THE UTILITY OF BRIEF COGNITIVE SKILLS TRAINING IN REDUCING PAIN CATASTROPHIZING DURING EXPERIMENTAL PAIN

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ABSTRACT

GREGORY L. STONEROCK: Assessing the Utility of Brief Cognitive Skills Training in Reducing Pain Catastrophizing during Experimental Pain
(Under the direction of Karen M. Gil)

Individuals who experience pain often engage in catastrophizing (CAT), a cognitive style involving rumination about pain, magnification of perceived threat, and a feeling of helplessness to cope with the pain. Moreover, high levels of catastrophizing have been shown to lead to poorer pain outcomes, such as lower pain tolerance and greater pain-related disability. Training in cognitive coping skills can help individuals to manage pain more effectively. In the current study, 111 pain-free undergraduate participants completed two modalities of experimental pain tasks (pressure, cold pressor) before and after an intervention targeted at reducing CAT through three cognitive-behavioral coping strategies: distraction, mindfulness/acceptance of pain, and cognitive restructuring. Pain responses from this group were compared to two other groups, one that underwent a positive mood induction procedure and one that underwent a similar procedure aimed at having no effect on mood (neutral mood group), which served as a control group. Participants also completed a new measure, the Catastrophizing Visual Analog Scale (CAT-VAS), designed to assess in-the-moment CAT during pain tasks. This new measure improves upon previous retrospective self-report measures of CAT given that CAT measured during or immediately after the pain experience accounts for more variance in pain responses (e.g., Edwards, Campbell, & Fillingim, 2005). Overall, the cognitive skills group showed lower CAT, higher pain tolerance, and greater reductions

in subjective pain report post-intervention than either the positive or neutral mood groups. In addition, the CAT-VAS was more powerful in predicting pain response than existing retrospective questionnaire measurements. The results provide support for cognitive appraisal and fear-avoidance models of pain and pain coping, in which rumination and negative appraisal of pain escalate over time and promote a continued state of pain and distress whereas active coping attempts lead to greater pain relief.

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Introduction

Pain is a multifaceted noxious experience that is not explained fully by physiological variables. Beyond sensory mechanisms, pain has evaluative (i.e., cognitive), affective and behavioral components that interact with physiology, as well as each other, in producing the subjective experience of pain. Intrapersonal phenomena relevant to the experience of pain include mood states (e.g., Geisser, Robinson, Keefe, & Weiner, 1994), fear and anxiety (e.g., Rhudy & Meagher, 2000), psychosocial stress (van Houdenhove, 2000), neuroticism (e.g., Goubert, Crombez, & Van Damme, 2004), gender roles (e.g., Levine & De Simone, 1991; Unruh, 1996) as well as other psychosocial factors. Variation in these psychosocial variables helps to explain individual differences in pain perception in both experimental and clinical contexts (e.g., Burton, Tillotson, Main, & Hollis, 1995; Gracely, Geisser, Giesecke, Grant, Petzke, Williams, et al., 2004; Peters, Vlaeyen, & Weber, 2005). Greater knowledge about the unique contributions of psychological factors to pain has opened pathways for the development of psychosocial interventions that reduce pain and improve pain-related adjustment (Burton et al., 1995; Gil, Wilson, Edens, Webster, Abrams, Orringer, et al., 1996).

Recently, a psychological construct known as catastrophizing (CAT) has emerged as an important factor for explaining why individuals facing ostensibly the same painful stimulus or condition can report highly divergent subjective experiences of pain (e.g., Keefe, Brown, Wallston, & Caldwell, 1989). Broadly defined, CAT is a negative cognitive style or "mental set" through which pain is viewed as intense, unbearable, or

overwhelming, usually accompanied by an amplified subjective experience of the pain (Sullivan, Thorn, Haythornthwaite, et al., 2001). When individuals catastrophize about pain, they show both heightened attentional focus on the pain and difficulty shifting their focus elsewhere (Crombez, Bijttebier, Eccleston, Mascagni, Mertens, et al., 2003; Goubert, Crombez, & Van Damme, 2004; Sullivan & Neish, 1998). Factor analyses have suggested that CAT consists mainly of magnification of the experience of pain, cognitive rumination about pain, and feelings of helplessness (e.g., D'Eon, Harris, & Ellis, 2004; Sullivan, Bishop, & Pivik, 1995).

Over the last two decades, research has suggested that CAT has substantial value in explaining individual differences in responses to pain. In individuals with clinical pain, higher CAT is associated with more intense pain reports and pain-related disability (e.g., Geisser, Robinson, & Henson, 1994; Severejins, Vlaeyen, van den Hout, & Weber, 2001). Furthermore, pain-free individuals tend to show lower CAT on established measures than those with clinical pain (e.g., Osman, Barrios, Gutierrez, Kopper, Merrifield, & Grittmann, 2000). Because so much of the pain experience is subjective, one cannot determine whether self-report of pain intensity "objectively" equates to more intense pain. Still, CAT shows positive associations with observable measures, such as greater number of pain behaviors, more activity reduction, and higher levels of medication and health care use (e.g., Gil, Anthony, Carson, Redding-Lallinger, Daeschner, & Ware, 2001). Even though the majority of studies on CAT and pain are cross-sectional (Sullivan et al., 2001), CAT has shown predictive value for determining which pain-free individuals will go on to develop chronic pain after an injury (Linton,

Buer, Vleayen, & Hellsing, 2000) and which chronic pain patients will see their functional impairment worsen over time (Keefe et al., 1989).

Despite the use of the term "mental set" to describe CAT, CAT is not simply present or absent; questionnaire measures of CAT aim to assess to what degree catastrophic thoughts and attributions typify one's response to pain (e.g., Rosenstiel & Keefe, 1983; Sullivan et al., 1995). This conceptualization facilitates studies that examine how CAT interacts with other pain variables to produce the final pain experience. CAT appears to moderate the relationship between clinical pain and physiological variables (e.g., cardiovascular stress function; Wolff, Burns, Quartana, Lofland, Bruehl, & Chung, 2008) and has been examined as a possible mediator of the impact of gender (Edwards, Haythornthwaite, Sullivan, & Fillingim, 2004) and depression (Geisser, Robinson, Keefe, & Weiner, 1994) on pain perception.

Theoretical Models: Cognitive and Evaluative

Although early research questions on CAT focused around operationalization and measurement, Sullivan et al. (2001) were among the first to explore CAT from a theoretical perspective, relating the construct to broader theoretical models. One of these, the schema activation model, proposes that unpleasant life experiences can promote pessimistic beliefs and interpretations of life events which perpetuate a state of emotional distress and suffering. For example, Beck (1976) theorized that individuals who experience clinical depression show an exaggerated negative schema that applies to their views of themselves, the world, and the future. Individuals with this schema interpret feedback from their environment in a negative way that fits their schema. Furthermore, they tend to seek out information from their environment that reaffirms their existing

schema. Within this schema activation framework, CAT in reference to pain is a specific instantiation of these kinds of globalized negative thought patterns (Crombez et al., 2003). People who catastrophize about pain thus would be more likely to look for signs that painful events will occur and that existing pain is worsening, to interpret ambiguous situations and stimuli as potentially painful, and to believe that they are helpless to control it. This explanation of CAT is partially supported by studies that show depression as a risk factor for the development of pain after injury (e.g., Carroll, Cassidy, & Côté, 2004).

A related model, the appraisal model, suggests that individuals first evaluate stimuli as benign or potentially stressful, and then check these appraisals against their beliefs about their coping efficacy (Lazarus & Folkman, 1984; Sullivan et al., 2001). From this perspective, CAT would be a tendency to appraise more situations as potentially painful and pain itself as unchangeable. Indeed, CAT is typically negatively correlated with coping efficacy (Sullivan et al., 2001). Interestingly, cognitive appraisal processes mediated the relationship between depression and perceived clinical pain intensity in a sample of 100 heterogeneous pain patients (Turk, Okifuji, & Scharff, 1995). Geisser, Robinson, Keefe and Weiner (1994) similarly found that CAT mediated the depression-pain relationship in a sample of 19 women and 10 men with fibromyalgia. Taken together, these findings would suggest that, even though CAT has similarities with the negative schemas and biased information processes that underlie depression from a cognitive perspective, it offers more explanatory value for pain than depression alone.

Prospective research has indicated that CAT, like depression, is a risk factor for the development of chronic pain after an acute lower back injury (Linton et al., 2000). These

authors examined both fear of pain and CAT and noted that fear-avoidance beliefs were a stronger risk factor than CAT for the development of long-term pain-related disability. These authors and others explained this potential mechanism using a fear-avoidance model (e.g., Lethem, Slade, Troup, & Bentley, 1983). In this model, people who have strong fears of pain or (re-)injury avoid situations with the potential for pain, including physical activities that pose minimal risk of harm. This pattern preserves pain-related disability, as avoidance does not allow one the opportunity to disconfirm the beliefs that underlie the avoidance.

