeostasis (immediate life) through changes in multiple interacting compensatory physiological processes. For example, when an organism is under high demand for the expenditure of physical energy (allostatic load, the cumulative result of an allostatic state), the stability of physiological systems that maintain life is enhanced by changing physiological set points (allostatic state) of other systems and associated behaviors in response to changing stressors (McEwen & Wingfield, 2010; McEwen & Wingfield, 2003). These changes can be either temporary or permanent. Thus, the maintenance of allostatic states requires energy. Allostatic overload can occur if there are unpredictable events, such as disease or social interaction, requiring additional loads (McEwen & Wingfield, 2003).

While the allostatic state can have protective and adaptive effects in the short term, if allostatic overload is maintained persistently, it can be accompanied by physiological or psychological pathologies (Goldstein & Kopin, 2006). If demand of the energy exceeds the available energy, Type 1 allostatic overload occurs (McEwen & Wingfield, 2003), leading to physiological conditions such as body weight loss and the suppression of reproduction (Wingfield, Moore, & Farner, 1983). However, if the organism continues to take in or store as much or even more energy than it needs even when energy demands are not exceeded, Type 2 allostatic overload occurs, leading to various physiological problems, such as fat deposition from stress-related food consumption, choice of a fat-rich diet, metabolic imbalances, neuronal changes (such as the loss of pyramidal neurons in the hippocampus), atherosclerotic plaques, high cholesterol, and chronic pain and fatigue (McEwen & Wingfield, 2003). Thus, various biological, psychological, and social factors may impact allostatic overload, leading to pathologies as well as chronic pain.

Transactional Model of Stress and Chronic Pain Experience

As mentioned above, cognitive appraisals of stressors affecting activation of coping strategies has been found to be highly integral to the pain experience. Thus, the relationship between cognitive appraisal, coping, and the pain experience will be discussed further in subsequent sections, with some empirical research evidence.

Primary appraisal and pain experience.

Considering that chronic pain can lead to disability among some individuals but not others, the ways they appraise their pain experience may produce different results. Thus, cognitive appraisal, especially primary appraisal, can play an important role in how individuals interpret their pain experiences. In various chronic pain literatures, primary appraisals have been studied as a predictor for increased pain (Ramirez-Maestre et al., 2008), impairment (Jensen et al., 1994; Jensen et al., 1999; Turner et al., 2000), and affective distress (Meredith et al., 2005; Osborne et al., 2007). Jackson, Wang, and Fan (2014) conducted a meta-analysis based on the transactional model of stress to evaluate the association between primary appraisals of pain as a source of threat or challenge and response to acute laboratory induced pain as well as to chronic non-cancer pain. Their study analyzed 22 laboratory pain studies involving 2,031 participants, and 59 chronic pain studies based on 9,135 patients. The results from laboratory pain studies indicate that elevated threat appraisals are associated with overall increases in pain ratings and lower pain tolerance, whereas higher challenge appraisals are linked to higher pain tolerance but not pain intensity. Furthermore, their findings from chronic pain studies suggest that threat appraisals are positively correlated with pain intensity, impairment, and affective distress, whereas challenge appraisals are associated with more favorable outcomes (Jackson et al., 2014). This suggests that primary appraisals to the pain experience may predict pain-related outcomes.

For example, if they appraise the pain sensations as threatening or harmful, they may tend to engage in passive or emotion-focused coping. It may lead them to react in an emotionally negative way and limit their daily activities or withdraw from social activities, potentially resulting in disability. On the other hand, if they appraise their pain experience as challenging, they may engage in active or problem-focused coping, leading to less distress and more favorable performance (Ramirez-Maestre et al., 2008; Snow-Turek, Norris, & Tan, 1996). Challenge appraisal can result in adaptive behaviors, which may increase overall well-being in these individuals. Therefore, the ways in which individuals cognitively appraise pain sensations or stimuli may affect their pain outcomes in maladaptive or adaptive ways.

Based on the transactional model of stress, several studies have been conducted to evaluate the role of cognitive primary appraisal in relation to coping and the overall well-being of patients with chronic pain. Ramirez-Maestre, Esteve, and Lopez (2008) conducted a cross-sectional study with 122 patients experiencing musculoskeletal chronic pain to examine the influence of cognitive appraisals and pain outcomes. Their findings show that participants who make higher threat appraisal to their pain experience tend to engage in passive (emotion-focused) coping strategies while those with higher challenge appraisal tend to engage in active (problem-focused) coping strategies as described in the primary appraisal section of this paper. In addition, those who engaged in passive coping tend to show higher pain intensity, greater impairment, and low levels of functioning, whereas those engaged in high levels of active coping tend to have higher daily functioning. Their findings indicate that interaction of primary and secondary appraisals of pain may indirectly predict pain-related outcomes such as pain intensity, impairment, and the level of functioning through the mediating role of active or passive coping.

Secondary appraisal and pain experience.

Secondary appraisal, which is the individual's evaluation concerning what can be done in response to internal and/or external demands and constraints, can be impacted by the interaction of personal and environmental factors, facilitating his or her specific coping strategies. In addition, various personal constraints, environmental constraints, and the level of threats can restrict how an individual reacts to a stressor, which can influence him/her from using coping resources effectively (Lazarus & Folkman, 1984). In particular, how much resources one believes that he/she has can determine how well he/she deals with a situation or stimuli. As pain is a complex phenomenon of objective and subjective experiences, the process of interpreting pain sensations is influenced not only by how threatening the stimuli is but also by how much resources are available to deal with the stimuli. For instance, individuals who encounter pain sensations may choose to accept their pain and continue living their lives as usual if they believe such pain sensations is temporary and will not cause any more injury. However, individuals may choose to refrain from engaging in various activities if they believe such pain sensations will get worse or develop further injury from engaging in those activities.

Negative beliefs about pain can sometimes be exaggerated and can cause individuals to limit their activities. This exaggeration is referred to as catastrophizing, and catastrophic thinking about pain is referred to as pain catastrophizing. Pain catastrophizing, a particular interest of the present study, has been found to be strongly related to secondary appraisals, influencing the pain experience and pain outcomes (Thorn, Rich, & Boothby, 1999). When individuals believe that they do not have enough personal or environmental resources to deal with the painful stimuli, they may engage in negative coping strategy by exaggerating the situations, which can lead to avoid any activity that may accompany such stimuli. Consequently, pain catastrophizing is considered as a type of coping strategies. Thus, in this study, pain catastrophizing is viewed as a secondary appraisal process.

Pain catastrophizing and pain outcomes. Pain catastrophizing is defined as an exaggerated negative cognitive process, particularly coping strategy, about experienced or anticipated painful stimulation (Smith, Herman, & Smith, 2015; Sullivan, Bishop, & Pivik, 1995). Pain catastrophizing has been characterized as involving rumination (a tendency to focus constantly on pain-related thoughts), magnification (a tendency to exaggerate the negative appraisal of pain stimuli), and helplessness (a tendency to believe that one has no ability to deal with painful situations) (Chaves & Brown, 1987; Rosenstiel & Keefe, 1983; Spanos, Radtke-Bodorik, Ferguson, & Jones, 1979). Pain catastrophizing has been identified as predictor for pain-related disability (Sullivan et al., 2001). When the person believes he/she has enough resources to deal with a pain-related stimulus, he/she may engage more in a more positive and active coping strategy, rather than a negative and passive coping strategy. On the other hand, when the person perceives a painful stimulus to be beyond his/her resources, he/she may engage more in emotion-focused coping strategies by exaggerating the pain experience, potentially leading to pain-related disability.

Several factors contribute to the pain-catastrophizing tendency. In cases of chronic pain, pain-related anxiety and fear have been found to be associated with detrimental pain-related outcomes (Crombez, Vlaeyen, Heuts, & Lysens, 1999). Chronic pain patients with higher pain-related anxiety tend to anticipate higher levels of pain compared to those with low anxiety, often leading to more maladaptive behavioral outcomes (McCracken & Gross, 1993). Such maladaptive behaviors are more likely to be reinforced by avoiding the pain stimuli. When people with pain symptoms are exposed to a situation or a stimulus that may cause pain, some tend to engage in negative cognitive responses such as worry, fear, and avoidance (McCracken & Gross, 1993). In many cases, such efforts to avoid increased pain experience or any further injury are reinforced by successful avoidance (Crombez et al., 1999). Thus, a vicious cycle of fear, pain catastrophizing, and avoidance may develop.

Another factor contributing to the tendency to catastrophize is locus of control or self-efficacy expectation over pain. People with lower self-efficacy expectancies or lower internal locus of control are less likely to engage in active coping strategies and endure the difficulties and aversive consequences compared to those with higher self-efficacy expectancies or internal locus of control (Bandura, Delia, Taylor, & Brouillard, 1988; Crisson & Keefe, 1988; Turk & Okifuji, 2002). In addition, higher anxiety sensitivity and hyper-somatic sensitivity can contribute to higher pain catastrophizing (Drahovzal, Stewart, & Sullivan, 2006). All these factors can influence the process of secondary appraisal of pain stimuli. Pain catastrophizing, a maladaptive coping strategy to primary appraisals, can lead to deleterious pain outcomes. Consequently, there are several studies that examined the associations between primary appraisals, pain catastrophizing, and pain-related outcomes.

Jones et al. (2003) conducted a study to examine the associations between catastrophizing, primary appraisals, and pain outcomes. The authors identified 104 adult patients with a broad range of chronic pain conditions (e.g., rheumatoid arthritis, osteoarthritis, fibromyalgia syndrome, temporomandibular dysfunction). They found that catastrophizing was significantly associated with primary appraisals, indicating that threat appraisals may be associated more with catastrophizing than the rest of the variables. In addition, catastrophizing was inversely related to the pain-related outcomes.

While the study by Jones et al. were cross-sectional designs, another study was conducted using an experimental design by Forsythe et al. (2011). The authors recruited 155 healthy college students, excluding any students with chronic or pain-related conditions. These participants completed a cold pressor task and a series of questionnaires. Although the authors looked at gender differences and racial differences in pain ratings, this study’s primary findings were that higher threat/harm appraisals were associated with lower pain tolerance while higher challenge appraisals were associated with higher pain tolerance, and higher pain catastrophizing was also associated with higher pain intensity and pain unpleasantness.

In addition to these studies, Wertli et al. (2014) conducted a systematic review of 16 literatures to evaluate whether psychological factors, including catastrophizing thoughts, predict the development of chronic low back pain (LBP). The findings suggest that participants with high catastrophizing scores tend to report higher pain, demonstrate greater disability, and experience a worse outcome regardless of whether they have acute, subacute, and chronic LBP, compared to those with low catastrophizing scores (Wertli et al., 2014). Burns et al. (2015) also conducted a systematic review of the literature to establish whether pain catastrophizing can be a predictor for chronic pain following total knee arthroplasty (TKA) (Burns et al., 2015). The review includes six prospective longitudinal studies with different sizes of the samples, and the results suggest that pain catastrophizing can be identified as a significant predictor of chronic pain after TKA (Burns et al., 2015).

Based on the various studies mentioned above, it is reasonable to consider pain catastrophizing as a secondary appraisal and a powerful predictor of negative pain-related outcomes. Even though pain catastrophizing is strongly associated with maladaptive pain outcomes, it is worth noting that a primary appraisal still influences a secondary appraisal, and they interact with each other in shaping one’s stress responses and emotional reactions, which can impact the individual’s pain experiences.

Reappraisal and pain experience.

A changed appraisal based on feedback from the interaction between personal and environmental factors and from coping efforts can also impact pain outcomes. While not many studies specifically examine the relation between cognitive reappraisal and the pain experience, there is an extensive amount of literature that discusses cognitive reappraisal from a therapeutic perspective, such as cognitive-behavioral therapy (CBT). CBT is an empirically supported psychotherapeutic treatment that aims to help individuals resolve their psychological problems through a systematically goal-oriented procedure involving the cognitive re-evaluation process (Kerns et al., 2010). CBT involves cognitive interventions to identify maladaptive thoughts and replace them with adaptive ones and this particular process is considered cognitive reappraisal (Turk et al., 1983). The cognitive reappraisals of CBT have been found to be one of the beneficial treatments for reducing pain and disability, increasing functional ability, and stabilizing mood (Kerns et al., 1986). The use of CBT for pain management has been shown to be effective for a variety of chronic pain problems (Chen et al., 2004; Eccleston et al., 2002; Morley et al., 1999; Weydert et al., 2003; Kerns et al., 2010). Although reappraisal is a tremendously important aspect of pain management, the present study does not particularly examine the relationship between reappraisal processes and pain experience; thus, it is only briefly discussed above.

Stress appraisal, physiological responses, and pain experiences.

Blood Pressure. As mentioned in the previous section, a primary appraisal of a threat or a challenge in the context of a personally salient stressor with limited coping resources results in a physiological stress response such as an increase in blood pressure and cortisol. Acute stress generates increased activity of the sympathetic nervous system. In particular, acute pain induced by the cold pressor task has shown that muscle-sympathetic nerve activity is positively associated with blood pressure (Nordin & Fagius, 1995). Furthermore, persistent pain may lead to chronically elevated blood pressure (Sacco et al., 2013). Prolonged high blood pressure may cause malfunction of the endogenous opioid systems and as a result may reduce their analgesic effect (Sacco et al., 2013). The exact pathway of this effect is beyond the scope of this study, but a positive association between resting blood pressure and clinical chronic pain intensity has been reported (Bruehl et al., 2002). Another study suggests that chronic stress and chronic pain may reduce endorphin levels and increase pain sensitivity (Quintero et al., 2000). Therefore, perceived chronic stress can chronically increase blood pressure, which may act as a predictor for the severity of the chronic pain experience.