However, avoidance does not occur solely in the presence of fear. Even without an acutely frightening pain experience, individuals have multiple pathways through which they learn how to evaluate which stimuli pose threats and ways to avoid them (Goubert, Crombez, & Peters, 2004). CAT may not differ from fear of pain in terms of behavioral consequences; research comparing the relative impact of fear of pain and CAT on experimental pain response suggests that these two factors can be predictive of the same pattern of avoidance (George, Dannecker, & Robinson, 2006). Similarly, CAT and fear of pain each imply an anxious anticipation of a threat, as opposed to fear in direct response to an observed threat. Fear of an observed threat should lead to increased activity in the sympathetic nervous system, and therefore decreased perceived pain; in contrast, anxious anticipation of pain or discomfort might lead to increased pain sensitivity and more discomfort being identified as pain (Asmundson, Norton, & Vlaeyen, 2004). Research in fibromyalgia patients has shown that CAT indeed predicts greater activity in areas of the brain that relate to anticipation of and attention to pain (Gracely et al., 2004).

A more comprehensive cognitive and behavioral model, proposed by Vlaeyen and Linton (2000) and amended by Asmundson, Norton, and Vlaeyen (2004), aimed to clarify the complex relationships between CAT, fear, and negative pain-related outcomes. The model posits that CAT is the first step in a maladaptive response cycle provoked by a pain experience. Pain-related fear follows directly from CAT, followed by avoidance and hypervigilance towards bodily sensations, disuse and depression, and finally continued pain experiences. This conceptualization, which expands upon the fear-avoidance model, has received some empirical support from analyses of questionnaire data from low back pain patients (Goubert, Crombez, & Van Damme, 2004). Structural equation models suggested that vigilance levels, which were positively associated with pain intensity, were dependent upon levels of CAT and fear of pain. This model integrates the fear-avoidance perspective with the appraisal model, as it supposes that one must first evaluate a stimulus as threatening before experiencing fear and adapting to the threat.

In summary, the schema activation, appraisal, and fear-avoidance models conceptualize CAT as an appraisal process through which people seek out information that confirms irrational beliefs about the dangers of pain, exaggerate the potential threat of pain, and leads them to avoid these perceived threats. This avoidance then leads to increased suffering and long-term disability. Through this appraisal process, individuals' experience of pain is amplified, and they think of pain as intolerable, threatening, and uncontrollable. Over time, these negative experiences promote overestimation of the potential for pain in both noxious and neutral stimuli, pain-related fear, and subsequent avoidance of these stimuli. Avoidance of these stimuli, regardless of its relation to fear, then promotes negative reinforcement of this pattern of pain coping.

Theoretical Models: Communal Coping

CAT appears to make the experience of pain more noxious, yet CAT levels remain fairly stable over periods of weeks to months in individuals who are not receiving any intervention to reduce CAT (Keefe et al., 1989; Sullivan et al., 1995; Sullivan et al., 2001). From an operant conditioning perspective, if CAT makes pain worse, one would expect CAT levels to decrease over time (i.e., avoiding a thought pattern that increases the amount of punishment associated with pain). Thus, this perspective would suggest that for individuals to maintain high levels of CAT, they must experience secondary gains that provide enough benefit to result in a net reinforcement of the behaviors. In this vein, Sullivan and colleagues (2001) offer the intriguing hypothesis that individuals who report intense pain and show high negative mood are likely to draw the attention of others and, in the short term especially, elicit care from the environment. This hypothesis has received partial support; for example, a group of patients with irritable bowel syndrome (IBS) who showed high CAT also tended to have more submissive and help-seeking personality styles (Lackner & Gurtman, 2004). Though communicating intense pain to others may indeed elicit care, it is dangerous to assume that pain behaviors are conducted in a deliberate effort to achieve secondary gains (Goubert, Crombez, & Peters, 2004). Still, findings that suggest that CAT has an interpersonal function challenge the notion that CAT is purely an appraisal process and require additional theoretical context.

Thorn (2003) provided an initial theoretical framework for the social and operant roles of CAT in her discussion of the communal coping model (CCM). The CCM holds as a primary assumption that when individuals cope with pain, they may have broader goals than simply reducing pain; if their behavior elicits social support, this could support

continued high levels of CAT. Jackson and colleagues (Jackson, Iezzi, Chen, Ebnet, & Eglitis, 2005) conducted an innovative study in which the key predictors of tolerance of cold pressor, an experimental pain task in which participants immerse a hand into water cold enough to invoke pain, were participant gender and the instructions given to the participants on how to cope with the pain. Some participants were allowed to do anything but talk to the experimenter; the others were assigned to a condition where they were allowed to talk to an experimenter who was trained to respond in a sympathetic manner. Of the people given the opportunity to interact with the experimenter, about two thirds did so. People who interacted with the experimenter tended to have lower tolerances for pain (i.e., lower latencies to removing their hand from the cold pressor apparatus), to report more CAT and to seek more emotional support. Overall, this study seems to support the CCM's conceptualization of CAT, in that people who showed lower pain tolerances talked more about their pain during the pain task and reported using CAT and seeking emotional support more as coping strategies. Moreover, men and women may have important differences in their pain responses.

However, in the long term, CAT may exhaust the positive social support available in the environment, leading to "diminishing returns" and more negative responses from the social environment. Losing support and sympathy from the environment would therefore be associated with a long-term increase in one's subjective distress, even though it may elicit helpful short-term responses This idea received additional support in a study examining the relationships between pain, CAT, and perceived social support from spouses and significant others (Buenaver et al., 2007). In this study, CAT showed a significant positive relationship with perceived solicitous responses from the social

environment (e.g., how much significant others offered help when the patient was in pain) in long-term chronic pain patients with an average of 4.8 years of clinical pain. This relationship was moderated by pain duration; specifically, the association between CAT and perceived solicitous responses was weaker for people with longer pain durations. In addition, CAT was positively associated with depression and pain interference (e.g., lower daily activity), and each of these relationships was partially mediated by perceived punishing responses from the social environment – for example, a significant other becoming irritated when the partner is in pain.

The mixed outcomes associated with CAT serve as a reminder that evaluation of coping efficacy as adaptive or maladaptive is complex and depends substantially on the outcome of interest. To illustrate this point, Sullivan and colleagues (2001) provide the example of an individual attempting to continue with daily activities and chores despite experiencing clinical pain; the individual's behavior can be considered adaptive in the sense that pain-related disability was decreased but maladaptive in the sense that pain was not reduced. In a detailed analysis of coping strategies predicting future disability in arthritis patients, Smith and colleagues (Smith, Wallston, Dwyer, & Dowdy, 1997) note that "active coping" may not be universally superior to other forms of coping. For example, increasing activity at an inappropriate time can cause injury and worsen existing symptoms in people with arthritis. Similarly, Turk and Okifuji (2002) suggest that adjustment to chronic pain can be hampered by using strategies that are more appropriate for coping with acute pain from an injury, such as activity avoidance. Thus, whether a coping strategy like increasing activity or using relaxation improves or hinders adjustment depends on the outcome of interest.

In summary, the CCM suggests that when individuals catastrophize, their intentions might not be pain reduction *per se*, but a more general gathering of resources for dealing with the pain, including support from the social environment. CAT is positively reinforced in this model because the amplification of negative pain experiences by CAT is outweighed by benefits drawn from the social environment. Although empirical support for the model has been mixed, the model underscores the importance of considering the impact of CAT in a broader context.

Demographic Factors and CAT

Individual differences in pain and CAT are not explained solely by psychological variables; demographic factors are also associated with difference in pain experiences. Broadly speaking, women, racial and ethnic minorities, and older people appear to face greater risks for chronic pain (Green, Ndao-Brumblay, Nagrant, Baker,& Rothman, 2004). Interestingly, some research has suggested that levels of CAT also differ across these groups (e.g., Campbell, Edwards, & Fillingim, 2005). Examining how these demographic variables relate to pain experiences can help to elucidate the causal factors that bring about more general individual differences in pain and to determine whether treatment efficacy will be similar across demographic groups (Fillingim, 2000).

Regarding gender, women tend to show higher prevalence rates of clinical pain syndromes (Edwards et al., 2004; Fillingim, 2000), though there may be exceptions (e.g., cancer pain; see Vallerand & Polomano, 2000), In addition, women tend to have more recurring pain experiences more often than men, including pain from menstruation, pregnancy or childbirth (Unruh, 1996). In experimental pain tasks, women also tend to show lower pain thresholds and report higher pain intensity than men (Berkley, 1997;

Vallerand & Polomano, 2000). The effect sizes for these gender differences in pain threshold and tolerance tend to range from moderate to large (Riley, Robinson, Wise, Myers, & Fillingim, 1998).

Although many potential physiological and psychosocial explanations have been advanced for these gender differences (Unruh, 1996; Levine & De Simone, 1991; Riley et al., 1998), cognitive and affective factors appear to play an especially important role (e.g., Fillingim, 2000). Women specifically tend to show higher levels of CAT than men on the Pain Catastrophizing Scale (PCS; Sullivan et al., 1995), a self-report questionnaire assessing rumination about, magnification of and helplessness toward pain. Interestingly, two separate groups examining gender, CAT and pain have found that when CAT is controlled for, gender no longer has a unique effect on pain responses; this finding suggests that CAT could mediate the effect of gender on pain report (Edwards et al., 2004; Sullivan et al., 2000).