Cortisol. In response to stressors, the HPA axis releases hormones which affect various physiological functions (Miller et al., 2007). In particular, cortisol, known as a stress hormone, has been substantially studied in terms of biopsychosocial perspectives because of its detrimental impact on mental and physical health (Miller et al., 2007). Cortisol has been found to influence cognition, metabolism, and immune function. Densen, Spanovic, and Miller (2009) conducted a meta-analysis consisting of 80 experiments in 66 articles to examine the influence of cognitive appraisals and specific emotions/cognitions (e.g., basic emotions, rumination and worry, and social threat) on cortisol and immune reactivity to emotional stress. They found that threat appraisals were significantly associated with increased cortisol reactivity and reduced immune responses whereas challenge appraisals were significantly associated with lower levels of cortisol reactivity and greater immune responses. In addition, rumination and worry were associated with increased cortisol reactivity as well as submissiveness and the fear of losing social approval (Densen, Spanovic, & Miller, 2009). Thus, it is reasonable to suggest that catastrophizing and threat appraisals may be associated with increased cortisol responses.

In the context of pain, perceived stress can cause analgesia and hyperalgesia, depending on the type of stressor as well as the intensity and duration of the pain (McEwen & Kalia, 2010). This is because the role of the HPA axis in pain is complex. Some studies have suggested that cortisol secretion during a non-pain-related acute stress response (e.g., public speaking) may be associated with distracting attention and thus inhibiting the pain experience; however, cortisol secretion in response to pain-related acute stress may be associated with an intensified pain experience and fear of pain (Benedetti, Amanzio, Vighetti, & Asteggiano, 2006; Colloca & Benedetti 2007; Densen et al., 2009). The detailed mechanisms are beyond the scope of this paper, but a summary of these studies is that when a potential stressor is interpreted as threatening or frightening, the amygdala activates the HPA axis leading to cortisol secretion, and cortisol conditions maladaptive emotional responses in the amygdala and forms a fear-based memory, which leads to further HPA axis activation (Benedetti et al., 2006; Colloca & Benedetti, 2007; Keltner et al., 2006). In a related study, Benedetti et al. (2006) showed that a verbally induced nocebo effect is associated with increased pain intensity and cortisol reactivity during laboratory induced acute pain.

Additionally, chronic perceived stress can alter and dysregulate the function of the HPA axis, which can result in overproduction of cortisol, underproduction of cortisol, or a flattened cortisol awakening and reduced diurnal variation (Miller et al., 2007). Prolonged and increased cortisol is suggested to be associated with the increased inflammation. Prolonged cortisol dysfunction has been suggested as a contributor to develop chronic pain primarily through pro-inflammatory processes (Hannibal & Bishop, 2014). Several studies have linked chronic stress-induced hypocortisolism to chronic pain conditions such as fibromyalgia, chronic fatigue syndrome, chronic pelvic pain, and temporomandibular disorder through decreased inflammatory responses (Ehlert et al., 2001; Tsigos & Chrousos, 2002; Tak & Rosmalen, 2010). Furthermore, prolonged elevation of inflammatory cytokines increases the sensitivity of nociceptors, which manifests as increased pain sensitivity (Hannibal & Bishop, 2014). Some studies suggest that flattened cortisol awakening response and reduced diurnal variation are also related with increased pain in chronic pain patients (Johansson et al., 2008; Park & Ahn, 2012). Godfrey et al.

(2013) has also examined the association between salivary cortisol and pain sensitivity to a cold pressor task in 198 female pain-free twins. They found that lower diurnal variation of cortisol was associated with higher pain ratings. They suggested that dysregulation of the HPA axis resulting in a reduced variation of cortisol diurnal rhythm among chronic pain is associated with increased pain sensitivity. Thus, it seems that cortisol can be a factor for pain experiences in acute and chronic pain.

Bidirectionality: Stress appraisal and pain experience. The experience of pain may also increase the appraisal of stress, in a bi-directional manner, ultimately exacerbating the pain experience. From a study by Hassinger, Semenchuk, and O'Brien (1999) with 52 college students (26 with migraine headache and 26 control), the authors found that individuals with migraine headache rated a cold pressor task as significantly more painful compared to the headache-free participants, and those with headache tend to use more maladaptive coping strategies (e.g., social withdrawal, catastrophizing) to deal with stress and pain experience outside of laboratory. The authors suggest that these individuals with migraine headache may have learned from past pain experiences and tend to make higher pain ratings and more negative cognitive appraisals to painful sensations. It suggests that the association between cognitive appraisal processes and pain experience may be bidirectional and reciprocal, and determined by multidimensional factors.

Mindfulness as a New Topic in Chronic Pain

Within the biopsychosocial perspective, a growing number of studies have investigated different ways to influence psychological factors to treat chronic pain and achieve positive pain-related outcomes. More recently, mindfulness has received significant attention for its potential to play a protective role in the experience of pain and as a treatment for a variety of chronic pain conditions. The following sections will discuss mindfulness as well as the role of mindfulness in the pain experience and in cognitive appraisals within the transactional model of stress and coping.

Mindfulness.

The concept of mindfulness originates from Eastern spiritual traditions, in particular Buddhist philosophy, but in recent times has been influenced by Western philosophy and culture (Rau & Williams, 2016). While there is not a universally agreed-upon definition of mindfulness, it has been described as “bringing one’s complete attention to the present experience on a moment-to-moment basis” (Marlatt & Kristeller, 1999, p. 68) or “paying attention in a particular way: on purpose, in the present moment, and nonjudgementally” (Kabat-Zinn, 1994, p. 4). In addition, Biship et al. (2004) propose an operational definition of mindfulness employing a two-component model of self-regulation of attention and orientation to experience. The authors defined mindfulness as “a process of regulating attention in order to bring a quality of non-elaborative awareness to current experience and a quality of relating to one’s experience within an orientation of curiosity, experiential openness, and acceptance” (Biship et al., 2004, p. 234).

Mindfulness has been studied predominantly using mindfulness meditation training interventions such as the Mindfulness-Based Stress Reduction as well as self-report measures of state and trait mindfulness, such as the Mindful Attention Awareness Scale and the Five Facet Mindfulness Questionnaire (Creswell & Linsday, 2014). Distinctions have been made between different types of mindfulness, such as dispositional (i.e., trait) and cultivated (i.e., trained or practiced), supported by theoretically related Buddhist concepts and empirical research (Creswell & Linsday, 2014). Therefore, mindfulness can be recognized not only as an innate individual difference, but also as a set of skills that can be improved through the practice of meditation

(Biship et al., 2004; Baer, 2003; Rau & Willams, 2016). For the purpose of this study, mindfulness is defined as a dispositional construct that can influence one's overall well-being by staying in the present moment non-judgmentally and being aware of oneself and the environment without reacting to inner experiences.

A growing body of literature has demonstrated that mindfulness can enhance overall well-being and promote physical and psychological health (Shapiro, Oman, Thoresen, Plante, & Flinders, 2008; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010, Keng, Smoski, & Robins, 2011, Teasdale et al., 2000). Staying in the present moment reduces the symptoms of anxiety because anxiety is often a byproduct of worrying about future events. Furthermore, mindfulness tends to reduce depressive symptoms, as depression is often the result of extensive rumination of past events (Baer, 2003). The ability to direct one's attention to the present moment may help to disconnect negative thought processes, which may result in more positive cognition, leading to overall well-being.

Mindfulness and chronic pain.

While the mechanism of mindfulness association with chronic pain has not been fully understood (e.g., physiological basis), much clinical work has been done to examine mindfulness as a treatment modality for chronic pain patients. Indeed, as Kerns, Sellinger, and Gooden (2011) indicated in their review article, mindfulness has been shown to be a successful treatment for chronic pain patients. In particular, mindfulness has been found to reduce anxiety and depression and improve overall life satisfactions among chronic pain patients. Mindfulness has been utilized in different interventions such as Acceptance and Commitment Therapy (ACT) (Hayes et al., 1999), Mindfulness-Based Cognitive Therapy (MBCT) (Segal et al., 2002), Dialectical Behavior Therapy (DBT) (Linehan, 1993), and Mindfulness-Based Stress Reduction (MBSR) (Kabat-

Zinn, 1990). These interventions have shown significant clinical improvement in physical and mental health among a broad range of clinical populations including chronic pain (Carmody & Baer, 2007).

Since mindfulness can be conceptualized as a way to observe and accept experiences (e.g., physical symptoms, emotions, or thoughts) without judgment or reactivity, it is reasonable to suggest that mindfulness may change how chronic pain patients experience their nociceptive pain and, as a result, its application can affect their behaviors. Chronic pain patients might suffer from, and even be disabled by, the restricted awareness, the exaggerated negative thoughts and emotions, and habitual avoidance (McCracken, 2005). Recent studies indicate that mindfulness can offer benefits for pain-related outcomes. Some researchers have investigated the association between pain outcomes and mindfulness as a trait in the pain experience, while others have examined the effects of mindfulness intervention programs in the pain experience (Liu, Wang, Chang, Chen, & Si, 2013; McCracken, Gauntlett-Gilbert, & Vowles, 2007)

Many researchers have attempted to determine whether mindfulness-based interventions can provide benefits for the overall pain experience. For example, Kabat-Zinn (1982) conducted a study with 51 chronic pain patients who underwent a 10-week Stress Reduction and Relaxation Program and found a statistically significant reduction in pain ratings from the pre- to the post program. In addition, other researchers have conducted empirical studies with healthy participants to rule out the possibility of alternative explanations such as distraction (Liu et al., 2013).

A randomized experimental study was conducted with 86 healthy college student participants to examine the effect of a short-term mindfulness-based intervention on the pain experience (Liu et al., 2013). The intervention was delivered in a therapist-free form (listening to an audio recording). The participants were randomly assigned to three types of intervention groups: mindfulness, distraction, and spontaneous strategies (resting and listening to light music). After each participant listened to an assigned 15-minute recording, they were asked to undergo a cold pressor task that measured pain tolerance, pain ratings, and distress rating. These authors found that the participants in the mindfulness intervention significantly improved pain tolerance and had lower pain ratings and distress ratings compared with spontaneous strategies. They also found that the distraction group significantly improved the pain tolerance but did not reduce the distress ratings compared with spontaneous strategies. Consistent with the studies by Kabat-Zinn (1982), this study indicates that mindfulness may improve the experience of pain by reducing pain ratings and increasing pain tolerance. Similarly, Kingston, Chadwick, Meron, and Skinner (2007) conducted a study with college students to assess the role of mindfulness practice on pain tolerance to a cold pressor task, and found that pain tolerance increased significantly among students who had practiced mindfulness compared with the control group.

While a tremendous amount of research exists on the benefits of mindfulness intervention, there are not as many studies on the benefits of trait mindfulness. One of the studies examining the benefits of trait mindfulness was conducted (McCracken et al., 2007). They recruited 105 chronic pain patients to investigate the associations between mindfulness and the emotional, physical, and social functioning of chronic pain patients. They found that greater trait mindfulness significantly predicts more positive physical, social, cognitive, and emotional function. They also found that patients with higher trait mindfulness use less medication. They also found that the trait of mindfulness can predict lower pain intensity. It may suggest that being in the present moment without judgment or reactivity can offer considerable benefits in terms of how chronic pain patients experience their nociceptive pain.

Mindfulness has also been used as a stress reduction treatment for patients with chronic pain. Mindfulness has a relatively long history in terms of stress and stress management, which is beyond the scope of this paper. For a fuller examination, refer to the literature (Baer, Carmody, & Hunsinger, 2012; Chiesa, & Serretti, 2009; Sharma, & Rush, 2014). Some researches of pain management have suggested mindfulness can help reduce pain-related stress, which may alleviate symptoms associated with chronic pain and improve overall life satisfaction (Feuille, & Pargament, 2015; Davis, Zautra, Wolf, Tennen, & Yeung, 2015). Such an approach for reducing stress in pain patients suggests that mindfulness could play a role in the context of the transactional model of stress and coping.

Mindfulness and primary appraisal.

Although, to this author's knowledge, no study has examined the complete relation among mindfulness, cognitive stress appraisal, physiological relativities, and pain outcomes, a substantial body of research has examined partial relations. Mindfulness appears to increase cognitive flexibility because the tendency to pay attention to the present moment and being in the present moment nonjudgmentally tends to influence the cognitive appraisal process. As indicated earlier, mindfulness interventions have been studied greatly in relation to changing perceptions or cognition through therapy such as the MBCT; however, to this author's knowledge, few studies have examined the particular association with trait mindfulness and all three types of cognitive stress appraisals in the context of chronic pain. In particular, there is little research that has examined the relationship between trait mindfulness and primary appraisal.

Weinsten, Brown, and Ryan (2009) conducted a series of studies to investigate the association between trait mindfulness and cognitive appraisals, particularly primary and secondary appraisals. Each study was conducted with different groups of healthy college students. The authors conducted four different studies, and Study 1 examined the association between trait mindfulness measured by the MAAS and threat appraisals of laboratory-induced stressful situations as well as coping strategy. In order to provide external validity, Study 2, a short-term longitudinal design, examined how trait mindfulness measured a month prior by the MAAS was associated with perceived stress and coping strategy measured one month later. Study 3 examined the association between trait mindfulness measured by the MAAS to the stress process and well-being at the level of day-to-day experience for a seven-day period by asking the students to write down the five-item state version of the MAAS (Brown & Ryan, 2003) three times a day in order to control the possibility of retrospective memory bias that may cause the result of Study 2. Finally, Study 4 examined the association between trait mindfulness and primary appraisals in response to a specific real-world challenge, by studying college students' level of stress at midterm and during the final examinations. The results from all of these studies consistently confirmed that individuals with high trait mindfulness tend to make more benign stress appraisals or less threat appraisals, which results in the less frequent use of maladaptive coping strategies.

Mindfulness and secondary appraisal: pain catastrophizing.

Mindfulness has been extensively studied in relation to a secondary appraisal process, particularly pain catastrophizing. Since mindfulness is a state of being in the present moment in a nonjudgmental or accepting way, it is reasonable to suggest that mindfulness can reduce maladaptive cognitions including cognitive coping strategies such as pain catastrophizing. Thus, increasing attention has been paid to examining the association between pain catastrophizing and mindfulness.

Day, Smitherman, Ward, and Thorn (2015) conducted a study with 214 healthy undergraduate participants, who were asked via the Internet to fill out the PCS and the FFMQ. The authors found that higher mindfulness scales – particularly the Non-judging, Non-reactivity, and Awareness scales, were significant predictors of lower catastrophizing scores. This finding is reasonable because the Non-reactivity comprises items asking whether one is calm or nonreactive when experiencing distressing thoughts, feelings, or situations; the Awareness scale is related to not being distractible or functioning without attention (e.g., being on autopilot); and the Non-judging scale consists of items related to judging negative thoughts and emotions, which is conceptually similar to not experiencing worry (Day et al., 2015).

The association between mindfulness and pain catastrophizing was also examined in chronic pain patients. Schütze, Rees, Preece, and Schütze (2010) conducted a study with 104 outpatients with a wide range of chronic pain conditions. Each participant completed several self-reported measures for trait mindfulness and the pain experience. The authors found that higher trait mindfulness is a significant predictor for lower levels of each of the pain-related variables. In particular, consistent with the findings of the study by Day et al. (2015), these authors found that mindfulness and pain catastrophizing are inversely associated, suggesting that trait mindfulness can offer clinical benefits by reducing pain catastrophizing in chronic pain patients.

Mun, Okun, and Karoly (2014) also investigated the relation among trait mindfulness, pain catastrophizing, and pain-related impairment with 335 college students divided into high and low reported pain severity levels. Each participant in both groups was asked to complete the self-report measures of the FFMQ, the PCS, and the Chronic Pain Acceptance Questionnaire (McCracken et al., 2004). Consistent with the studies mentioned above, these authors found that trait mindfulness was a significant predictor for both lesser pain catastrophizing and pain-related impairment.

While Mun et al. (2014) examined the effect of trait mindfulness on pain outcomes, Cassidy, Atherton, Roberson, Walsh, and Gillet (2011) investigated whether the relations of mindfulness with physical functioning and depression were mediated by catastrophizing. They conducted a cross-sectional, longitudinal study with 87 chronic low back pain patients, and each participant underwent a three-month mindfulness-related intervention program. The authors found that mindfulness significantly increased following participation in the intervention and that the association between mindfulness and disability was significantly mediated by pain catastrophizing as well as the association between mindfulness and depression. Similar to the findings of Mun et al. (2014), this study suggest that mindfulness may predict lower pain catastrophizing and thus more favorable pain-related outcomes.

Mindfulness and reappraisal.

A substantial body of literature suggests that mindfulness is associated with positive cognitive reappraisal. The association between mindfulness and reappraisal in context of pain has been studied mostly from a therapeutic perspective, as discussed earlier. Mindfulness practice may encourage positive reappraisal capacities and may reduce pain-related distress or disability. A study by Hanley and Garland (2014) suggests that dispositional mindfulness is positively related with self-reported positive reappraisal. Garland, Gaylord, and Park (2009) suggest a mindful-coping model based on the transactional model of stress. In terms of this model, when a given event is appraised as a threat, harm, or loss, the individual with high dispositional mindfulness may decenter from the stress into the mode of mindfulness. This process increases attentional flexibility and broadens awareness, and, as a result, the individual can reappraise the stressor in a more positive manner by giving it new meaning, which influences positive emotion and reduces stress. This affects the subsequent appraisal process of primary and secondary appraisal, stopping a vicious cycle of negative cognitive process. Thus, several therapeutic programs utilizing such ideas of mindfulness and cognitive appraisal have been developed. For example, the ACT, the MBCT, the DBT, and the MBSR have been showing strong evidence and much promise for the prevention and treatment of chronic pain (Kerns et al., 2010).

Mindfulness and physiological stress responses.

Mindfulness has also been associated with improved physical health, but little information is available to understand the underlying mechanisms for this improvement. Tomfohr, Pung, Mills, and Edwards (2015) conducted a study with 130 healthy college students to understand the association between trait mindfulness and physiological reactivity. The authors measured trait mindfulness using the Five Facet Mindfulness Questionnaire (FFMQ), blood pressure (BP), and interleukin-6. They found that there was a significant inverse association between trait mindfulness and BP such that this trait of higher mindfulness was associated with a lower mean level of BP as well as with a lower pro-inflammatory response.

Brown, Weinstein, and Creswell (2012) have also enhanced our understanding by conducting a study with 44 healthy college students to examine whether trait mindfulness can buffer from the negative impact of stress by investigating cortisol and negative affective responses to a social stress task. They found that cortisol response to a social evaluative threat task was inversely associated with trait mindfulness such that individuals with high mindfulness show less cortisol response. They suggested that mindfulness may protect neuroendocrine and affective responses to social evaluative stress. This evidence provides limited support for the idea that trait mindfulness may attenuate the physiological responses to stress.

The Present Study

While the associations among mindfulness, cognitive stress appraisal, and BP and cortisol described above have been linked to the experience of pain, no study has explored the complete relations between these individual associations. Based on the information discussed above, it can be assumed that high trait mindfulness may reduce the individual's negative cognitive primary appraisal of whether a pain encounter is appraised as a threat, which impacts more negative coping strategies of pain catastrophizing (secondary appraisals). As a result, it may affect more biological responses and may lead to a more maladaptive pain experience.

This study will examine these associations in a sample of young healthy college students who will be asked to complete a cold pressor task (CPT) as both a pain stimuli and stressor. Given the fact that young and healthy students with limited pain experience participated in the study, cognitive stress appraisals prior to a cold pressor pain induction may be different from cognitive stress appraisals during the cold pressor recovery period. Therefore, cognitive stress appraisals will be measured immediately after the instructions for the CPT to capture how individuals make threat/challenge appraisals to the anticipation of pain. Cognitive stress appraisals will be again measured immediately after the CPT to capture how ones make threat/challenge appraisals while continuously experiencing the pain during the recovery period.

A more integrative understanding of the association between variables known to exacerbate the chronic pain experience may help in the development of more effective psychological and multidisciplinary treatment. Thus, the purpose of this study is to examine how cognitive stress appraisals, pain catastrophizing, as a coping strategy, and their interaction influence pain experience, in terms of pain ratings and pain tolerance as well as physiological reactivity of cardiovascular function and cortisol to an induced acute pain. It is also to examine how mindfulness as a trait disposition influences these relations.

Hypotheses of the present study

Hypothesis 1: *Threat appraisal prior to the cold pressor task (Threat Appraisal 1), threat appraisal after the CPT (Threat Appraisal 2), and the magnitude of change in threat appraisals (Threat Appraisal 2 - 1) will be positively associated with the pain ratings immediately following the CPT but inversely associated with pain tolerance. Threat Appraisal 1, Threat Appraisal 2, and the magnitude of change in Threat Appraisals will be positively associated with physiological reactivity to the CPT.*

Hypothesis 2: *Pain catastrophizing will be positively associated with Threat Appraisal 1, Threat Appraisal 2, and the magnitude of change in threat appraisals.*

Hypothesis 3: *Pain catastrophizing will be positively associated with pain rating after the CPT, and will be inversely associated with pain tolerance. Pain Catastrophizing will be positively associated with cardiovascular and cortisol reactivity.*

Hypothesis 4: *Trait mindfulness will be inversely associated with Threat Appraisal 1 as well as Threat Appraisal 2. Trait mindfulness will also be inversely associated with pain catastrophizing.*

Hypothesis 5: *Pain catastrophizing and Threat Appraisal 1 together will be positively associated with the pain ratings after the CPT and inversely associated with pain tolerance. Pain Catastrophizing and Threat Appraisal 1 will be positively associated with physiological reactivity of SBP, DBP, HR, and Cortisol. The interaction between pain catastrophizing and Threat Appraisals for all outcome variables will be significant such that those who score higher* *in pain catastrophizing will demonstrate greater physiological reactivity and lesser pain tolerance when Threat Appraisal 1 is low compared with when it is high. The same results are expected with Threat Appraisal 2.*

Hypothesis 6: *The association between Threat Appraisals and pain catastrophizing and outcomes of physiological reactivity and pain experience, found from the hypothesis 5, will be significantly different between individuals with high trait mindfulness and those with low trait mindfulness.*

Chapter II

Methods

Participants

The final data of this study consists of 93 participants, undergraduate students attending University of Michigan-Dearborn. There were initially total 134 participants who gave consent for their participations to the study and completed a demographics questionnaire (Appendix A). Of those 134 participants, 26 participants were excluded based on exclusion criteria (see below). In addition, there were 15 additional participants who were excluded from the data analysis; 12 participants due to cortisol awakening response requirements, two participants due to potential hypertension (see below), and one participants based on univariate outlier analysis of Threat Appraisals 1. Participants were recruited and screened via University of Michigan-Dearborn Introductory Psychology Pool (SONA), an online research participation management system. Students voluntarily selected a study to participate for course credit from the provided list of the available research studies on campus. The study consists of male participants (n = 50) and female participants (n = 43), who identified as European Americans (n = 41), Arab Americans (n = 32), African Americans (n = 8), Hispanics (n = 6), Asians (n = 3), and others (n = 3). The participants had an average age of M = 20.09 (SD = 4.44, range 18 – 50).

Participants aged greater than or equal to 18 years have been included. Participants were excluded from the entire study if they had not eaten a meal in the last four hours, had not drunk any water or any liquid in the last two hours, or had consumed alcohol within 12 hours of the study. Participants were excluded from the entire study if they any medical disorders (e.g., cardiovascular disease, chest pain, irregular heartbeat, high blood pressure, asthma, Type I diabetes, kidney diseases), current psychiatric disorders (e.g., depression, anxiety) or took any medications that could affect cardiovascular functioning or cortisol reactivity within 72 hours prior to the study (e.g., pain medications, stimulants, steroids, cold or flu medications, blood pressure medications, any psychiatric medications). In addition, participants were excluded from the entire study if they had a history of chronic pain, Cold Raynaud's disorder, frostbite on their hands, or fainting or seizures. Participants who have an implanted medical device, an open cut or sore on their non-dominant hand, or are pregnant were excluded from the entire study. Part ways through the study, data collection methods were modified to have the study sessions only in the afternoon. Initially, the study sessions started at 11AM but there were several participants who woke up within three hours and a half prior to the study. With an IRB approval, participants were required to be awake at least three hours and a half prior to the study which was notified in eligibility requirement through SONA system. Participants were excluded from the data analysis if they had not been awake more than three hours and a half. In addition, participants were excluded from the data analysis if they had an average systolic blood pressure at rest was equal or greater than 160 mm Hg.

Research Design

A correlational design was conducted examining the relations between the variables of interest.

Apparatus

Cold Pressor Task (CPT). A cold pressor apparatus consisted of Igloo 38-gallon ice cooler divided into two compartments by a mesh net. One compartment was filled with the ice and cold water, and the other compartment was filled with cold water where participants put their non-dominant hand. The cold water was circulated by a portable power pump (Attwood, 200 gallons per hour) and a temperature at 40°F (4–5 °C) was maintained and verified by a thermometer.

Blood pressure and heart rate. Blood pressure and heart rate were collected using a Critikon Dinamap Vital Signs Monitor 1846 SX automated blood pressure machine.

Measures

Demographic and screening questionnaire. (Appendix A) The 21-item demographics and screening questionnaire was completed by all participants to determine whether participants met the inclusion and exclusion criteria of the study. It assesses participants' age, gender, ethnicity, and religion as well as exclusion criteria such as alcohol consumption, current medical conditions, current medication use, and a history of chronic pain experience, cold sensitivity, or seizures. Information about participants' wake-up time was also collected to control the cortisol awakening response. In addition, the height and weight of each participant was measured by a researcher using a wall-mounted ruler and a professional medical scale.

Pain outcomes (pain ratings, pain threshold, and pain tolerance). Participants were asked for their baseline pain ratings by a Likert scale of 0-10 (0 being "no pain at all" and 10 being "the worst pain you can imagine") before they engaged in a CPT. Pain threshold was measured by the time (seconds using a digital stopwatch) when participants reported the first time they felt the pain. Pain tolerance was measured by the length of time in seconds that the participants kept their hand in the cold water. The second pain ratings by a Likert scale of 0-10 (0 being "no pain" and 10 being "the worst pain you can imagine") were measured immediately after participants removed their hand from the cold water.

Salivary cortisol. Participants provided their salivary samples via passive drool method, which involves in pooling saliva in their mouth and drooling through a straw into a clear 14-mL polypropylene cryovial tube. The requested sample amount was 1-mL which was marked in the tube. Participants provided two saliva samples; the baseline sample before the CPT and the second sample 20 minutes after the CPT. It has been reported that it takes 15-20 minutes for cortisol to peak for its response to the induced acute pain (Skoluda et al, 2015). Samples were stored in the freezer at -4°F (-20°C) until assay. Assays were performed by the Core Facility Assay at the University Michigan Ann Arbor.

Stress appraisal measure (SAM 1 & 2). (Appendix B & C) Cognitive stress appraisals were measured by the 12 item Stress Appraisal Measure (SAM), which was developed by Peacock and Wong (1990) based on the transactional model of stress and coping. The questionnaire consists of 12-items measuring three subscales of threat appraisal, challenge appraisal, and perceived stressfulness. Each subscale consists of four items using a 5-point Likert scale (1 = not at all, 2 = slightly, 3 = moderately, 4 = considerably, and 5 = extremely). Sample questions include “How threatening is this situation?”, “How eager am I to tackle this problem?”, and “To what extent do I perceive this situation as stressful?” The SAM has shown high validity that each subscale taps relatively distinct dimension of stress appraisal to the stress experience (Peacock & Wong, 1990).