Pain and CAT also appear to differ by race and ethnicity. Research in this area has generally focused on comparisons between African American and Caucasian American populations, unfortunately leaving much unknown about pain coping in other racial and ethnic groups. African Americans tend to report more pain than Caucasian Americans both in clinical settings and in response to the same laboratory pain stimulus (Edwards, Fillingim, & Keefe, 2001). Experimental pain threshold does not appear to differ between samples of healthy African Americans and Caucasian Americans, although the former also showed some lower pain tolerances depending on pain modality (Campbell et al., 2005).

Interestingly, African Americans may catastrophize more than Caucasian Americans as well; a clinical pain study among individuals who had received worker's compensation for low back pain found small to moderate effect sizes for race/ethnicity on both the total score and subscores of the PCS (Chibnall & Tait, 2005). This difference in CAT appears to be one of very few differences in pain coping between African Americans and Caucasians (e.g., Tan et al., 2005). A study of patients with rheumatoid arthritis suggested that Caucasian Americans tended to try to ignore pain more, whereas African Americans tended towards more frequent use of praying/hoping and diverting attention (Jordan, Lumley, & Leisen, 1998).

Whether age predicts differences in CAT is less clear. Experimental pain studies often are conducted among younger individuals (e.g., college undergraduates), whereas clinical pain patients tend to be older (e.g., Green et al., 2004). Patterns of CAT may change in concert with cognitive development; adolescents report both using cognitive coping strategies more often than children, including CAT and positive self-statements, and having a greater sense of control over pain (Lynch, Kashikar-Zuck, Goldschneider, & Jones, 2007). In a study of an adapted version of the PCS for children, scores on Helplessness and Magnification were significantly negatively correlated with age (Crombez et al., 2003). Still, CAT clearly does not disappear during adolescence; over 50% of pain-free older adolescents who reported on how they would cope in hypothetical painful situations were characterized as "catastrophizers" as opposed to "copers" (Brown, O'Keeffe, Sanders, & Baker, 1986).

Regarding pain patients, findings on the relationship between age and CAT have been mixed. Some studies suggest that adult pain patients show no age differences in coping

strategies used, including CAT (e.g., Keefe & Williams, 1990). In contrast, other suggest that younger adults show the highest levels of CAT and report the highest perceived pain, including both individuals with clinical pain (Burckhardt et al., 2001, Severejins et al., 2001) and healthy individuals undergoing dental hygiene procedures (Sullivan & Neish, 1998). As people grow older, they may develop and use more strategies for coping with pain, view their pain as less threatening or novel, or simply express distress about pain less (Sullivan & Neish, 1998). Taken together, it appears that younger adults are the most likely age group to show high levels of CAT.

Psychological Interventions for Pain and CAT

The relationships between pain and psychosocial variables such as CAT carry both positive and negative implications for health and adjustment. Stress, emotional distress, and other psychological factors have been acknowledged as important predictors of adjustment to fibromyalgia (Burckhardt, Clark, & Bennett, 2001), rheumatoid arthritis (Parker, Smarr, Buckelew, Stucky-Ropp, Hewett, Johnson, et al., 1995), temporomandibular disorders (TMD; Rudy, Turk, Kubinski, & Zaki, 1995), and sickle cell disease (SCD; Gil, Carson, Porter, Scipio, Bediako, & Orringer, 2004). Poorer adjustment to pain can entail time missed from work or school, increased health care contacts and costs, loss of activity, or an increase in disability and pain resulting from injury (e.g., Gil et al., 2004; Burton et al., 1995). However, when individuals are more adept at psychological and behavioral coping strategies and better able to avoid negative thinking or coping, they tend to avert these outcomes more often and either maintain or recover their typical level of psychological and behavioral functioning (e.g., Linton et al., 2000).

Cognitive and behavioral interventions in particular utilize the relationships between pain and psychosocial variables to help patients to reduce their pain and improve their adjustment, either as stand-alone treatments or as adjuncts to medical treatment. For example, adults and children with sickle cell disease who were randomly assigned to receive 3 45-min training sessions in cognitive coping strategies not only showed higher pain thresholds on experimental pain tasks, but also showed better adjustment to SCD than controls in the form of lower interference with household activities, fewer school absences, and fewer health care contacts, among other measures (Gil et al., 1996; Gil et al., 2001). Similarly, an early intervention for individuals at high risk for developing chronic low back pain revealed significant benefits over standard care at 1-year follow-up (Whitfill, Haggard, Bierner, Pransky, Hassett, & Gatchel, 2010). The early intervention consisted of 6-9 sessions of physical therapy for acute low back pain combined with 6-9 "behavioral medicine sessions" consisting of training in coping strategies and stress management. In addition to reporting less pain and disability, participants randomized to receive an early intervention also were more likely to have returned to work at 1-year follow-up. A 12-session coping skills training for individuals with osteoarthritis in the knee and their spouses showed similar benefits to psychological adjustment including self-efficacy for managing arthritis pain, as well as to the recovery of physical strength in the joint (Keefe, Blumenthal, Baucom, Affleck, Waugh, Caldwell, et al., 2004).

Interestingly, a few interventions specifically examined the impact of reducing CAT on how well individuals manage pain. One group of investigators (Smeets, Vlaeyen, Kester, & Knottnerus, 2006) assessed the benefits of physical therapy, cognitive-behavioral therapy (up to 20 sessions with a focus on problem-solving training), and the

combination of the two versus no treatment in individuals with chronic low back pain. The group observed that reductions in CAT mediated treatment gains from physical therapy and significantly altered the regression coefficients of other predictors of the pain. Thorn (2002) developed a cognitive treatment for chronic headache pain with the explicit goal of reducing catastrophizing through examination of automatic thoughts, cognitive restructuring, planfulness and positive-self statements, among other techniques. A randomized controlled trial examining this type of treatment revealed that individuals with chronic headache experienced significantly greater reductions in CAT and anxiety than waitlist controls, and approximately half of these participants experienced at least a modest reduction (25-49%) in headache frequency (Thorn, Pence, Ward, Kilgo, Clements, Cross, et al., 2007). These studies each demonstrate that, in addition to other benefits of cognitive-behavioral treatment, a change specifically in CAT can have a positive impact on clinical pain outcomes.

In addition to these longer-term, multiple-session interventions, one-time psychological interventions have shown utility in improving pain outcomes on experimental pain tasks. Many of these interventions have involved either instruction in specific behavioral skills to practice during pain or an induction of a different mood state. For example, one group conducted a laboratory test of change in the nociceptive flexion reflex (NFR) threshold, a marker of descending nociception, among individuals with osteoarthritis of the knee (Emery, Keefe, France, Affleck, Waters, Fondow, et al., 2006). Individuals who participated underwent a 45-minute intervention involving training in progressive muscle relaxation and diaphragmatic breathing between two trials of electric stimulation to the knee; both men and women showed increased thresholds for the NFR.

Among healthy individuals, another group developed a 16-minute intervention to induce a state of hopefulness and to promote the use of goal-oriented thinking and strategies in participants undergoing a cold pressor task (Berg, Snyder and Hamilton, 2008). These investigators observed that after receiving the intervention, participants tolerated the painful stimulus for a longer duration despite experiencing no difference in the subjective intensity of the pain. Unfortunately, although each group detected changes that suggest an improvement in pain tolerance or threshold, control group comparisons were not made; thus, one cannot determine the efficacy of these specific interventions versus no intervention.

Intriguingly, individuals who underwent a positive mood induction for only 3-5 minutes showed reduced post-test pain and anxiety on a finger pressure pain task (Bruehl, Carlson, & McCubbin, 1993). Participants receiving this positive mood intervention outperformed those who were instructed to use whatever coping strategies they chose to minimize discomfort during this task or given a brief training in deep breathing for relaxation. The authors suggests that training and practice in the use of a specific technique during experimental pain yielded better results for participants. Similar increases in pain tolerance were found in another study for a positive mood induction that took place over the course of about 15 minutes between cold pressor trials (Zelman, Howland, Nichols, & Cleeland, 1991); this group also found that inducing a depressive mood reduced participants' pain tolerance. In sum, previous research suggests that psychological interventions for pain, even those that are very brief, can have a considerable impact on individuals' perception of and ability to cope with and tolerate pain.

Assessment of CAT by Questionnaire

CAT is typically assessed by questionnaire. The two most prominent measures of CAT currently are the PCS and a subscale of the Coping Strategies Questionnaire (CSQ; Rosenstiel & Keefe, 1983), a 50-item questionnaire which asks individuals to self-report how often they use a variety of coping strategies, including CAT. These two measures have different benefits and limitations; for example, the full CSQ allows one to compare the frequency of CAT directly with other coping strategies, many of which are associated with better pain outcomes. However, the CAT subscale of the CSQ (CSQ-CAT) shows significant overlap with other psychological constructs such as negative affect, helplessness, and perceived coping efficacy (Geisser, Robinson, & Henson, 1994; Hirsh, George, Riley, & Robinson, 2007). The PCS asks respondents solely about CAT and thus is narrower in scope, but it assesses the multiple dimensions of CAT more thoroughly than the CSQ-CAT and relates more directly to the theory behind CAT.