The SAM was measured twice by each participant with slightly different written instructions. The first SAM (Appendix B) was measured immediately after the instruction of the CPT, which informing participants that the CPT would not cause any permanent skin damage but it would be very painful. It also had written instructions to answer regarding “your thoughts about the *up-coming task* that was just described to you” and “how you view this situation *right* *now*". The second SAM (Appendix C) was measured immediately after the participants completes the CPT. It instructs participants to answer regarding "your thought about the *situation you are experiencing with pain right now*" and "how you view this situation *right now*". Scores of each subscale were obtained by summing the scores from the items. The higher scores indicate higher threat/challenge/stressfulness appraisals. The reliability of the scales displayed the internal consistency (Cronbach's alpha) ranging from .74 to .81 (Peacock & Wong, 1990). The present study showed Cronbach's α = .78 and .86 for Threat Appraisal 1 and Threat Appraisal 2 respectively, α = .76 and .73 for Challenge Appraisal 1 and 2 respectively, and α = .75 and .84 for Stressfulness Appraisal 1 and 2 respectively, suggesting all acceptable level. One participant missed two items on each SAM, and mean substitutions were used for this participant.

Pain catastrophizing scale (PCS). (Appendix D) Pain catastrophizing was measured by the Pain Catastrophizing Scale, which was developed by Sullivan, Bishop, and Pivik (1995). The PCS assesses 3 subscales of catastrophizing about pain: magnification (e.g., "It's awful and I feel it overwhelms me"), rumination (e.g., "I can't seem to keep it out of my mind"), and helplessness (e.g., "There's nothing I can do to reduce the intensity of the pain"). These aspects of negative expectations (magnification) (Chaves & Brown, 1987), excessive worry and focus on negative thoughts (rumination) (Spanos, Radkte-Bodorik, Ferguson, & Jones, 1979), and the perceived inability to cope effectively with pain (helplessness) (Rosenstiel & Keefe, 1983) have been demonstrated to be predictors of negative pain outcomes. Furthermore, it has been demonstrated that the PCS shares characteristics with primary and secondary appraisal processes of the transactional model of stress and coping (Sullivan et al., 1995).

The PCS consists of 13 items to rate how often participants experience certain thoughts and feelings on a 5-point Likert scale ranging from 0 ("Not at all") to 4 ("All the time").

Participants were asked to fill out the paper and pen format of questionnaire with an instruction to indicate "the degree to which you have the listed thoughts and feelings when you are in pain." Scores were obtained by summing the scores from all items. The higher scores indicate greater pain catastrophizing. The reliability of the scale displayed the internal consistency Cronbach's α = .87 for total PCS, .87 for rumination, .66 for magnification, and .78 for helplessness (Sullivan et al., 1995). In the present study, Cronbach's α displayed .93 for total PCS, .88 for rumination, .76 for magnification, and .89 for helplessness, indicating acceptable level of the reliability.

Mindfulness (MAAS & FFMQ). (Appendix E & F) In the present study, trait mindfulness was measured using the Mindfulness Attention Awareness Scale (MAAS) Short Version (Brown & Ryan, 2003) and the Five Facet Mindfulness Questionnaire (FFMQ) (Baer et al., 2006).

The self-report measure, MAAS (Appendix E), has been widely used as a valid measure of trait mindfulness from a single factor. It assesses how often individuals experience mindfulness states, particularly focusing on the presence or absence of attention to and awareness of what is happening in the present moment (Brown & Ryan, 2003). The MAAS Short Version consists of 15 items measuring degree of their awareness in their daily life functioning (e.g., "I drive places on "automatic pilot" and then wonder why I went there"). The frequency of how often the participants have experiences referenced by each item is measured using 6-point Likert scale ranging from 1 (almost always) to 6 (almost never). Scores were obtained by summing the scores from all items. The higher scores indicate greater mindfulness. The MAAS displays good convergent and discriminant validity, excellent test-retest reliability ($r = .81$, $p < .001$) (Brown & Ryan, 2003). In addition, it reports internal consistency (Cronbach's alpha) ranging from .82 to .87 (Brown & Ryan, 2003). In the present study, the MAAS displayed Cronbach's α = .88, indicating acceptable level of the reliability.

The FFMQ (Appendix F) is also widely used instrument assessing trait mindfulness from five distinct mindfulness factors, developed by Baer et al. (2006). The self-report measure, FFMQ, consists of 39 items assessing five facets of mindfulness including "observing" (monitoring internal and external experiences), "describing" (describing internal experiences with words), "acting with awareness" (paying attention to present moment when engaging activities), "nonjudging" (allowing thoughts, emotions, and feelings without judgement), and "nonreactivity" (allowing to experience thoughts, emotion, and feelings without reacting to them) (Baer et al., 2006). Participants were asked to rate their opinions of what was generally true for them in terms of their tendency to be mindful in their daily lives. Ratings are based on 5-point Likert scale ranging from 1 (never or very rarely true) to 5 (very often or always true). Subscale scores were obtained by summing the scores from the items of each scale, and it also provides the total scores by summing the scores from all 39 items. Higher scores indicate higher levels of mindfulness. The FFMQ has been found to have good convergent and discriminant validity and particularly the subscales of "acting with awareness", "nonjudging", and "nonreactivity" were significant predictors of psychological symptoms (Baer et al., 2006). The 5 factors have been found to display adequate to good internal consistency (Cronbach's α) ranging from .75 (Nonreactivity) to .91 (Describing) (Baer et al., 2006). In the present study, the FFMQ displayed Cronbach's α = .86 for total FFMQ, .64 for observing, .88 for describing, .85 acting with awareness, .87 for nonjudging, and .68 for nonreactivity, indicating acceptable level of reliability.

Procedure

All participants were recruited from the psychology subject pool through the online research participant management system (SONA). Participants were informed during the recruitment process that, as eligibility criteria to participate in the study, they should be at least 18 years and older and generally healthy. They were also informed that they would be excluded from the study if they had not had a meal within the last four hours, had not drunk any water or liquid within the last two hours, or had alcohol intake within 12 hours of the study. The course credits were offered based on the expected time period for the study.

Participants individually arrived at the laboratory for the study. Upon arrival, a written informed consent form (Appendix G) was provided to participants. Once the informed consent was obtained, participants completed a demographic and screening questionnaire (Appendix A). If participants met the study's inclusion and exclusion criteria, the study would proceed. Participants excluded at this point of the study were dismissed with full course credits.

Participants who continued were asked to go to a restroom to rinse their mouths with a provided paper cup as a preparation for collecting clean saliva samples. When returned, participants' height and weight were measured by a researcher and then escorted to the area with a cold pressor box. Once seated, a blood pressure cuff was attached participants' dominant upper arm and their baseline BP and HR were measured for the period of 10 minutes (with 3-minute increments). The last 6 minutes of which were used for data analysis. After completion of collecting baseline BP and HR, participants were asked to provide a baseline saliva sample via a passive drool method. The collected saliva samples were immediately stored in a laboratory freezer.

After the baseline saliva sample was collected, a cover of the cold pressor box was opened by a researcher. While participants could see the cold pressor box and ice water, the instruction of the task was provided to them: “we would like you to keep your non-dominant hand in the cold water as long as you can or until an instruction to remove it. It is not going to cause any permanent damage on your skin but it will be very painful. However, you can remove your hand at any time you feel the pain is too unbearable (pain tolerance).” Participants were also asked to report the first time they feel the pain (pain threshold) in their hand while keeping it in the cold water continuously. In addition, they were advised to report if they felt dizzy during the task. Immediately after the instruction, participants were asked to complete the SAM 1 (Appendix B). While they completed it, the blood pressure and heart rate were measured.

After completing the SAM 1, participants were asked to rate their current pain level on scale of 0 (being no pain at all) to 10 (being the worst pain they can imagine). Participants were reminded to report the first time when they felt the pain, and instructed to put their hand in the water up to the wrist whenever they were ready. During the CPT, blood pressure and heart rate were measured at 10-seconds post immersion and with 90-second intervals. During the CPT, the pain threshold was measured the time that participants reported when they felt the pain. The pain tolerance was measured by the length of time participants kept their hand in the cold water. If participants kept their hand in the cold water for five minutes they were instructed to remove their hand out of the cold water. Immediately after removal of their hand from the cold water, they were instructed not to dry their hand and asked to rate their current pain level. They were then asked to complete the SAM 2 (Appendix C).

After completion of the SAM 2, participants were instructed to dry their hand using a towel. The blood pressure cuff was also removed and the cold pressor box was closed. Participants were then instructed to complete several questionnaires. They were also informed that they might be interrupted for the second saliva sample collection but the specific time period was not provided to them. While waiting for 20 minutes, participants were asked to complete the PCS, the MAAS, and the FFMQ. The second saliva samples were collected 20 minutes after participants removed their hand from the cold water and the collected saliva samples were immediately stored in the laboratory freezer.

Once the second saliva sample was collected and all instruments were completed, participants were debriefed about the study and thanked for their participation. A debriefing form (Appendix H) included the contact information of University of Michigan-Dearborn counseling and support services and Henry Ford Medical Center, in case participants needed additional services following the participation of the study. Participants were compensated with the course credits toward the introductory psychology course.

Statistical Analysis Related to the Hypotheses

All analysis was performed using SPSS statistics, Version 24. To test Hypothesis 1, bivariate correlations were conducted between Threat Appraisals and pain experience (pain ratings, pain threshold, and pain tolerance) and hierarchical linear regressions of threat appraisals and physiological reactivity (SBP, DBP, MAP, HR, and cortisol) controlling for baseline physiology. To test Hypothesis 2, bivariate correlations were conducted between Threat Appraisals and pain catastrophizing. To test Hypothesis 3, bivariate correlations were conducted between pain catastrophizing and pain experience (pain ratings, pain threshold, and pain tolerance) and hierarchical linear regressions were conducted between pain catastrophizing and physiological reactivity (SBP, DBP, MAP, HR, and cortisol) controlling for baseline physiology. To test Hypothesis 4, bivariate correlations were conducted between Threat Appraisals, PCS, and mindfulness (MAAS, FFMQ total, and FFMQ subscales of observing, describing, acting with awareness, nonjudging, and nonreactivity). To test Hypothesis 5, hierarchical multiple linear regressions with baseline entered first were conducted to examine the effect of PCS and Threat Appraisals as well as their interaction on physiological reactivity and pain outcomes. Finally, to test Hypothesis 6, the association and interaction between FFMQ total scores, Threat Appraisals and pain catastrophizing, and pain experience and physiological reactivity were examined with a three-way interaction analyses conducted using multiple regressions.

Chapter III

Results

Descriptive

Descriptive statistics for age, gender, ethnicity, and BMI are displayed in Table 1. Descriptive statistics for Threat Appraisals, pain catastrophizing, mindfulness (MAAS, FFMQ total, and FFMQ subscales), pain threshold, and pain tolerance are displayed in Table 2.

Manipulation Check

Manipulation checks were conducted prior to testing primary hypotheses. It was to ensure that the lab-induced acute pain task elicited changes in cognitive stress appraisals, pain experience, and physiological responses. The results from paired samples *t*-test's and Cohen's *d* of effect sizes comparing baseline and CPT data for Threat Appraisals, pain ratings, SBP, DBP, MAP, HR, and cortisol are shown in Table 3. There were statistically significant differences between all variables prior to and post CPT. It indicates that the CPT successfully elicited significant psychological and physiological changes.

The study used two different instruments to measure trait mindfulness because there is no universally agreed-upon operational definition. Thus, the relations between the measures were evaluated by conducting correlation analysis for MAAS, FFMQ total, and FFMQ subscales. The results are displayed in Table 4. As expected, MAAS and FFMQ total were significantly correlated with each other. MAAS was significantly correlated with Acting with Awareness and Nonjudging and marginally correlated with Describing. However, MAAS was not associated with Observing and Nonreactivity. FFMQ total was significantly correlated with all FFMQ subscales.

Primary Analyses

Prior to data analysis, data were checked for skewness and kurtosis. In addition, data were checked for univariate and multivariate outliers. There was no significant issue with the distribution of the data. Threat Appraisal 1 had one outlier based on univariate outlier analysis (+5.07 *SD*), which was excluded in all analysis.

Hypothesis 1: *Threat appraisal prior to the cold pressor task (Threat Appraisal 1), threat appraisal after the CPT (Threat Appraisal 2), and the magnitude of change in threat appraisals (Threat Appraisal 2 - 1) will be positively associated with the pain ratings immediately following the CPT but inversely associated with pain tolerance. Threat Appraisal 1, Threat Appraisal 2, and the magnitude of change in Threat Appraisals will be positively associated with physiological reactivity to the CPT.*

The correlations between Threat Appraisals and pain experience are shown below in Table 5. Contrary to expectations, Threat Appraisal 1 was not significantly associated either with pain ratings after the task or pain tolerance. As expected, Threat Appraisal 2 was positively associated with pain ratings after the task. However, the association between Threat Appraisal 2 and pain tolerance was not significant. Also, as expected, the magnitude of changes in Threat Appraisals (2 - 1) was significantly and positively associated with pain ratings after the task. It was, also as expected, significantly and inversely associated with pain tolerance.

The results of the hierarchical linear regressions of threat appraisals and physiological reactivity controlling for baseline physiology are displayed in Table 6. No associations were found between Threat Appraisal 1 and any physiological reactivity, which was unexpected.

Statistically significant associations were found between Threat Appraisal 2 and DBP as well as HR. However, no associations were found between Threat Appraisal 2 and SBP or cortisol reactivity. Consistent with the results of Threat Appraisal 2, the magnitude of changes in Threat Appraisals were significantly association with DBP and HR while no association was found with SBP or cortisol responses.

Hypothesis 2: *Pain catastrophizing will be positively associated with Threat Appraisal 1, Threat Appraisal 2, and the magnitude of change in Threat Appraisals.*

The correlations between Threat Appraisals and pain catastrophizing are shown in Table 7. As expected, significant positive associations were found between pain catastrophizing and Threat Appraisal 1, Threat Appraisal 2, and the magnitude of changes in Threat Appraisals.