Both of these questionnaires ask respondents to describe how they typically react or feel in painful situations, retrospectively and prospectively. This approach presupposes that an individuals' level of CAT is similar across situations and over long periods of time, like a trait. Although CAT levels appear to have substantial test-retest reliability over the course of weeks or months (e.g., Sullivan et al., 1995; Sullivan et al., 2001), measurements using this timeframe may not be sensitive enough to individuals' CAT in response to specific events and therefore offer little information on which situations they appraise as threatening. For example, CAT measured by questionnaire could not explain pregnant women's decisions to take or refuse epidural analgesia because CAT was correlated with both fear of labor pain and fear of pain from the insertion of the needle

for the epidural (Van den Bussche, Crombez, Eccleston, & Sullivan, 2007). Thus, knowing which threat elicits CAT would improve the capacity of CAT to predict pain behavior and medication use. Additionally, recent research suggests that CAT can be modulated to some extent through experimental cues. For example, participants in experimental pain studies have been induced to catastrophize through seeing a video of a person displaying behavioral cues of intense pain while undergoing a task the participant will soon undergo, suggestions to think a CAT or non-catastrophic thought, or direct presentation of a stimulus as a threat through instructions about the task (Bialosky, Hirsh, Robinson, & George, 2008; Severejins, van den Hout, & Vlaeyen, 2005).

These findings challenge the notion that CAT is consistent across time and situations and suggest that a different framework for measuring CAT is in order. The ecological momentary assessment (EMA; Stone & Shiffman, 1994) research framework offers ideas on how to gather data regarding how a person is responding to a specific event, such as painful stimulation, at a particular moment in time. EMA research relies upon frequent assessment of the construct of interest, often during a critical moment when some cognition or stimulus is present. Examples include daily diaries (e.g., Gil et al., 2001), minute-by-minute assessment of sleep patterns through actigraphy (e.g., Ancoli-Israel, Cole, Alessi, Chambers, Moorcroft, & Pollak, 2003) and collections of salivary cortisol initiated several times daily by an electronic watch (e.g., Smyth, Ockenfels, Porter, Kirschbaum, Hellhammer, & Stone, 1998). Methods like EMA in which a psychological construct is assessed in the moment tend to reduce the possibility of biased or incomplete recall of one's experiences and allow for increased confidence that self-report data are accurate compared to retrospective self-report (Schwartz & Stone, 1998; Stone &

Shiffman, 1994). EMA studies are already yielding new information about pain coping that more general pretest-posttest measures of coping does not (e.g., Gil et al., 2001).

Timing of CAT Measurement

Recently, both time of measurement and reference to a particular event have been taken into account in CAT research. Edwards, Campbell and Fillingim (2005) referred to CAT measured during pain as "*in vivo* catastrophizing"; they examined *in vivo* CAT by asking participants to rate their CAT on items derived from the PCS during a cold pressor task. Interestingly, only *in vivo* ratings predicted cold pressor tolerance; the correlation between *in vivo* ratings and pretest PCS ratings was .46. This group reported similar findings using the CSQ-CAT; ratings on a single item created by the experimenters that was rated during pain predicted cold pressor tolerance, whereas pretest CSQ-CAT scores, as well as a specific item from the CSQ-CAT that resembled the *in vivo* item, only weakly correlated with pain tolerance. A follow-up study (Campbell, Kronfli, Buenaver, Smith, Berna, Haythornthwaite, et al., 2010) of individuals with TMD or arthritis indicated that a "situational" PCS, that is, one that is administered immediately after a specific painful event and asks for catastrophizing ratings relative to that event, was superior to a "dispositional" PCS (a nonspecific retrospective self-report) in predicting not only for cold pressor but also for thermal pain.

Another research group (Hirsh, George, Bialosky, & Robinson, 2008) has assessed *in vivo* CAT by altering instructions on existing measures, but their findings have been less encouraging. They administered the PCS, CSQ-CAT and Fear of Pain Questionnaire (FPQ-III) to undergraduate participants prior to a cold pressor task, then presented the PCS and CSQ-CAT when the task was complete with instructions to rate their CAT

relative to that task. Pain threshold, tolerance time and reported pain intensity from the task were also measured. After conducting several hierarchical linear regression analyses entering gender first and a block with the FPQ-III and CAT measure questionnaires second, the authors concluded that CAT did not significantly predict pain, whereas high scores on the (FPQ-III) did predict higher pain.

Why is it that both of these groups found that using the PCS or CSQ as a posttest measure of CAT does not improve measurement of CAT from pretest, even when instructions are given to rate CAT relative to a very recent pain experience? In the Hirsh et al. (2008) study, participants completed both versions of the CAT questionnaires very close together in time – the cold pressor task was limited to a maximum of three minutes with questionnaires immediately given thereafter. These authors do not mention how instructions for the posttest measures were given, nor do they include a manipulation check demonstrating that the alternative instructions were noticed and comprehended. Thus, participants may have assumed reasonably that the CAT measures were identical at both time points and at some level attempted to maintain consistency in their responses across the two measurement points. The adapted questionnaires used at posttest may really relate to "*post vivo*" catastrophizing. In contrast, the *in vivo* ratings made during experimental pain in Edwards et al. (2005) did significantly predict cold pressor tolerance.

Hirsh et al. (2008) suggested that their attempts to measure CAT could have been unsuccessful because cold pressor tasks "may not be sufficiently threatening to elicit psychological reactions, such as catastrophizing, consistent with those associated with clinical pain" (p. 811). However, their methodology leaves the possibility that a sufficient

threat actually is present and measurable, but must be measured during the painful stimulus itself. Thus, it appears that a measure that assesses *in vivo* CAT may have special utility in predicting pain behaviors, and may have similar value in predicting the amount of pain experienced.

Rationale for the Current Study

Among psychological factors, CAT appears to have a substantial and important role in the experience of pain in the moment and the development of chronic pain and disability. Although CAT can be thought of as a communal coping strategy that is beneficial for eliciting short-term care, CAT amplifies pain and suffering and appears to be a maladaptive means of coping with pain. Cognitive and behavioral interventions for chronic pain have demonstrated that psychosocial adjustment can be improved by addressing negative schemas regarding pain coping efficacy and challenging beliefs and patterns of appraisals that overestimate threat from the environment. Thus, an intervention targeted specifically at reducing CAT in response to current pain should be especially helpful towards pain reduction. Experimental pain can serve as a viable proxy for and generalize to clinical pain (Edens & Gil, 1995), and prior research in coping has suggested that training in coping strategies in the context of experimental pain has the potential to offer benefits for coping with clinical pain (e.g., Gil et al., 1996; Berg et al., 2008). Experimental pain paradigms also allow the environment and stimulus producing pain to be identical for each individual; this reduction in variability of pain may allow the efficacy of an intervention to be assessed more easily.

These factors suggest that an intervention targeted at CAT could be developed and tested successfully using experimental pain among healthy volunteers rather than clinical

pain in a patient population. The proposed study aims to create and examine the utility of such an intervention. Recruiting from an undergraduate population offers the benefit of a high baseline level of CAT for healthy volunteers, as studies that have demonstrated age differences in CAT suggest that pain-free young adults catastrophize more than older individuals (Brown et al., 1986; Sullivan & Neish, 1998). Moreover, the most recent research in measurement of CAT (e.g., Edwards et al., 2005) suggests that CAT measured in reference to a specific pain experience, during the experience of pain, offers unique benefits that ordinary questionnaire measures do not. New measures for CAT that adhere to these principles are needed; the proposed study aims to assess the utility of such a new measure.

Specific Aims and Hypotheses

The overarching hypothesis of the current study is that **healthy participants who undergo an intervention that aims specifically to counter catastrophic cognitions, hereafter referred to as the cognitive skills intervention, will experience better pain outcomes on an experimental pain task than either those who undergo a procedure that aims to induce a positive mood state or, as a control, those who undergo a similar procedure planned to have no effect on mood.** Induction of positive mood was selected as an alternative approach to cognitive skills training primarily for two reasons. First, significant debate exists as to whether CAT is distinguishable from other constructs that relate to negative affectivity, such as depression (Sullivan et al., 2001). A direct comparison between two procedures aimed at either reducing CAT through cognitive means or increasing positive mood should shed light on this debate. Second, prior coping research has suggested that, on the whole, active coping attempts (e.g., using distraction or cognitive restructuring strategies, avoiding CAT) tend to improve adjustment to pain, whereas the benefits of passive coping (e.g., hoping, waiting, resting), if any, are less clear (Keefe, Blumenthal, et al., 2004; Keefe, Caldwell, Queen, Gil, Martinez, Crisson, et al., 1987; Gil, Wilson, & Edens, 1997; Smith et al., 1997). The current study design allows for the examination of differences between active coping skills training and a more passive approach to pain coping.

Two pain modalities, pressure and cold pressor, were selected for use in this study for several reasons. First, if the cognitive skills intervention indeed leads to changes in pain

outcomes demonstrating these changes across two pain modalities would improve the generalizability of this finding to other types of pain. Moreover, using distinct pain tasks for testing and training provides confidence that any effects were not due to exposure to the specific pain task alone. This design improves upon prior skills training interventions in which a single type of experimental pain was used for both training and testing (e.g., Gil et al., 1996). Using different pain modalities also allows for greater variation in the intensity of pain stimulation; thus, the efficacy of the coping intervention in relieving CAT and pain can be assessed in the context of both mild to moderate and strong acute pain.

Hypothesis 1: Lower CAT after cognitive skills intervention compared to positive mood induction or neutral mood (control) groups. It is hypothesized that participants who receive an intervention specifically targeted at reducing CAT will experience a reduction in CAT that is superior to that of the groups receiving mood induction procedures. Specifically, individuals in the study who undergo experimental pain tasks, receive a cognitive skills intervention, and then undergo the same pain task again will report lower CAT during this second pain task than participants in the other groups.

Hypothesis 2: Positive association between CAT and pain intensity/unpleasantness; negative association between CAT and pain tolerance. Previous research has indicated consistently that CAT is an important and powerful predictor of pain outcomes. It is hypothesized that participants who catastrophize more, regardless of intervention group, will experience worse pain outcomes on experimental pain tasks, including higher maximum perceived pain intensity and unpleasantness. It is also hypothesized that participants who catastrophize more will tolerate the pain stimulus for less time and

withdraw from or end the pain task sooner. This hypothesis can be tested best before any intervention.

Hypothesis 3: Better pain outcomes in cognitive skills intervention group versus positive and neutral mood groups. It is hypothesized that participants in the cognitive skills intervention group will show better pain outcomes than both individuals who receive a positive mood induction and individuals who undergo a similar procedure intended to have no effect on mood (neutral mood group). Specifically, the cognitive skills intervention group will show significantly better pain tolerance (i.e., longer times before withdrawal from a painful stimulus), report overall lower pain ratings (both maximum pain intensity and maximum pain unpleasantness) than the positive and neutral mood groups, and report lower unpleasantness than the neutral mood group. Given that previous research has suggested that mood induction may affect pain unpleasantness more than pain intensity (Loggia, Mogil, & Bushnell, 2008), it is unclear whether unpleasantness should be expected to differ between the cognitive skills intervention group and positive mood group.

Additional aims: Evaluation of validity and utility of the new in-the-moment CAT measurement instrument. In addition to testing the specific study hypotheses, the current study aims to assess the predictive utility of a new instrument for measuring in-the-moment CAT, the catastrophizing visual analog scale (CAT-VAS). It is hypothesized that the CAT-VAS will serve as a better predictor of pain outcomes than existing measures of CAT. Specifically, CAT-VAS scores should still account for a significant portion of the variance in pain outcomes when PCS and CSQ-CAT scores have been included as covariates in analyses predicting pain outcomes.

Statistical analyses were also conducted to examine the reliability of the new instrument as well as its convergent and divergent validity. With regard to convergent validity, it is hypothesized that the new CAT-VAS will show a significant positive association with scores on the PCS and CSQ-CAT. Determining that the CAT-VAS offers unique information about pain variables above and beyond mood is a more complex question, as CAT has tended to correlate with mood variables such as depression and negative affect (Hirsh, George, Riley, & Robinson, 2007; Sullivan et al., 2001). However, it is hypothesized that, when participant scores on measures of mood and depression are added as predictors into models that include CAT-VAS scores as predictors of pain responses, CAT-VAS scores will still account for a significant portion of the variance in the pain outcomes.

Method

Participants and Setting

A total of 117 individuals were recruited to participate in this study. Participants were undergraduate students, ages 18 and older, taking an introductory psychology course at the University of North Carolina at Chapel Hill (UNC). For compensation, participants received two credit hours towards completing a six-hour course requirement for experimental participation. Participants were excluded from participation if they: (1) were under 18 years old, (2) had chronic pain or current major pain; (3) had a condition for which exposure to cold pressor pain is counterindicated, such as sickle cell disease, previous frostbite or Reynaud's disease; (4) were currently taking pain medication, or (5) had undergone the cold pressor task in the past, as undergraduate participants who are having their first exposure to the experimental cold pressor task show higher levels of CAT than other groups, including patients preparing for painful medical procedures (Sullivan et al., 1995). Exclusion criteria were described in an informed consent document and evaluated by means of a questionnaire with open-ended response items (e.g., "Are you in pain today?" and "Have you ever been in a study in which you were exposed to cold temperatures?"; see Appendix 1). The questionnaire was checked by the experimenter before the participant was allowed to undergo the procedures of the experiment; any responses that indicated that the participant might not meet criteria to enter the study were followed up with open-ended questioning.

Of the 117 participants who completed the first visit, 111 individuals completed all of the procedures of the study. Of the 111 study completers, 64 identified as female (55%). Seventy-seven of the participants identified racially as White (66%), whereas 20 identified as Black or African American (17%), 8 as Asian (7%), and 2 as American Indian/Alaskan Native (2%); 10 identified as another race or multiracial (9%). In terms of ethnicity, 10 of the participants also identified as Hispanic or Latino/a (9%). The mean age of participants was 20.3 (s = 4.3; minimum 18; maximum 50; 2 participants over 30 years old, 7 participants over 22 years old). Only four of the 111 participants reported being in any pain when they first enrolled in the study, and each of these participants indicated that they were free of pain before undergoing any experimental pain tasks in their subsequent visit.

Experimenters and Experimenter Training

Experimental procedures were conducted by a total of 10 undergraduate research assistants (RAs; 7 female, 3 male) between Fall 2009 and Fall 2010 inclusive. RAs were blind to the specific study hypotheses; they were informed that the cognitive skills training group and other two groups were each equally likely to show some benefit to participants in managing pain (i.e., change through mood change for the video clips versus explicit skills practice in the cognitive skills training group).

RAs were trained in groups of 2 or more whenever possible to allow each RA to both observe the procedures and experience them as a participant would. First, the principal investigator (PI) demonstrated the experiment from start to finish following the scripts, leaving ample time for questions and repetition of the demonstrations. Second, after RAs studied the scripts, they participated in no fewer than 4 practice sessions with the PI or

another RA playing the role of a participant. Practice sessions started with frequent pauses as needed to ask the PI questions or to review any steps in the experimental procedures that were missed or contained errors. In later practice sessions, experimenters were allowed to work through all of the procedures without being interrupted and received feedback about their execution of the experiment only after all procedures were complete. During these later sessions, the PI or RA who served as the participant asked the experimenter questions and made comments to ensure that experimenters had sufficient practice in responding to questions and reorienting themselves to the experiment.

RAs were not permitted to conduct the experiment with genuine participants until they had executed each section of the protocol twice in a row without any substantive errors (e.g., omitting a pain task or failing to ask for a pain rating). To ensure that the experiment continued to be properly executed, experimental visits were audiotaped for participants who had consented to taping. The PI reviewed audiotapes of the first five experimental visits conducted by each RA in their entirety, as well as a randomly selected 20% of other sessions. After review, the PI discussed tapes with RAs in groups on a biweekly basis to reinforce proper execution of the procedures and to address any concerns (e.g., potential responses to participants' behaviors or questions).

In each visit involving pain tasks, two RAs were present. Just before the participant arrived for the experimental visit, one of the research assistants ("the tester") was randomly assigned to do all of the pain testing procedures, whereas the other RA ("the trainer") completed all of the other tasks, including administering interventions. The PI

acted as the tester for 3 of the 111 experimental visits due to schedule conflicts between research assistants and participants.

General Procedures

A visual outline of the general procedures of the study, including their sequence in the experiment, is provided in Figure 1. The experimental protocol for this study was approved by the UNC Behavioral Institutional Review Board (IRB). The consent form stated that the study aims were to examine the relationship between thoughts, emotions, and sensations. Participants were informed that although procedures may cause pain or discomfort, the potential for injury was minimal to none, and were told that they could stop any of the procedures or leave the study at any time without penalty.

Interested individuals from the undergraduate Psychology Participant Pool signed up for a visit time posted on UNC's Human Participation in Research (HPR) website. Upon arriving for the first of two visits, participants were provided with the consent form and given an opportunity to have any questions about the procedures answered before agreeing to participate; all individuals who appeared for their scheduled time agreed to participate. During the rest of this visit, hereafter referred to as the *pre-experimental visit*, participants completed several questionnaires over the course of 20-30 minutes. At the end of the visit, eligible participants signed-up for the 90-minute *experimental visit*, the second and final session scheduled within 14 days of the first visit. All experimental visits took place in the same dedicated office space in the psychology building at UNC.

Pre-Experimental Visit

CAT and coping strategies. Participants' typical level of CAT was assessed at baseline with both the PCS and the CSQ. The full CSQ was administered, rather than a

revised version or the CSQ-CAT only, both to ensure the validity of the CAT subscale and to collect data on other variables related to coping that might explain differences in pain response (e.g., coping efficacy).

The PCS is a 13-item retrospective self-report questionnaire that aims to assess the intensity and frequency of catastrophic thoughts relative to pain. Respondents are asked to rate how much they would usually have each thought while experiencing pain on a Likert-like scale ranging from 0 (not at all) to 4 (all the time). The PCS consists of three subscales—helplessness, rumination, and magnification of pain—that have been supported in a factor analysis as highly-related second-order factors related to the first-order factor of CAT, represented by the total score (Sullivan et al., 1995). The PCS has shown good internal consistency on the entire instrument (Cronbach's alphas = .87-.95) and adequate to good internal consistency on its component factors (Cronbach's alphas = .60-.95) in both its initial validation among college undergraduates (Sullivan et al., 1995) and in replications in clinical and nonclinical samples (d'Eon et al., 2004; Osman et al., 2000).