Hypothesis 3: *Pain catastrophizing will be positively associated with pain rating after the CPT, and will be inversely associated with pain tolerance. Pain Catastrophizing will be positively associated with cardiovascular and cortisol reactivity.*

The correlations between pain catastrophizing and pain ratings, pain threshold, and pain tolerance are shown in Table 8. A Significant positive association between pain catastrophizing and pain ratings after the task was found, while no significant association was found between pain catastrophizing and pain tolerance. The results of the hierarchical linear regressions of pain catastrophizing and physiological reactivity (SBP, DBP, HR, and cortisol) controlling for baseline physiology are shown in Table 9. Pain catastrophizing was significantly and positively associated with HR but no other association was found between pain catastrophizing and other physiological responses.

Hypothesis 4: *Trait mindfulness will be inversely associated with Threat Appraisal 1 as well as Threat Appraisal 2. Trait mindfulness will also be inversely associated with pain catastrophizing.*

The results of the correlations between Threat Appraisals, pain catastrophizing, and mindfulness are shown in Table 9. Overall, trait mindfulness was inversely associated with Threat Appraisal 1 and Threat Appraisal 2, which was expected. MAAS was significantly associated with Threat Appraisal 1 and marginally associated with Threat Appraisal 2. FFMQ total was significantly associated with both Threat Appraisal 1 and Threat Appraisal 2. Different associations between FFMQ subscales and Threat Appraisals were found. Acting with Awareness was significantly associated with Threat Appraisal 1 but not with Threat Appraisal 2. In addition, Nonreactivity was significantly associated with Threat Appraisal 2 but not with Threat Appraisal 1. Observing was significantly associated with Threat Appraisal 2 and marginally associated with Threat Appraisal 1. Describing was significantly associated with both threat appraisals. Nonjudging was significantly associated with threat appraisal 1 and marginally associated with threat appraisal 2. Moreover, pain catastrophizing was significantly and inversely associated with all subscales except Observing.

Hypothesis 5: *Pain catastrophizing and Threat Appraisal 1 together will be positively associated with the pain ratings after the CPT and inversely associated with pain tolerance. Pain Catastrophizing and Threat Appraisal 1 will be positively associated with physiological reactivity of SBP, DBP, HR, and Cortisol. The interaction between pain catastrophizing and Threat Appraisals for all outcome variables will be significant such that those who score higher in pain catastrophizing will demonstrate greater physiological reactivity and lesser pain* *tolerance when Threat Appraisal 1 is low compared with when it is high. The same results are expected with Threat Appraisal 2.*

The results of multiple hierarchical linear regressions for pain catastrophizing and Threat Appraisals in physiological reactivity (SBP, DBP, HR, and cortisol) and pain experience (pain ratings, pain threshold, and pain tolerance) are shown in Table 10. Contrary to expectations, there was no significant interaction effect of pain catastrophizing and Threat Appraisals in physiological reactivity and pain experience. One exception was found, with a statistically significant interaction of pain catastrophizing and Threat Appraisal 1 and cortisol reactivity.

Hypothesis 6: *The association between Threat Appraisals and pain catastrophizing and outcomes of physiological reactivity and pain experience, found from Hypothesis 5, will be significantly different between individuals with high trait mindfulness and those with low trait mindfulness.*

Given the lack of overall findings from Hypothesis 5 and the number of statistical test completed, the single significant finding of an interaction effect of threat appraisal 1 and pain catastrophizing in cortisol reactivity may be spurious. An interpretation of this finding may be misleading; thus, Hypothesis 6 was not tested.

Chapter IV

Discussion

The purpose of this study was to examine how cognitive stress appraisals, pain catastrophizing as a coping strategy, and their interaction influence the pain experience in terms of pain ratings and pain tolerance as well as physiological reactivity of cardiovascular function and cortisol to induced acute pain. The study also aimed to examine how the attribute of mindfulness as a trait disposition could influence these relations.

An initial manipulation check was conducted. The results from paired sample *t*-tests suggest that acute pain induction using the CPT elicited significant changes in cognitive stress appraisals, particularly Threat Appraisals, pain ratings, and physiological reactivity of cardiovascular function and cortisol. Thus, the CPT was successful in eliciting a pain experience and stress responses as intended. It is notable that the cardiovascular responses were possibly caused by both a pain-related stressor and vasoconstriction from exposure to the cold water.

Based on the overall pattern of findings across hypotheses, a general and integrative discussion of the findings is presented before discussing the results of each individual hypothesis. In general, there were mixed findings – some of our hypotheses were supported while others were not. Overall, psychological predictor variables were associated with psychological outcome variables; however, psychological factors across the board did not predict pain tolerance and physiological reactivity. That is, significant associations were found between Threat Appraisals, pain catastrophizing, pain ratings, and trait mindfulness; however, Threat

Appraisals, pain catastrophizing, and their interaction were not direct predictors of pain tolerance and physiological reactivity. The lack of significant findings in the associations between the predictors and pain tolerance is discussed first, followed by the lack of significant findings in those with physiological reactivity.

It was surprising that psychological factors in this study did not predict pain tolerance. A large number of participants (n = 51, 55% of participants) kept their hand in the cold water to the cut-off time, which was set at five minutes. This result was unexpected because a cold pressor task has been widely used as a non-invasive pain induction methodology (Edens & Gil, 1995). This is inconsistent with the existing literature using a cold pressor task at 40°F (4–5°C), which shows a mean time of approximately 90 seconds (Mitchell, MacDonald, & Brodie, 2004). The high prevalence of maximum pain tolerance in this study may be explained, to some extent, by psychosocial factors.

One of the potential psychosocial factors may be social desirability. Social desirability is defined as an individual's tendency to represent him/herself in more socially desirable ways by changing their cognitive or behavioral responses (Tracey, 2015). Social desirability was suggested to be a multidimensional construct having two components: self-deceptive enhancement and impression management (Paulhus, 1984). Self-deceptive enhancement has been viewed as a person's unconscious belief in his/her exaggerated positive cognitive or behavioral responses, whereas impression management has been viewed as a person's conscious misrepresented cognitive or behavioral responses (Paulhus, 1984). It should be noted that functional contextual factors may influence whether a response can be considered as self-deceptive or impression management. Consequently, the presence, frequency, and amount of social desirability responding can vary based on personal and situational factors such as emotional stability and the importance of the outcomes (Tracey, 2015).

Social desirability has received much attention in the literature as a possible confounding factor in experiments involving self-report questionnaires as well as personality traits. On the other hand, some researchers have viewed social desirability as an adaptive interpersonal skill and as self-control (Holden, & Fekken, 1989; Uziel, 2010). While, to this author's knowledge, no study has directly examined the association between social desirability and pain tolerance, some studies do suggest that, within limits, social desirability may lead to better psychological and health functions (Graval & Sandal, 2006; Winters & Neale, 1985), which has direct implications for the current study. In particular, a study by Graval and Sandal (2006) suggests that higher social desirability is related to active coping strategies and higher self-efficacy, which are associated with less health complaints, implying better functioning. Thus, it is reasonable to propose that should social desirability be higher for this study's participants, as discussed below, the participants may have behaved in ways to fulfill this social desirability by pleasing the researcher, avoiding embarrassment, or looking good by keeping their hand in the cold water to the cut-off time.

These conscious and/or unconscious behaviors may be influenced by various personal and situational factors. One factor to consider is that the University of Michigan-Dearborn is a relatively smaller campus with much smaller classes and a potentially more cohesive community. This sense of community may have influenced the extent to which participants wanted to be socially desirable or help the student researcher, whom they may have regarded as their colleague. Another factor to consider is that the way in which the participants perceived the situation may have influenced the degree of their social desirability. For example, the researcher's gender could also have affected the participants' pain tolerance. Male participants may have tolerated more pain because the researcher was female, which is consistent with findings from several studies (Aslaksen, Myrbakk, Hoifodt, & Flaten, 2007; Levine and De Simone, 1991). The males' perceptions of themselves as typical males may also have accentuated their desire to demonstrate their masculinity to the female researcher by tolerating more pain (Otto & Dougher, 1985). In addition to the gender of the researcher, her ethnicity and attitudes while interacting with the participants may also have influenced their tendency to engage in social desirability and thus increase their pain tolerance. Additionally, the researcher's friendly, empathetic, and pleasant attitude, which is consistent with her cultural background, may have influenced the presence, frequency, and extent of participants' social desirability, leading to higher pain tolerance. The study by Levine and De Simone (1991) found a similar result that the attractiveness of the researcher was associated with higher pain tolerance.

Finally, it should be noted that social desirability may encourage participants to engage in higher self-efficacy and/or active coping strategies (Graval & Sandal, 2006), which may have enabled them to exhibit higher tolerance to pain. Thus, social desirability may be one potential explanation that accounted for the unexpected finding in regard to participants' greater pain tolerance.

Another lack of significant findings in this study was that, in general, psychological factors did not predict physiological reactivity in terms of cardiovascular and cortisol reactivity. This overall lack of findings may be explained partly by the fact that a nociceptive pain experience can activate the SAM axis and HPA axis independently of the psychological factors of threat appraisals and pain catastrophizing, leading to physiological reactivity (Karatsoreos & McEwen, 2011). As discussed in the introduction of this paper, "stress" can be elicited by internal and/or external factors. Based on the transactional model of stress, we hypothesized that if an individual perceives and interprets a painful stimulus as a threat that leads him/her to engage in a maladaptive coping strategy (e.g., pain catastrophizing), the stress-related response systems, such as the SAM axis and the HPA axis, in our bodies would be activated. However, the painful stimuli can directly impact physiological responses independently of cognitive appraisals, which is consistent with the allostasis model of stress (Karatsoreos & McEwen, 2011).

According to the allostasis model of stress, when our bodies encounter a stressor, they achieve stability, homeostasis, by adapting multiple interacting compensatory physiological processes (McEwen & Wingfield, 2010). When there is an environmental perturbation, such as temperature changes, physiological changes occur, particularly through the SAM axis and the HPA axis, to adapt to the changing environment (Karatsoreos & McEwen, 2011). The autonomic nervous system and cortisol, which are of particular interest in the study, play an important and positive role in promoting adaptation to acute stressors. The CPT, a stressor used in this study, elicited significant physiological reactivity. Indeed, this is consistent with the allostatic model of stress. When the body encounters a cold stimulus (as a threat), allostatic load occurs, which activates the SNS (activating the SAM axis) and the thalamus (activating the HPA axis). Increased blood pressure, heart rate, and cortisol can be explained by activations of these pathways. The SNS and cortisol can be considered "mediators" of adaptation to a stressor (Karatsoreos & McEwen, 2011, p. 577). While participants displayed significant physiological reactivity to the CPT, the variance in physiological reactivity from psychological factors may have been relatively minor due to the allostatic response.

Thus, the lack of support for an association between psychological predictors and physiological reactivity may be related to the contribution of physiological reactivity from the acute pain stimulus, independent of psychological factors. In other words, the net results of allostatic load by psychological factors may be shielded by the larger effects created by various physiological adaptation processes to the stressor. This overall inconsistency between psychological factors and physiological reactivity in the transactional model of stress will be referred to throughout each individual hypothesis discussion. The results of each hypothesis will be discussed in the next sections, followed by discussions of the strengths and limitations of the study, future research, and implications.

Hypothesis 1 Discussion

Contrary to expectations, threat appraisals of the anticipation of pain (Threat Appraisal 1) were not significantly associated with any pain experience or physiological reactivity to the CPT. However, it is noteworthy that baseline pain ratings were positively associated with Threat Appraisal 1, suggesting that the initial pain experience is influenced by the threat appraisal of the anticipation of additional pain. One possible explanation for this result is that the anticipation of a painful stimulus among members of a young, healthy group who were told there would be no permanent skin damage, may be less likely to lead to threat appraisals of an upcoming pain induction task. In addition, external and internal factors, such as the participants' limited experience with pain, previous memories about their experience with cold water, their personal beliefs about their self-efficacy on tasks, and their attitudes toward the researcher (social desirability) could have influenced how they appraised the situation. Since Threat Appraisal 1 was assessed while participants interpreted their anticipation of the pain experience, these internal and external factors could have potentially influenced the amount of variance in their threat appraisals associated specifically with pain.

On the other hand, Threat Appraisal 2 was assessed when participants were most likely to focus on their continuous experience of the actual pain. All other factors that influenced Threat Appraisal 1 may not have influenced the cognitive process in the same ways when Threat Appraisal 2 was assessed, resulting in Threat Appraisal 2 being more directed to actual pain. How attention is being used may differ at the time of Threat Appraisal 2 measure. This is consistent with the proposal that higher intensity of pain experience is more susceptible to greater attention to pain sensation (Villemure & Bushnell, 2002). This suggests that while one's attention may be divided among various internal and external factors when making a threat appraisal of the anticipation of pain, his/her attention to the painful sensation may be dominant when making a threat appraisal of actual pain. As a result, threat appraisals of the anticipation of pain and of the actual pain may have quantitative and qualitative differences, potentially leading to different pain outcomes.

With regard to the above discussion, Threat Appraisal 2 was significantly and positively associated with pain ratings after the task and with DBP and HR. Contrary to expectations, no association was found between Threat Appraisal 2 and pain tolerance, SBP, or cortisol. However, the significant association with DBP and HR may have been partly influenced by the type of pain induction method the study used – the application of cold, which induces vasoconstriction. While the expected association between Threat Appraisal 2 and pain rating is relevant, the more limited overall findings in pain tolerance and physiological reactivity may be the result of both social desirability and the allostatic processes of pain described earlier.

While associations between the magnitude of changes in Threat Appraisals and pain-related stress outcomes primarily mirrored those with Threat Appraisal 2, it is noteworthy that the magnitude of changes in Threat Appraisals was significantly and inversely associated with pain tolerance to the task. Thus, those who made higher changes from Threat Appraisal 1 to Threat Appraisal 2 were less likely to tolerate the pain experience compared to those who made lessor changes. This may be explained by the suggestion that those who made higher changes could have anticipated the upcoming pain experience not as threatening, but when they experienced the actual pain, they could have interpreted the situation as a much higher threat than they had anticipated. As a result, greater changes in Threat Appraisals may have occurred, leading to lower pain tolerance.