The CSQ is a 50-item self-report questionnaire that asks respondents to report how often they use various coping strategies in response to pain. The CSQ consists of eight subscales of six items each, relating to cognitive and behavioral coping strategies directed at pain; the strategies assessed are CAT, diverting attention, reinterpreting pain sensations (e.g., "I just think of it as some other sensation, such as numbness"), using coping self-statements (e.g., "I tell myself to be brave and carry on despite the pain"), ignoring pain sensations, praying/hoping, increasing activity, and increasing pain behavior (e.g., taking medication). Two additional items assess perceived ability to control and decrease pain.

The subscales represent the use of CSQ items use a 7-point Likert scale (0 = never/no control/cannot decrease at all, 3 = sometimes/some control/can decrease it somewhat, 6 = always/complete control/can decrease it completely). The CAT subscale of the CSQ has shown good internal consistency in its initial validation among low back pain patients (Cronbach's alpha = .78; Rosenstiel & Keefe, 1983) as well as in a sample of 965 chronic pain patients (Cronbach's alpha = .84; Robinson, Riley, Myers, Sadler, Kvall, Geisser, et al., 1997).

The PCS was administered both at the pre-experimental visit and at the experimental visit after all pain tasks were completed. Some evidence suggests that PCS ratings may explain more variance in pain response when they are made in response to a recent or specific painful stimulus, even when specific instructions to rate with that pain in mind are not given (Edwards et al., 2005). Participants were instructed simply to complete the questionnaire and were not asked to modify the instructions for this second administration. A minority of participants asked whether they should "think about what just happened" (i.e., the experimental pain in this study) when completing the PCS after the pain tasks were over; RAs were instructed to tell participants simply to read the original instructions and do the best they could to follow them, to minimize systematic differences in test-taking approach.

Mood. Participants' general mood states were assessed at the first visit using the Positive and Negative Affect Scales (PANAS; Egloff, 1998; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item questionnaire that assesses positive and negative affect independently (10 items each). Respondents report to what extent they have experienced positive (e.g., enthusiastic, proud, inspired) and negative (e.g., distressed, nervous,

irritable) feelings on a 5-point Likert scale ranging from "very slightly or not at all" to "extremely". The PANAS has shown adequate to good internal consistency for both positive affect (Cronbach's alphas = .86-.90) and negative affect (Cronbach's alphas = .84-.87) over multiple time periods of reference, ranging from "right now" to over the past year. For the current study, to provide contrast with the in-the-moment mood measure that was used during the experimental visit, the period of reference was the past week.

Depressive symptoms. The presence and severity of depressive symptoms were assessed at the first visit using the Center for Epidemiological Studies-Depression Scale (CES-D; Radloff, 1977). The CES-D consists of 20 items that assess the frequency of depressive symptoms over the last week, with response ratings ranging from 0 (rarely or none of the time) to 3 (most or all of the time); total scores range from 0 to 60. The CES-D was designed to assess depressive symptoms in the general population and has been widely used in research on pain (e.g., Carroll et al., 2004; Tan et al, 2005). The CES-D is widely used and has good reliability and convergent validity (Radloff, 1991; Tan et al., 2005) and discriminability in undergraduate populations (Santor, Zuroff, Ramsay, Cervantes, & Palacios, 1995).

Experimental Visit

A general description of the experimental visit is provided here; each procedure of the visit is outlined individually later in this section. First, the trainer led participants through a structured interview, during which they were introduced to the concept of CAT, asked to identify CAT thoughts that they themselves have during pain, asked to identify three

mood words from the PANAS that typify their everyday mood, and asked to rate their current level of positive and negative mood.

Second, the trainer the trainer switched places with the tester, who led participants through two pressure pain tasks, one each on their nondominant index and middle fingers. During these and all other pain tasks, participants rated their level of CAT at 30-second intervals. After the pressure tasks, participants completed another mood rating scale and underwent their first cold pressor task. Two mood ratings were collected just before cold pressor tasks, both to assess for the impact of current affective state on pain ratings and as a manipulation check for the impact of interventions on mood.

Third, participants underwent one of three procedures with the first experimenter; receiving a cognitive skills intervention, watching a movie clip intended to increase positive mood (positive mood group), or watching a clip intended to have no impact on mood (neutral mood group). In the post-intervention period, all participants underwent a third pressure pain task, a third mood rating scale, and a second cold pressor task.

Fourth, participants completed a fourth mood rating scale, second PCS, and a survey on the experiment to be used as a manipulation check and treatment credibility check. Finally, participants were debriefed on the study aims, given credit for participating and thanked for their time.

Education on identifying CAT and using rating scale. During the experimental visit, the trainer conducted a semi-structured interview with the participant introducing the topic of catastrophizing. The trainer first handed the participant the PCS they completed at the pre-experimental visit (without examining it) and asked which of the thoughts on the PCS occur most frequently for the participant when he or she is in pain (i.e., which

were rated the highest). Participants who did not disclose at least three CAT cognitions were encouraged to think of any other cognitions not on the PCS that they still experience as catastrophizing. The trainer then instructed the participant to write these thoughts on a provided blank sheet of paper, informed the participant that these cognitions were of particular interest for the study and ask the participant to consider primarily the specific cognitions they discussed in the interview when making ratings on catastrophizing during the experiment.

Mood word identification. For this step, participants were asked by the trainer to identify three emotion words, either from the PANAS or from their own vocabulary if necessary, that describe how they tend to feel in their general, everyday lives. This process was intended to resemble closely the process of CAT thought identification that had just been completed. Participants wrote these emotion words on the same piece of paper as the CAT thoughts they generated from the PCS. Because participants were randomly assigned to an intervention after this exercise took place, the trainer conducted this emotion word generation exercise blind to the intervention the participant would be receiving. All participants selected three words from the PANAS without assistance.

Current mood state VAS. Participants were asked to rate their current mood state on a set of two horizontal 100mm lines, anchored at 0mm (Not Positive/Negative At All) and 100mm (Entirely Positive/Negative). Research has generally supported the viability of a mood VAS as a short, reliable measure that shows adequate concurrent validity with other mood scales in both depressed and non-depressed individuals (Ahearn, 1997; Larsen & Fredrickson, 1999). Negative and positive mood were measured each on a separate VAS from zero to maximum for several reasons. First, theories of mood describe

positive and negative mood as largely independent (e.g., Watson, Clark, & Tellegen, 1988). Second, participants are more frequently confused by a VAS with opposite anchors and a "neutral" point in the center than a VAS with anchors representing zero to maximum (Ahearn, 1997). Additionally, the first mood VAS allowed participants to practice using a VAS before using the CAT-VAS.

Mood VAS ratings were collected a total of four times. The first mood VAS was given prior to any pain testing, as described above, which served both as a baseline measure of mood for the experimental visit and a practice for making VAS line ratings prior to rating CAT during pain. The second was given immediately before the pre-intervention cold pressor task and the third immediately before the post-intervention cold pressor task, to serve as a manipulation check for the positive mood induction (no other procedure was expected to increase positive mood). The fourth was given immediately after the final cold pressor task to assess change in mood in response to the task.

Catastrophizing Visual Analog Scale (CAT-VAS): This new measure, designed to assess present-moment pain catastrophizing, was created with the benefits of ecological momentary assessment (EMA) data collection in mind (e.g., Stone & Shiffman, 1994). This measure was used for all experimental pain tasks. The CAT-VAS consists of a series of 7 100mm horizontal VAS lines arranged vertically on a sheet of paper with a set of brief instructions on how to rate one's current catastrophizing level using the VAS line. VAS lines are anchored at the left (minimum) and right (maximum) with the words "No catastrophizing" and "Catastrophizing as much as possible," respectively. The first 21 participants were randomly assigned to this version of the CAT-VAS or to versions with alternative anchor sets ("No catastrophizing" and "Severe catastrophizing"; "No

catastrophizing" and "Catastrophizing all the time") to determine whether the anchors created ceiling/floor effects in ratings. Pilot testing revealed no significant differences in ratings across groups by anchor set; the CAT-VAS anchors retained for the remaining participants ("No catastrophizing" and "Catastrophizing as much as possible") were the ones that the fewest participants reported difficulty understanding or using. These anchors were intended to capture the frequency of catastrophic thoughts as well as their intensity or urgency. This approach is similar to the choice of rating anchors by Sullivan, Bishop and Pivik (1995) for the PCS as well as in more recent studies of brief catastrophizing measures, such as daily diary studies (e.g., Keefe, Affleck, et al., 2004).

To use the scale during the pain tasks, participants made a mark on a VAS line sequentially every 30 seconds, starting at 0 seconds and ending at 180 seconds, for a total of 7 ratings. During the instructions for the pain tasks, participants were informed that they should consider the statements from the PCS that they had identified as their most common CAT thoughts when making ratings. The tester, who had a stopwatch, prompted participants to rate their level of CAT by saying "NOW" at the appropriate 30-second intervals during the task. This time interval between ratings is similar to, or larger than, intervals used in other experimental pain studies (e.g., Edwards, Smith, Stonerock, & Haythornthwaite, 2006). Continuous VAS ratings of CAT by electronic or mechanical means (e.g., Meagher et al., 2001) were considered for this measure, but even though such a method could provide more nuanced data, it was considered too likely that this form of rating would present a strong distraction from the experimental pain stimulation. The issue of ratings as a distractor will be revisited in a later section.

If a pain task ended early (e.g., due to participants withdrawing their hands from the pain testing apparatus or saying "STOP"), the tester prompted the participant to mark the next VAS line with their catastrophizing level (i.e., the tester said "NOW" again). Experimenters were instructed not to examine the ratings given by the participant to ensure that knowing the participant's level of catastrophizing would not bias their behavior as they conduct the experiment. Instead, the experimenter marked on a separate worksheet the time the task ended and how it ended (e.g., "100 seconds, said 'stop'").

Pressure pain tasks. The first two pain tasks used experimental pressure pain aimed to produce a pain sensation of moderate intensity. The goals of the first pressure tasks were to establish familiarity with the CAT-VAS and with the rating procedures of the study for the participant, to establish a baseline measure of pain prior to the other experimental pain task, to provide a modality and intensity of experimental pain that allows for sufficient variation in subjective pain intensity and unpleasantness for statistical analysis, and to provide data for examination of order effects.

A full description of pain testing procedures is available in Appendix 2. Pressure pain tasks were conducted by applying pressure to the index and middle fingers alternately using a modified strain gauge apparatus as described by Forgione and Barber (1971). The modified Forgione-Barber device has been used in prior research with both clinical pain patients and healthy controls (e.g., Gil et al., 1996; Tsao, Myers, Craske, Bursch, Kim, & Zeltzer, 2004) and has been supported as a valid means of inducing a consistent amount of noxious stimulation without causing tissue damage or confounding pain with other physiological variables, such as changes in vasomotor activity (Forgione & Barber, 1971; Gil & Edens, 1995). Individuals typically report that their pain gradually increases over

time to a dull, aching sensation during stimulation from the Forgione-Barber device (Gil et al., 1996). The amount of pressure (i.e., weight applied to the device) selected during pilot testing and design was intended to induce mild to moderate pain, with an average subjective rating of about 40 on a 0 to 100 scale.

A pain task continued until one of the following occurred: (1) the time elapsed reaches 180 seconds, at which point the tester removed the weight and wedge and prompted the participant for a final CAT-VAS rating; (2) the participant said the word "STOP" aloud or otherwise told the tester explicitly to stop, at which point the tester stopped the task as above; or (3) the participant removes his or her finger. Participants were instructed prior to the first pain task that they are free to stop the pain task at any time by saying "STOP" aloud. The tester, who used a stopwatch, noted the time elapsed for the task in any of these cases and the way in which the task ended.

When the pain task ended, participants were prompted to state aloud a numerical rating of both the maximum intensity and maximum unpleasantness of the painful stimulation, from 0 (no pain/no unpleasantness) to 100 (pain as intense/unpleasant as I can imagine). Participants were not informed about how long the experiment would last or of the physical characteristics of the experimental stimuli (e.g., amount of weight being applied). Participants who asked during the task were told that they could stop the tasks at any time and asked whether they would be able to wait for this information until the experiment had concluded; no participant raised any concern about this approach.

During the pre-intervention period, participants completed two pressure pain tasks, one each on the index and middle fingers of the nondominant hand, with the order of these randomized across the entire sample, lasting 180 seconds apiece. During the post-

intervention period, an additional pressure task was conducted on the same finger as the first of the pressure tasks. This post-intervention pressure pain task was conducted both to offer an opportunity for participants to practice different coping skills (e.g., skills from the cognitive skills intervention) with a stimulus less intense than cold pressor and to provide data on changes in intensity and unpleasantness ratings.

Cold pressor task. The cold pressor task, in which a participant submerges his or her nondominant hand into a container of cold water, is an experimental pain induction method that causes deep, tonic pain sensations. This task is among the most common experimental pain induction methods and shows excellent reliability and validity (Edens & Gil, 1995; Mitchell, Macdonald, & Brodie, 2004; Walsh, Schoenfeld, Ramamurthy, & Hoffman, 1989) and is considered to be one of the most valid experimental analogues for clinical pain (Mitchell et al., 2004). The cold pressor task as outlined below uses standard procedures that aim both to minimize differences in the stimulus between participants and tasks and to maximize the reliability and validity of the procedure (Eccleston, 1995; Mitchell et al., 2004).

Cold water and ice were used to establish and maintain a temperature between 1 and 2 degrees Celsius before the beginning of a task. This temperature range was selected because it was considered intense enough that a substantial portion of participants would end the task early, giving sufficient variability for analysis of pain tolerance (Walsh et al., 1989). Prior to each cold pressor task, participants first submerged their nondominant hand for at least 60 seconds into a separate container of water maintained at approximately 20 to 21 degrees Celsius (room temperature; e.g., Severejins et al., 2005; Sullivan et al., 1995).

Aside from the pain stimulus employed, the procedures for cold pressor tasks were identical to those of the pressure task; participants made CAT-VAS ratings every 30 seconds, indicated if they wished to stop by removing the hand or saying "STOP," and rated their maximum perceived pain intensity and unpleasantness verbally on a 0 to 100 scale. Participants completed the cold pressor task once during the pre-intervention period and once during the post-intervention period to allow for assessment of the effectiveness of the intervention. In each case, any pressure pain tasks preceded a cold pressor task.

CAT induction using cold pressor task instructions. Although *in vivo* CAT has been measured with some success in prior studies (Campbell et al., 2010; Edwards et al., 2005), Hirsh and colleagues (2008) suggested that posttest CAT measures did not significantly predict cold pressor response because the cold pressor stimulus is not a sufficient threat to elicit CAT. Prior studies in the health psychology and pain literatures have indicated that psychological responses to experimental stimuli can be modified as to elicit the levels of the construct necessary for research, including pain response and CAT (e.g., Bialosky et al., 2008; Wilson, Chaplin & Thorn, 1995). If additional manipulation would be necessary to elicit CAT from participants, a combination of a particularly threatening pain task such as cold pressor and a psychological manipulation to increase CAT could accomplish this manipulation.

Thus, during the pilot phase of the study, an effort was made to elevate CAT through pre-test instructions about the task (e.g., Wilson et al., 1995). Participants were instructed (Appendix 3) after the second pain pressure task that the upcoming cold pressor task would be more intense and challenging pain task and that some people find the pain to be

intolerable. This step was taken because inducing some catastrophizing prior to the experimental tasks and intervention was thought to be potentially necessary to avoid floor effects on this key variable, even though young adults may show higher levels of CAT than older adults (Brown et al., 1986; Sullivan et al., 1995).

Intervention period. After this first round of experimental tasks, participants underwent the procedures of the intervention condition to which they were randomized. Randomization occurred while the experimental visit was already taking place; to make sure that the first section of the experimental visit (CAT explanation, mood word generation and mood VAS ratings led by the trainer) did not vary systematically by condition, the trainer randomized the participant to a condition in a separate room while the participant completed the first group of pain tasks. These groups were counterbalanced to include roughly equal numbers of participants. All participants underwent a third pressure pain task approximately 10 minutes after the cold pressor task has ended. In the cognitive skills intervention group, this task served as an opportunity to practice the skills in the context of pain, which has been shown to help participants to use coping strategies more once training is complete (Gil et al., 1996). This interval was selected to allow any residual effects of cold pressor stimulation to subside before the next task (e.g., Mitchell et al., 2004).

Cognitive skills intervention. After the first cold pressor task, participants assigned to this group were given overviews on three cognitive techniques for addressing thoughts related to CAT. Specifically, the trainer went through a semi-structured script (see Appendix 4) discussing how to apply distraction, mindfulness/acceptance strategies, and cognitive restructuring of catastrophic thoughts directly to the experience of acute pain.

For the first two of these strategies, the trainer described examples of each strategy. Potential distractions described included redirecting thoughts toward other activities or away from the current situation as well as diverting attention to physical surroundings or other sensations such as breathing. Mindfulness/acceptance was described as attempting to "just notice" or to "watch" any pain that was occurring, rather than ruminating or evaluating it negatively. For cognitive restructuring, the trainer first described the process of examining a thought and either reframing it in a more positive or realistic light (e.g., "I worry about the pain overwhelming me, but I can stop it at any time and it won't do any damage to my body," "I know I can handle this"). During this part of the intervention, which took about 5 minutes, participants had frequent opportunities to ask questions about the strategies.