Hypothesis 2 Discussion

As expected, pain catastrophizing was significantly and positively associated with Threat Appraisal 1, Threat Appraisal 2, and the magnitude of changes in Threat Appraisals. As the transactional model of stress suggests, this finding supports that the primary appraisal process influences the secondary appraisal process, but the secondary appraisal process also influences the primary appraisal process (Lazarus & Folkman, 1984). Consistent with the existing literature, individuals who appraise the stressor as a threat tend to engage in more maladaptive coping strategies, but those who engage in more maladaptive coping strategies, such as catastrophizing, are more likely to appraise the situation as more threatening (Forsythe et al., 2011; Jones et al., 2003; Ramire-Maestre et al., 2008).

Moreover, Threat Appraisals and the magnitude of changes in Threat Appraisals were significantly and positively associated with the pain catastrophizing subscales of rumination, magnification, and helplessness. This suggests that those who appraise a painful stimulus as a threat are more likely to ruminate, exaggerate, and/or feel helpless about their pain experience. This is consistent with the existing literature (Smith et al., 2015; Sullivan et al., 1995). Conversely, those who tend to ruminate, magnify, or feel helpless about the pain experience are more likely to interpret the painful stimulus as a threat. This finding supports the reciprocal association between primary and secondary appraisal processes based on the transactional model of stress.

Hypothesis 3 Discussion

As expected, the study shows a significant positive association between pain catastrophizing and pain ratings after the task. This supports the idea that individuals who engage in maladaptive coping strategies tend to rate pain intensity higher than those who engage in adaptive coping strategies, which is consistent with several studies (Burns et al., 2015; Forsythe et al., 2011; Wertli et al., 2014). However, there was no significant association between pain catastrophizing and pain tolerance. This finding was contrary to expectations, and the limited overall findings between pain catastrophizing and pain tolerance may be the result of social desirability as described earlier.

The second part of Hypothesis 3 was to examine whether pain catastrophizing predicts physiological reactivity to acute pain induction. There was no association between pain catastrophizing and blood pressure and cortisol, but there was a significant positive association with heart rate reactivity. However, this finding should be interpreted with caution. Given the overall findings from this hypothesis and the number of statistical tests completed, the single significant finding of an effect of pain catastrophizing on heart rate reactivity may be spurious. Thus, an interpretation of this finding may be misleading. The limited overall findings between pain catastrophizing and physiological reactivity may also be the result of allostatic processes in induced acute pain, as described earlier.

Hypothesis 4 Discussion

It was expected that the trait mindfulness could play a role in buffering negative cognitive stress appraisals and maladaptive coping strategies. It was found that the MAAS was significantly and inversely associated with Threat Appraisal 1 and marginally associated with Threat Appraisal 2. In addition, the FFMQ total scores were significantly and inversely associated with both Threat Appraisals. Moreover, pain catastrophizing was significantly and inversely associated with the MAAS and the FFMQ total scores. Consistent with existing literature, this result suggests that mindfulness can be beneficial for cognitive stress appraisals, particularly threat appraisals and pain catastrophizing, with regard to pain and pain-related stress (Cassidy et al., 2011; Day et al., 2015; Mun et al., 2014; Schütze et al., 2010; Weinsten et al., 2009).

One of the novel findings in the current study was that different components of mindfulness showed different associations with threat appraisals of anticipated pain and of actual pain, while all components were inversely associated. Acting with awareness was significantly associated with threat appraisals of the anticipated pain but not with threat appraisals of the actual pain. Acting with awareness indicates an ability to pay attention to the present moment while engaging in activities (Baer et al., 2006). This finding suggests that acting with awareness would be more beneficial when individuals anticipate a painful experience. In addition, nonreactivity was significantly associated with threat appraisals of the actual pain but not of the anticipated pain. Nonreactivity indicates the ability to experience thoughts, emotions, and feelings without reacting to them (Baer et al., 2006). This finding suggests that nonreactivity would be more beneficial to those who experience actual pain. Post-hoc analysis results showed that the magnitude of changes in Threat Appraisals was significantly associated only with nonreactivity ($r = -.265$, $p < .05$), suggesting that individuals who have high nonreactivity scores tend to make lesser changes in threat appraisals when they experience pain. This suggests that nonreactivity may be an important factor in threat appraisals, particularly for those who experience actual pain, which may be different from their anticipation.

This finding indicates that interventions targeting mindfulness and/or specific components of mindfulness may be beneficial to cognitive stress appraisal processes, especially for pre- and post-surgical patients or cancer patients who may experience anticipatory anxiety toward the pain experience, and also chronic pain patients who continuously experience pain.

Hypothesis 5 Discussion

Contrary to expectations, Threat Appraisals, pain catastrophizing, and their interaction effect did not predict physiological reactivity or pain experience. There was one exception with cortisol reactivity when Threat Appraisal 1, pain catastrophizing, and their interaction were considered, but this result should be interpreted with caution, given the number of statistical analyses that were run. A possible explanation for this lack of findings may be the result of both social desirability and allostatic processes regarding pain as described earlier.

Hypothesis 6 Discussion

It was expected that mindfulness would play a positive role in pain-related stress processes, physiological reactivity, and pain experienced through acute pain induction. However, due to the lack of significant findings from Hypothesis 5, this hypothesis was not tested.

Strengths and Limitations of the Current Study

Strengths. A particular strength of this study is that it is the first to examine how cognitive stress appraisals, pain catastrophizing as a coping strategy, and their interaction may influence the pain experience, in terms of pain ratings and pain tolerance, as well as the physiological reactivity of cardiovascular function and cortisol to induced acute pain, and also how mindfulness as a trait disposition would influence these relations. Thus, a particular strength of the study is the theoretical integration of primary and secondary appraisals in stress-related outcomes from the perspective of the transactional model of stress and how mindfulness may influence this conceptualization of stress within the context of pain.

Another strength of this study is first to investigate the difference between threat appraisals of anticipated pain and actual pain, as well as their associations with other psychological factors (e.g., mindfulness and pain catastrophizing), physiological reactivity, and pain experience. Many studies have examined the anticipation of the pain experience, but to this author's knowledge no study has investigated how cognitive stress appraisals prior to and post CPT differ and how they are related to mindfulness and its components, pain catastrophizing, physiological reactivity, and pain experience.

From the methodological point of view, this study was conducted with strict inclusion and exclusion criteria to minimize confounding factors in the findings. Particularly, various substances, including caffeine and stimulants, as well as cardiovascular disease and medication, can impact a participant's sympathetic and parasympathetic nervous system. Also, a history of chronic pain, medical and mental disorders, frostbite, or cold sensitivity can impact the participant's pain experience and cognitive appraisal of acute pain induction. Thus, by controlling these factors, this study minimized the chance of confounding effects.

Limitations. There are several limitations of the current study. The first limitation is within the characteristics of the participants. Data in this study were collected only from undergraduate students attending the University of Michigan-Dearborn. A non-clinical sample of young, healthy college students engaged in an acute pain induction method may have yielded different results than a clinical sample of (chronic) pain patients. Additionally, pooling samples from a single location limits the generalizability of the results from this study to even a non-clinical sample from the general population or even a population vulnerable to pain, such as pre- and post-surgical or cancer patients.

In addition, the CPT was used to induce acute pain to participants in this study. Cold pressor pain has been used as a non-invasive acute pain induction method. While the CPT has several suggested advantages, such as a high level of safety, a high degree of participant control during the procedure, and a relatively rapid decrease in pain after termination of the task, several disadvantages have also been suggested. These include potential adaptation to the numbing effects of cold water, relatively fast recovery after the task, and the fact that participants perceive the cold stimulation more as discomfort than pain (Edens & Gil, 1995). Also, the cold water can cause vasoconstriction; thus, the blood pressure and heart rate used in this study may have been confounded by this possibility.

Another limitation of this study is that threat appraisals, pain catastrophizing, trait mindfulness, pain ratings, and pain threshold were measured by self-report methods. While there are several advantages to using self-report methods to measure these variables (i.e., participants give their opinions directly), there are also several disadvantages. Fixed-choice questions may lack flexibility and force people to answer in ways that could result in lower validity. Moreover, self-report methods may be prone to various biases, such as participants' subjective answers, social desirability, set response (e.g., middle choices, extreme choices), and number of questionnaires.

Another limitation of the study is a potential restriction of the range of participants' characteristics. The necessary description of the study guided by IRB was posted through SONA system which allowed potential participants to browse all currently approved experiments and select a study to participate with. Participants who have high pain sensitivity or pain catastrophizing may have opted out of the study, leading to a potentially restricted range of predictor and/or outcome variables. Moreover, the small sample size was limited due to the short time period for conducting a master's thesis. The decision was made not to adjust the *p* value for the number of statistical tests to aid interpretability, although the probability of a type I error must be considered within the context of this analysis.

Future Research

The overall results from this study suggest that psychological predictor variables of cognitive stress appraisals, pain catastrophizing, and mindfulness can predict psychological outcome variables for an acute pain stimulus. It would be beneficial for future studies to conduct analyses on a clinical population to demonstrate greater generalizability to chronic pain patients. More relevant to the current findings, future research could examine 1) the role attentional factors (e.g., social desirability) play in the transactional model of stress in relation to the anticipation of pain as well as to the actual experience of pain, and 2) the relative contribution of psychological factors and adaptive physiological reactivity in maintaining stability while experiencing a painful stressor across different contexts.

Contrary to expectations, overall, psychological factors did not predict a pain experience resulting from an acute pain stimulus. Beyond threat appraisals and pain catastrophizing, other psychosocial factors may affect pain experience. As suggested in the literature, one's pain experience should be considered within the context of his/her goals, which indicates attention to pain is increased when pain is relevant to his/her particular goal, leading to the inhibition of attentional processing of other information (Van Damme, Legrain, Vogt, & Crombez, 2010). Thus, other psychosocial factors (e.g., social desirability as one's goal) may inhibit attentional processing of pain, leading to greater pain tolerance. Thus, it would be beneficial for future studies to further investigate the role of attentional processes of psychosocial factors (e.g., social desirability) in the associations between pain experience, threat appraisals of anticipated pain, and of actual pain, and coping strategies within the transactional model of stress, with regard to the context of the pain experience.

Furthermore, in general, psychological factors did not predict physiological reactivity in terms of blood pressure, heart rate, and cortisol to an acute pain stressor. As discussed in the previous section, this result may be because the effect of psychological factors in physiological reactivity to a cold stimulus or physical pain may be relatively minimal to the effect of the physiological adaptation processes to maintain homeostasis. In particular, the reactivity of blood pressure, heart rate, and cortisol may be differentially impacted by both the cognitive interpretation of a threat (the descending pathway) and by the physiological adaptation processes to maintain homeostasis (the ascending pathway). Because allostatic processes may differentially influence physiological and psychological processes in response to a painful stressor beyond the effect of cognitive stress appraisals and coping strategies, the relative contribution of the ascending pathway and the descending pathway activation across different contexts may contribute to a better understanding of the relative influence of the transactional model in the pain experience. Future studies investigating the similarity and difference between the temporal summation (i.e., pain excites pain) and conditioned pain modulation (i.e., pain inhibits pain) may shed additional light on our understanding of the relative contribution of variance between the ascending pathway and the descending pathway to a painful stressor.

Implications and Conclusion

The study's findings suggest that the anticipation of pain and the actual experience of pain have different associations with cognitive threat appraisals, which, in turn, are associated with different pain outcomes. It suggests that customized pain management interventions targeting threat appraisals to reduce subjective pain ratings may be beneficial for chronic patients who engage in high fear-avoidance from the anticipation of pain as well as those who experience continuous pain.

Moreover, the study's findings suggest that, in general, mindfulness and specific components of mindfulness are inversely associated with threat appraisals of both anticipated pain and the experience of actual pain as well as with pain catastrophizing. Interventions targeting mindfulness and/or specific components of mindfulness may be effective in reducing threat appraisals and pain catastrophizing, not only for chronic pain patients but also for pre- and post-surgical pain patients and cancer patients who may anticipate an additional pain experience. In particular, mindfulness-based interventions that facilitate individuals' ability to act with awareness may be more effective for those who engage in high threat appraisals of the anticipation of pain, while mindfulness interventions utilizing nonreactivity may be more effective for those who actively experience pain.

Overall, the study partially supported the transactional model of stress when considering the effects of psychological predictor variables of cognitive stress appraisals and pain catastrophizing over subjective pain ratings to an acute pain stimulus. It also supported that mindfulness may be beneficial to the cognitive stress appraisal processes and pain catastrophizing. While the transactional model of stress was not supported, in general, when considering the effects of cognitive appraisal processes over physiological stress reactivity of cardiovascular function and cortisol, this study still suggests the importance of cognitive stress appraisals and coping strategies in pain-related stress processes.

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TABLES

Table 1

Descriptive Statistics

Variables	*N (%)*	*Range*	*M*	*SD*
Age	93	18 – 50	20.09	4.44
Gender				
Male	50 (53.8%)			
Female	43 (46.2%)			
Ethnicity				
European American	41 (44.1%)			
Arab American	32 (34.4%)			
African American	8 (8.6%)			
Hispanic	6 (6.5%)			
Asian	3 (3.2%)			
Others	3 (3.2 %)			
BMI	93	16.26 – 35.90	25.40	4.71

Note. BMI = Body Mass Index.

Table 2

Descriptive Statistics for the Sample Data (Non-Transformed) (*N* = 93)

Variables	*M*	*SD*
Threat Appraisal 1	6.65	2.63
Threat Appraisal 2	9.05	3.92
PCS	24.01	11.75
Mindfulness		
MAAS	55.04	11.90
FFMQ Total	123.67	15.82
Observing	25.74	4.43
Describing	26.12	5.84
Acting w/ Awareness	25.87	5.44
Nonjudging	25.06	6.48
Nonreactivity	20.88	3.85
Pain Threshold (sec)	25.36	18.40
Pain Tolerance (sec)	196.40	119.66

Note. BMI = Body Mass Index. SAM = Stress Appraisal Measure. PCS = Pain Catastrophizing Scale. MAAS = Mindfulness Attention Awareness Scale. FFMQ = Five Facet Mindfulness Questionnaire. SBP = Systolic Blood Pressure. DBP = Diastolic Blood Pressure. MAP = Mean Arterial Pressure. HR = Heart Rate.

Table 3

Pre-and Post-Cold Pressor Task Psychological and Physiological Responses: Paired T-Test (Non-Transformed) (*N* = 93)

	Baseline		CPT		Cohen's *d*
Variables	*M*	*SD*	*M*	*SD*	
SAM Threat	6.65	2.63	9.05	3.92	.72***
Pain Ratings	0.20	0.54	6.73	2.18	4.11***
SBP (mm Hg)	111.48	11.17	134.63	16.32	1.66***
DBP (mm Hg)	65.63	6.16	80.32	9.22	1.87***
MAP (mm Hg)	83.19	6.77	100.62	10.68	1.95***
HR (bpm)	76.33	11.91	85.98	15.26	.71***
Cortisol (µg/dL)	.201	.114	.344	.223	.81***

Note. CPT = Cold Pressor Task. SAM = Stress Appraisal Measure. SBP = Systolic Blood Pressure. DBP = Diastolic Blood Pressure. MAP = Mean Arterial Pressure. HR = Heart Rate.
*** = Paired sample t-test $p < .001$.

Table 4

Correlation between Mindfulness Measures

	1	2	3	4	5	6	7
1. MAAS	—						
2. FFMQ Total	.552***	—					
3. Observing	.113	.485***	—				
4. Describing	.197+	.681***	.299**	—			
5. Acting Awareness	.715***	.697***	.183+	.267*	—		
6. Nonjudging	.426***	.633***	-.076	.221*	.413***	—	
7. Nonreactivity	.114	.469***	.257*	.187+	.140	.089	—

Note. MAAS = Mindfulness Attention Awareness Scale. FFMQ = Five Facet Mindfulness Questionnaire.
+ = p < 0.10, * = p < .05, ** = p < .01, *** = p < .001.

Table 5

Correlations between Threat Appraisals and Pain Experience

	Threat 1	Threat 2	*Δ Threat*
Baseline Pain Ratings	.266*	.176⁺	-.003
Pain Ratings Post CPT	.172	.435***	.397***
Pain Threshold	.098	-.168	-.126
Pain Tolerance	.012	-.167	-.217*

Note. CPT = Cold Pressor Task. Threat Appraisal 1 = Threat Appraisal before the CPT. Threat Appraisal 2 = Threat Appraisal after the CPT. *Δ* Threat = Threat Appraisal 2 – Threat Appraisal 1.
$^{+}$ = p < 0.10, * = *p* < .05, ** = *p* < .01, *** = *p* < .001.

Table 6

Hierarchical Linear Regressions of Threat Appraisals and Physiological Reactivity controlling for Baseline Physiology

Psychological Variable	Physiological Variable HR Step	R	R^2	ΔR^2	B	t	β
Threat Appraisal 1							
	Systolic BP						
	Step 1: BL SBP	.734	.538	—	—	—	—
	Step 2: Threat 1	.734	.539	.001	.219	.493	.035
	Diastolic BP						
	Step 1: BL DBP	.551	.304	—	—	—	—
	Step 2: Threat 1	.551	.304	.000	.025	.080	.007
	Heart Rate						
	Step 1: BL HR	.622	.387	—	—	—	—
	Step 2: Threat 1	.623	.388	.002	.237	.494	.041
	Cortisol						
	Step 1: BL Cortisol	.422	.178	—	—	—	—
	Step 2: Threat 1	.423	.179	.001	-.002	-.306	-.029
Threat Appraisal 2							
	Systolic BP						
	Step 1: BL SBP	.734	.538	—	—	—	—
	Step 2: Threat 2	.735	.540	.002	-.205	-.686	-.049
	Diastolic BP						
	Step 1: BL DBP	.551	.304	—	—	—	—
	Step 2: Threat 2	.581	.338	.034*	.440	2.158	.187
	Heart Rate						
	Step 1: BL HR	.622	.387	—	—	—	—

Step 2: Threat 2	.643	.414	.027 *	.648	2.034	.167
Cortisol						
Step 1: BL Cortisol	.422	.178	—	—	—	—
Step 2: Threat 2	.424	.179	.001	-.002	-.355	-.034
Δ Threat Appraisal (2 - 1)						
Systolic BP						
Step 1: BL SBP	.734	.538	—	—	—	—
Step 2: Δ Threat	.739	.546	.008	-.469	-1.272	.091
Diastolic BP						
Step 1: BL DBP	.551	.304	—	—	—	—
Step 2: Δ Threat	.594	.353	.049*	.649	2.616	.222
Heart Rate						
Step 1: BL HR	.622	.387	—	—	—	—
Step 2: Δ Threat	.644	.415	.028*	.822	2.094	.170
Cortisol						
Step 1: BL Cortisol	.422	.178	—	—	—	—
Step 2: Δ Threat	.423	.179	.000	-.001	-.187	-.018

Note. Threat Appraisal 1 = Threat Appraisal before the CPT. Threat Appraisal 2 = Threat Appraisal after the CPT. *Δ* Threat = Threat Appraisal 2 – Threat Appraisal 1. BL = Baseline. SBP = Systolic Blood Pressure. DBP = Diastolic Blood Pressure. HR = Heart Rate.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 7

Correlations between Threat Appraisals and Pain Catastrophizing

	Threat Appraisal 1	Threat Appraisal 2	Δ Threat Appraisal
PCS Total	.457***	.628***	.400***
Rumination	.318**	.521***	.383***
Magnification	.463***	.541***	.287**
Helplessness	.467**	.627***	.391***

Note. Threat Appraisal 1 = Threat Appraisal before the CPT. Threat Appraisal 2 = Threat Appraisal after the CPT. *Δ* Threat = Threat Appraisal 2 – Threat Appraisal 1. PCS = Pain Catastrophizing Scale.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 8

Correlations between Pain Catastrophizing and Pain Experience

	1	2	3	4	5
1. PCS	—				
2. Baseline Pain Ratings	.075	—			
3. Pain Ratings Post CPT	.308**	.079	—		
4. Pain threshold	.095	.013	-.232*	—	
5. Pain Tolerance	-.103	-.050	-.192+	.294**	—

Note. PCS = Pain Catastrophizing Scale.
+ = p < 0.10, * = p < .05, ** = p < .01, *** = p < .001.

Table 9

Hierarchical Linear Regressions of Pain Catastrophizing and Physiological Reactivity controlling for Baseline Physiology

Psychological Variable	Physiological Variable HR Step	*R*	R^2	ΔR^2	*B*	*t*	*β*
PCS Total							
	Systolic BP						
	Step 1: BL SBP	.734	.538	—	—	—	—
	Step 2: PCS	.734	.539	.001	-.046	-.464	-.033
	Diastolic BP						
	Step 1: BL DBP	.551	.304	—	—	—	—
	Step 2: PCS	.566	.320	.017	.103	1.484	.069
	Heart Rate						
	Step 1: BL HR	.622	.387	—	—	—	—
	Step 2: PCS	.644	.415	.028*	.219	2.073	.168
	Cortisol						
	Step 1: BL Cortisol	.422	.178	—	—	—	—
	Step 2: Δ Threat	.423	.179	.001	-.001	-.291	-.028

Note. PCS = Pain Catastrophizing. BL = Baseline. SBP = Systolic Blood Pressure. DBP = Diastolic Blood Pressure. HR = Heart Rate.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 10

Correlation Matrix of Threat Appraisals, PCS, and Mindfulness

	1	2	3	4	5	6	7	8	9	10
1. Threat 1	—									
2. Threat 2	.598***	—								
3. PCS	.457***	.598***	—							
4. MAAS	-.231*	-.172+	-.369***	—						
5. FFMQ Total	-.350**	-.355***	-.434***	.552***	—					
6. Observing	-.198+	-.280**	.098	.113	.485***	—				
7. Describing	-.223*	-.215*	-.259*	.197+	.681***	.299**	—			
8. Acting Awareness	-.273**	-.149	-.329**	.715***	.697***	.183+	.267*	—		
9. Nonjudging	-.208*	-.173+	-.339**	.426***	.633***	-.076	.221*	.413***	—	
10. Nonreactivity	-.137	-.305**	-.245*	.114	.469***	.257*	.187+	.140	.089	—

Note. Threat Appraisal 1 = Threat Appraisal before the CPT. Threat Appraisal 2 = Threat Appraisal after the CPT. PCS = Pain Catastrophizing Scale. MAAS = Mindfulness Attention Awareness Scale. FFMQ = Five Facet Mindfulness Questionnaire.
+ = p < 0.10, * = p < .05, ** = p < .01, *** = p < .001.

Table 11

Hierarchical Linear Regressions showing Interaction Effect of Pain Catastrophizing and Threat Appraisals in Physiological Reactivity and Pain Outcomes

Psychological Variable	Physiological Variable HR Step	*R*	R^2	ΔR^2	*B*	*t*	*β*
Threat Appraisal 1 X PCS							
	Systolic BP						
	Step 1: BL SBP	.734	.538	—	—	—	—
	Step 2: Threat 1, PCS	.734	.542	—	—	—	—
	Step 3: Threat 1 X PCS	.740	.548	.006	-.049	-1.052	.296
	Diastolic BP						
	Step 1: BL DBP	.551	.304	—	—	—	—
	Step 2: Threat 1, PCS	.569	.323	—	—	—	—
	Step 3: Threat 1 X PCS	.578	.334	.010	-.037	-1.153	-.510
	Heart Rate						
	Step 1: BL HR	.622	.387	—	—	—	—
	Step 2: Threat 1, PCS	.645	.416	—	—	—	—
	Step 3: Threat 1 X PCS	.657	.432	.016	-.077	-1.569	-.637
	Cortisol						
	Step 1: BL Cortisol	.422	.178	—	—	—	—
	Step 2: Threat 1, PCS	.424	.179	—	—	—	—
	Step 3: Threat 1 X PCS	.477	.227	.048*	-.002	-2.340	-1.111
	Pain Rating						
	Step 1: Threat 1, PCS	.310	.096	—	—	—	—
	Step 2: Threat 1 X PCS	.310	.096	.000	.001	.130	.066
	Pain Threshold						
	Step 1: Threat 1, PCS	.114	.013	—	—	—	—

Step 2: Threat 1 X PCS	.114	.013	.000	.001	.014	.008
Pain Tolerance						
Step 1: Threat 1, PCS	.122	.015	—	—	—	—
Step 2: Threat 1 X PCS	.134	.018	.003	-.259	-.515	-.273
Threat Appraisal 2 X PCS						
Systolic BP						
Step 1: BL SBP	.734	.538	—	—	—	—
Step 2: Threat 2, PCS	.735	.540	—	—	—	—
Step 3: Threat 2 X PCS	.736	.542	.001	-.015	-.526	-.170
Diastolic BP						
Step 1: BL DBP	.551	.304	—	—	—	—
Step 2: Threat 2, PCS	.582	.338	—	—	—	—
Step 3: Threat 2 X PCS	.585	.342	.004	-.013	-.695	-.270
Heart Rate						
Step 1: BL HR	.622	.387	—	—	—	—
Step 2: Threat 2, PCS	.649	.421	—	—	—	—
Step 3: Threat 2 X PCS	.653	.426	.005	-.026	-.884	-.320
Cortisol						
Step 1: BL Cortisol	.422	.178	—	—	—	—
Step 2: Threat 2, PCS	.424	.180	—	—	—	—
Step 3: Threat 2 X PCS	.426	.181	.002	.000	-.439	-.190
Pain Rating						
Step 1: Threat 2, PCS	.437	.191	—	—	—	—
Step 2: Threat 2 X PCS	.451	.203	.012	-.006	1.177	.498
Pain Threshold						
Step 1: Threat 2, PCS	.168	.028	—	—	—	—
Step 2: Threat 2 X PCS	.170	.029	.001	.011	.230	.110

Pain Tolerance						
Step 1: Threat 2, PCS	.167	.028	—	—	—	—
Step 2: Threat 2 X PCS	.204	.041	.014	.329	1.124	.522

Note. Threat Appraisal 1 = Threat Appraisal before the CPT. Threat Appraisal 2 = Threat Appraisal after the CPT. PCS = Pain Catastrophizing. Threat X PCS = Interaction between Threat Appraisal and PCS. BL = Baseline. SBP = Systolic Blood Pressure. DBP = Diastolic Blood Pressure. HR = Heart Rate.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$.

APPENDICES

APPENDIX A: Demographic and Screening Questionnaire

Participant ID #:_________________

Date:____/____/______

Time: _________AM/PM

*1. Age: _________

2. Gender: __________

3. Ethnicity:

_____ European American (White, not of Hispanic Origin)
_____ Arab American
_____ African American
_____ Hispanic
_____ Asian
_____ Other: _________________

4. Religion:

_____ Atheist
_____ Agnostic
_____ Buddhism
_____ Christianity
_____ Hinduism
_____ Islam
_____ Judaism
_____ Other: _________________

*5. Please answer "YES" if all of the following questions describe your situation but "NO" if any one of the following questions describes your situation.

Have you eaten a meal in last four hours?
Have you drunk any water or any liquid (e.g., coffee, soda, etc.) in the last two hours?
Have you avoided alcohol within 12 hours of this study?

YES____ NO____

*6. Have you taken any of the following types of medication within 72 hours of the study?

Pain medications (for example, Asprin, Motrin/Ibuprofen)
Opioid pain medications (for example, Morphine, Lorcet, OxyContin)
Stimulants (for example, Ritalin, Concerta)
Steroids (for example, prednisone, asthma medications)
Cold or Flu medications
Blood pressure medications
Any psychiatric medications

YES____ NO____

*7. Do you have a history of chronic pain, duration of at least 3 months?
(For example, arthritis, migraines, or low back pain)
YES____ NO____

8. Do you have a history of significant physical injury?
YES____ NO____

*9. Do you have any of the following medical disorders?

Cardiovascular disorder/disease (For example, arrhythmias, heart murmurs, or hypertension)
Chest pain
Irregular Heart Beat
High Blood Pressure
Asthma
Type I Diabetes
Kidney Diseases
Current diagnosis of a psychiatric disorder such as depression or anxiety

YES____ NO____

*10. Do you have a history of Cold Raynaud's Disorder?
YES____ NO____

*11. Do you have an implanted medical device (for example, a pacemaker)?
YES____ NO____

12. Do you have a family history of heart attack or stroke prior to age 50?

YES____ NO____

*13. Do you have a history of frostbite on your hands?
YES____ NO____

*14. Do you have a history of fainting or seizures?
YES____ NO____

*15. Do you have an open cut or sore on your non-dominant hand?
YES____ NO____

*16. Are you pregnant?
YES____ NO____

17. What time did you wake up (approximate time)?
______:______AM/PM

18. Do you do aerobic exercise (e.g., running, swimming) on a regular basis (3 or more times a week for 30 minutes or more)?
YES____ NO____

19. Do you practice any type of meditation on a regular basis?
YES____ NO____

a. If YES, how many times per week do you practice?
____

b. If YES, what type of meditation do you practice?
- ☐ Mindfulness
- ☐ Concentration
- ☐ Contemplation

20. When you need to relax, do you spend time with your friends or family?
YES____ NO____

21. When you need to relax, do you do any sports, hobby, or any other activity?
YES____ NO____

Thank you and please return this questionnaire to the researcher!

APPENDIX B: SAM 1

This questionnaire is concerned with your thoughts about the **UP-COMING TASK** that was just described to you. There are no right or wrong answers. Please respond according to **how you view this situation right NOW**. Please answer ALL questions. Answer each question by CIRCLING the appropriate number corresponding to the following scale.

		Not at all	Slightly	Moderately	Considerably	Extremely
1.	Does this situation create tension in me?	1	2	3	4	5
2.	Does this situation make me feel anxious?	1	2	3	4	5
3.	Is this going to have a positive impact on me?	1	2	3	4	5
4.	How eager am I to tackle this problem?	1	2	3	4	5
5.	To what extent can I become a stronger person because of this problem?	1	2	3	4	5
6.	Will the outcome of this situation be negative?	1	2	3	4	5
7.	Does this situation tax or exceed my coping resources?	1	2	3	4	5
8.	To what extent am I excited thinking about the outcome of this situation?	1	2	3	4	5

9.	How threatening is this situation?	1	2	3	4	5
10.	To what extent do I perceive this situation as stressful?	1	2	3	4	5
11.	To what extent does this event require coping efforts on my part?	1	2	3	4	5
12.	Is this going to have a negative impact on me?	1	2	3	4	5

APPENDIX C: SAM 2

This questionnaire is concerned with your thoughts about various aspects of **<u>the situation you are experiencing with pain RIGHT NOW</u>**. There are no right or wrong answers. Please respond according to **how you view this situation right NOW**. Please answer ALL questions. Answer each question by CIRCLING the appropriate number corresponding to the following scale.

		Not at all	Slightly	Moderately	Considerably	Extremely
1.	Does this situation create tension in me?	1	2	3	4	5
2.	Does this situation make me feel anxious?	1	2	3	4	5
3.	Is this going to have a positive impact on me?	1	2	3	4	5
4.	How eager am I to tackle this problem?	1	2	3	4	5
5.	To what extent can I become a stronger person because of this problem?	1	2	3	4	5
6.	Will the outcome of this situation be negative?	1	2	3	4	5
7.	Does this situation tax or exceed my coping resources?	1	2	3	4	5
8.	To what extent am I excited thinking about the outcome of this situation?	1	2	3	4	5

9.	How threatening is this situation?	1	2	3	4	5
10.	To what extent do I perceive this situation as stressful?	1	2	3	4	5
11.	To what extent does this event require coping efforts on my part?	1	2	3	4	5
12.	Is this going to have a negative impact on me?	1	2	3	4	5

APPENDIX D: PCS

Everyone experiences painful situations at some point in their lives. Such experiences may include headaches, tooth pain, joint or muscle pain. People are often exposed to situations that may cause pain such as illness, injury, dental procedures or surgery.

We are interested in the types of thoughts and feeling that you have **WHEN YOU ARE IN PAIN.** Listed below are thirteen statements describing different thoughts and feelings that may be associated with pain. Using the scale, please indicate the degree to which you have these thoughts and feelings when you are experiencing pain.

		Not at all	To a slight degree	To a moderate degree	To a great degree	All the time
1.	I worry all the time about whether the pain will end.	0	1	2	3	4
2.	I feel I can't go on.	0	1	2	3	4
3.	It's terrible and I think it's never going to get any better.	0	1	2	3	4
4.	It's awful and I feel that it overwhelms me.	0	1	2	3	4
5.	I feel I can't stand it anymore.	0	1	2	3	4
6.	I become afraid that the pain will get worse.	0	1	2	3	4
7.	I keep thinking of other painful events.	0	1	2	3	4
8.	I anxiously want the pain to go away.	0	1	2	3	4
9.	I can't seem to keep it out of my mind.	0	1	2	3	4
10.	I keep thinking about how much it hurts.	0	1	2	3	4
11.	I keep thinking about how badly I want the pain to stop.	0	1	2	3	4
12.	There's nothing I can do to reduce the intensity of the pain.	0	1	2	3	4
13.	I wonder whether something serious may happen.	0	1	2	3	4

APPENDIX E: MAAS

Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather that what you think your experiences should be.

Answer by CIRCLING the appropriate number corresponding to the following scale.

		Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infreque-ntly	Almost Never
1.	I could be experiencing some emotion and not be conscious of it until sometime later.	1	2	3	4	5	6
2.	I break or spill things because of carelessness, not paying attention, or thinking of something else.	1	2	3	4	5	6
3.	I find it difficult to stay focused on what's happening in the present moment.	1	2	3	4	5	6
4.	I tend to walk quickly to get to where I'm going without paying attention to what I experience along the way.	1	2	3	4	5	6

5.	I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	1	2	3	4	5	6
6.	I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
7.	It seems I am "running on automatic" without much awareness of what I'm doing.	1	2	3	4	5	6
8.	I rush through activities without really being attentive to them.	1	2	3	4	5	6
9.	I get so focused on the goal I want to achieve that I lose touch with what I am doing right now to get there.	1	2	3	4	5	6
10.	I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
11.	I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6

12.	I drive places on “automatic pilot” and then wonder why I went there.	1	2	3	4	5	6
13.	I find myself preoccupied with the future or the past.	1	2	3	4	5	6
14.	I find myself doing things without paying attention.	1	2	3	4	5	6
15.	I snack without being aware that I’m eating.	1	2	3	4	5	6

APPENDIX F: FFMQ

Below is a collection of statements **about your everyday experience**. Please rate each of the following statements with the number that best describes your own opinion of what is **generally** true for you.

		Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true
1.	When I'm walking, I deliberately notice the sensations of my body moving.	1	2	3	4	5
2.	I'm good at finding words to describe my feelings.	1	2	3	4	5
3.	I criticize myself for having irrational or inappropriate emotions.	1	2	3	4	5
4.	I perceive my feelings and emotions without having to react to them.	1	2	3	4	5
5.	When I do things, my mind wanders off and I'm easily distracted.	1	2	3	4	5
6.	When I take a shower or bath, I stay alert to the sensations of water on my body.	1	2	3	4	5
7.	I can easily put my beliefs, opinions, and expectations into words.	1	2	3	4	5
8.	I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.	1	2	3	4	5
9.	I watch my feelings without getting lost in them.	1	2	3	4	5
10.	I tell myself I shouldn't be feeling the way I'm feeling.	1	2	3	4	5

11.	I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.	1	2	3	4	5
12.	It's hard for me to find the words to describe what I'm thinking.	1	2	3	4	5
13.	I am easily distracted.	1	2	3	4	5
14.	I believe some of my thoughts are abnormal or bad and I shouldn't think that way.	1	2	3	4	5
15.	I pay attention to sensations, such as the wind in my hair or sun on my face.	1	2	3	4	5
16.	I have trouble thinking of the right words to express how I feel about things.	1	2	3	4	5
17.	I make judgements about whether my thoughts are good or bad.	1	2	3	4	5
18.	I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5
19.	When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.	1	2	3	4	5
20.	I pay attention to sounds, such as clock ticking, birds chirping, or cars passing.	1	2	3	4	5
21.	In difficult situations, I can pause without immediately reacting.	1	2	3	4	5
22.	When I have a sensation in my body, it's difficult for me to describe it because I can't find the right words.	1	2	3	4	5
23.	It seems I am "running on automatic" without much awareness of what I'm doing.	1	2	3	4	5

24.	When I have distressing thoughts or images, I feel calm soon after.	1	2	3	4	5
25.	I tell myself that I shouldn't be thinking the way I'm thinking.	1	2	3	4	5
26.	I notice the smells and aromas of things.	1	2	3	4	5
27.	Even when I'm feeling terribly upset, I can find a way to put it into words.	1	2	3	4	5
28.	I rush through activities without being really attentive to them.	1	2	3	4	5
29.	When I have distressing thoughts or images, I am able just to notice them without reacting.	1	2	3	4	5
30.	I think some of my emotions are bad or inappropriate and I shouldn't feel them.	1	2	3	4	5
31.	I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.	1	2	3	4	5
32.	My natural tendency is to put my experiences into words.	1	2	3	4	5
33.	When I have distressing thoughts or images, I just notice them and let them go.	1	2	3	4	5
34.	I do jobs or tasks automatically without being aware of what I'm doing.	1	2	3	4	5
35.	When I have distressing thoughts or images, I judge myself as good or bad depending what the thought or image is about.	1	2	3	4	5
36.	I pay attention to how my emotions affect my thoughts and behaviors.	1	2	3	4	5
37.	I can usually describe how I feel at the moment in considerable detail.	1	2	3	4	5

38.	I find myself doing things without paying attention.	1	2	3	4	5
39.	I disapprove of myself when I have irrational ideas.	1	2	3	4	5

APPENDIX G: Informed Consent

EXPERIMENTAL SUBJECT POOL PARTICIPATION

CONSENT FORM

The psychology faculty considers participation in experimental research by subjects to be an educational experience for the students as well as a most important service to the research of the University. This research project has been approved by the University of Michigan-Dearborn Institutional Review Board (IRB Dearborn). Participation is voluntary, if you choose **not** to participate as a research subject you may participate in another research related activity at no expense to your academic record or standing. The purpose of today's experiment is to examine the association between psychological variables such as stress and the experience of physical pain:

Psychology Subject Pool Subjects

As a part of your participation in an Introductory Psychology course at the University of Michigan- Dearborn, you agree to serve as a research subject for this experiment. You have had the opportunity to read the "Subject Pool Participation" description information that was provided when you registered on the SONA System website as a research participant. You will receive 1.5 subject pool credits for your participation in today's study. You may withdraw at any time from today's study without penalty or loss of research participation credit.

Upper Level Psychology Course Research Subjects

As part of your participation in an upper level psychology course at the University of Michigan-Dearborn you agree to serve as a research subject for this experiment. You have had the opportunity to read the "Subject Pool Participation" description information that was provided when you registered on the SONA System website as a research participant. You will receive 1.5 extra credits for your participation. You may withdraw at any time from today's study without penalty or loss of extra credit.

Description of Subject Involvement:

The procedure in today's study involves: You will be asked to complete several measures of psychological variables such as stress, have your blood pressure and heart rate measured using a non-invasive blood pressure machine (similar to one used in a doctor's office), provide a saliva sample collection and engage in a cold pressor task (placing your hand in 40-degree Fahrenheit water). In addition, your height and weight will be measured. The risks include: some discomfort or pain during the cold pressor task when you put your hand in the cold water, increased heart rate, and potentially perspiration. While the researchers have worked to minimize risks, rare instances fainting could occur. You should advise the research assistant if you begin to feel lightheaded. Benefits include: there are no direct benefits to you.

Confidentiality:

We plan to publish or present the results of this study, but will not include any information that would identify you. There are some reasons why people other than the researchers may need to see information you provided as part of the study. This includes organizations responsible for making sure the research is done safely and properly, including the University of Michigan, government offices.

Contact Information:

If you have questions about the study you may contact Samsuk Kim (samsukk@umich.edu) or her faculty advisor, David Chatkoff, Ph.D. (chatkoff@umich.edu).

If you have questions regarding your rights as a research participant, or wish to obtain information, ask questions, or discuss concerns with someone other than the researcher(s), you may contact the Dearborn IRB Administrator at (734) 763-5084. Written questions should be directed to the Office of Research and Sponsored Programs, 2066 IAVS, University of Michigan-Dearborn, Evergreen Rd., Dearborn, MI 48128-2406, (313) 593-5468; the Dearborn IRB Administrator at (734) 763-5084, or email Dearborn-IRB@umich.edu.

Your participation will require no more than 1.5 hours. The purpose and procedure as well as the benefits and risks of the study have been explained to you and the results will be made available to you upon your request. By signing this document, you are agreeing to be in the study. You will be given a copy of this document for your records and one copy will be kept with the study records. Be sure that questions you have about the study have been answered and that you understand what you are being asked to do. You may contact the researcher if you think of a question later.

I agree to participate in the study.

Signature____________________________

Name: ______________________________

Address: ____________________________

Enrolled in: Psychology _______________

Psychology Instructor_________________

To be filled by experimenter:

Experiment: ______________________

Date: ____________________________

Experimenter: ____________________

APPENDIX H: Debriefing Form

University of Michigan – Dearborn

POST PARTICIPATION INFORMATION

Thank you for your participation in this research project.

This sheet is provided as a reminder that should your participation in this project lead to a desire to seek additional services, you may contact any of the agencies listed below.

UM-D Counseling and Support Services (UM-D students only) 313-593-5430

Henry Ford Medical Center- Fairlane for Students, Faculty and Staff (UM-D students only) 313-982-8495

Please feel free to contact either of these agencies, and once again thank you for your participation.