After introducing all three coping strategies, the trainer led the participants through the exercise of generating restructured thoughts for the CAT thoughts that they had identified as most common for them during the very first part of the experimental visit. This exercise was modeled after a chapter discussing techniques for modifying automatic thoughts in response to negative situations from a treatment manual for cognitive therapy for chronic pain (Thorn, 2004) and is similar to the introduction of cognitive techniques employed in a study of coping skills training for individuals with SCD (Gil et al., 1996). Participants reviewed each thought individually and were asked to generate an alternate version of the thought that was more realistic or positive. The semi-structured format allowed for the participant to ask clarification questions to the experimenter about the techniques and to determine how to implement the coping strategies in a way that matches his or her individual style. RAs were instructed to do their best to ensure that a

different counterthought was generated for each CAT thought the participant had identified earlier in the visit and to ask the participant to continue trying if they had trouble reframing thoughts in a positive light. For example, if a participant's restructured thought still greatly resembled their CAT thought (e.g., changing "I worry about when the pain will end" to "I think about when this will be over"), RAs prompted participants to continue working on that thought before moving on. Participants who needed assistance to generate these counterthoughts were given a worksheet (Appendix 5) with examples of reframed responses to potential catastrophic thoughts. The CAT thoughts on this worksheet were not identical to items from the PCS to ensure that participants would still need to generate their own counterthoughts.

After the semi-structured discussion of the intervention, participants were presented with the pressure pain stimulus again and instructed to practice the skills during the pain in an attempt to reduce CAT. This intervention period lasted a total of 10 minutes. It should be noted that brief, one-time interventions ranging from 3-5 to 20 minutes have been established as capable of eliciting lower pain report, lower anxiety, and other benefits in both healthy participants (e.g., Bruehl et al., 1993) and people with clinical pain (e.g., Haythornthwaite, Lawrence, & Fauerbach, 2001), and that at least one study has suggested that brief cognitive interventions may predict long-term changes in coping strategy choice (Tsao, Fanurik, & Zeltzer, 2003).

Positive mood induction group. After the first cold pressor task, participants assigned to this group watched a brief humorous video clip designed to increase their positive mood in the moment. The experimenter script for this group and the neutral mood group, discussed later in this section, are available in Appendix 6.

Positive mood induction has been shown to promote increased pain tolerance and reduce perceived pain unpleasantness (Hertel & Hekmat, 1994; Loggia, Mogil, & Bushnell, 2008; Meagher, Arnau, & Rhudy, 2001; Zelman et al., 1991). However, whether these effects persist despite the presence of CAT has not been explored. Showing a film or story is among the most effective means of eliciting positive mood experimentally (Gerrards-Hesse, Spies, & Hesse, 1994; Martin, 1990; Westermann, Spies, Stahl, & Hesse, 1996). Several investigators have reported success using 5-minute clips from comedic material including scenes from movies, outtakes from television shows and standup comedy routines to elicit joy and other positive emotions (e.g., Gross & Levenson, 1995; Johnson & Fredrickson, 2005).

This group watched two of the four "amusement" video clips as described and validated by Rottenberg, Ray, and Gross (2007) to elicit changes in positive emotion only (i.e., increased amusement, but no change in sadness, disgust, embarrassment, or other emotions). The clips used were a 3-minute segment of stand-up comedy from Bill Cosby's *Himself* (1983) and a 2-minute improvised comedy segment from the television show *Whose Line is it Anyway?* (1998). These clips were selected for their recency and relevance compared to other clips and were presented together in sequence to match the duration of the cognitive skills intervention as best as possible, which based on observations of the experiment among the first 5 participants in each group was estimated to be approximately 5 minutes prior to the generation of restructured thoughts.

Although some controversy exists as to whether differences in mood self-report after experimental mood induction are genuine or the result of demand characteristics from experimenter instructions (e.g., Kenealy, 1986; Martin, 1990), results from a meta-

analysis by Westermann et al. (1996) has suggested that using a film without providing instructions to attend to mood is equally as effective as other methods that require experimenter instructions. Thus, the trainer returned and gave only minimal instruction to participants in the mood induction group about this task. Participants were informed that before the next pain tasks, they would watch a video clip together with the trainer to provide a break between the first and second cold pressor tasks and be asked questions afterwards.

After the video ended, the trainer asked the participant to look at the three emotion words they generated and wrote down in the CAT education phase and to rate aloud how much they feel each of those three specific emotions at present on a 0-5 scale. This scale was chosen to minimize the similarity between these mood ratings and the 0-100 pain ratings made after pain tasks. The trainer also asked the participant to think of and write down a synonym for each of those three words, to mirror the thought generation exercise done in the cognitive skills intervention. Once this task was complete, the trainer indicated that the tester would now return and exited the room.

Neutral mood (control) group. Participants in this group viewed a video clip with the trainer between cold pressor tasks, similarly to the positive mood induction group; however, the video chosen was one of the two described by Rottenberg and colleagues that does not elicit any change in positive or negative emotion (Rottenberg et al., 2007). The clip a 5-minute segment from the documentary film *Alaska's Wild Denali* (1997), depicts landscapes and animals native to Denali National Park. Aside from watching a different clip, the procedures for this group (watching a clip, rating current mood and generating mood word synonyms) were otherwise identical to that of the positive mood

induction group. This third group was intended to serve as a control group for a baseline comparison with the other two groups, as it used a video clip task similar to the positive mood intervention and involved the same task led by the trainer meant to mirror the duration and interactivity of the cognitive skills intervention.

Post-intervention experimental pain tasks. After the intervention period was completed, the tester returned to administer a third pressure task on the same finger as the first test, a third positive and negative mood VAS, a second cold pressor task, and a fourth and final positive and negative mood VAS. Instructions were nearly identical for these tasks as for the pre-intervention tasks but edited slightly for brevity; participants were still instructed on how and when to make CAT-VAS ratings and how to signal the experimental to end the pain tasks. The time interval between the two cold pressor tasks, given the intervention period, pressure task, and instructions, was approximately 15 minutes. This interval was put in place in an effort to avoid any effects of temporal summation of pain between cold pressor tasks (Mitchell et al., 2004).

PCS post-test, credibility check and debriefing. After completing the final cold pressor task, participants completed a second PCS. The instructions were be altered; thus, if participants followed the instructions, they would still rate their general levels of CAT when they are in pain, not necessarily the CAT they are or just were experiencing.

Participants also completed a 10-question exit survey on the study and intervention itself, modeled after the treatment credibility assessment instrument described by Borkovec and Nau (1972). On this questionnaire, participants gave open-ended descriptions of how much they were able to control CAT after what they did in the time between cold pressor tasks, outlined the strategies they used, if any, to control the pain

before and after the intervention, and described any effects they noticed of completing the CAT-VAS while undergoing the pain tasks ("Did making ratings on the scale affect how you did the pressure and cold water tests? If so, how?"). In addition, they answered 5 Likert-like questions on a scale of 0 to 10 related to the credibility and utility of the tasks they did during the intervention period (e.g., "How confident were you that what you did with the trainer after the first cold water task would help you to get through the second one?").

After participants completed the study, they were debriefed on the study aims, received contact information for the IRB in the event that they had additional questions, and thanked for their participation.

Results

To determine whether the randomization to one of the three intervention groups was successful in rendering the groups statistically indistinguishable, univariate ANOVAs and Chi-square tests of proportionality were conducted on demographic characteristics and questionnaire measures. Variables that differed significantly by group were selected to be used as covariates in subsequent analyses. A summary of the results of these analyses appears in Table 1, and means and standard deviations for the questionnaires appear in Table 2.

Although the randomization was largely successful, a significant difference was observed among intervention groups for race. Specifically, the cognitive skills intervention group contained proportionally more participants who identified as White, $X^2(2) = 7.46$, $p = .0239$, and the positive mood group contained proportionally more participants identifying as Black, $X^2(2) = 9.23$, $p = .0099$. Race was retained as a predictor for analyses of the study hypotheses. The only other significant difference between groups was observed within the questionnaire measures; members of the cognitive skills intervention group rated their ability to decrease pain with their coping strategies as higher than respondents in either of the other two groups, $F(2,108) = 4.09$, $p = .0195$.

Additional univariate ANOVAs were conducted to determine whether the 6 individuals who did not return for the experimental visit differed from the individuals who completed the whole experiment; the results also appear in Table 1. Almost all of

these tests revealed no significant differences between study completers and non-completers. However, two differences were observed. First, non-completers reported higher current pain than completers (M=1.00 for non-completers, M=0.10 for completers, $F(1,115) = 8.87$, $p = .0035$); however, it is notable that only one of the six non-completers reported being in current pain, at an intensity of 6 out of 10. Second, non-completers gave lower ratings than completers of their ability to control pain; still, this difference did not reach statistical significance (M=4.00 for study completers, M=3.17 for non-completers, $F(1,115) = 3.64$, $p = .0588$).

Preliminary Analyses

Descriptive statistics for the outcomes of each of the pain tasks are given in Table 3 and Figure 2 for all groups combined. Participants tended to report substantially higher intensity and unpleasantness in response to cold pressor (between 75-80 on a 0-100 scale) than pressure (close to 40), both before and after the intervention period. Fewer than 20% of pressure tasks were ended by participants before the full 180 seconds had elapsed, whereas over 50% of participants terminated the cold pressor tasks early. On average, participants requested to stop the pain task earlier for cold pressor than for pressure, often within the first minute of the task.

Because participants might give different ratings to stimuli they have experienced previously during the experiment, one must first test for the presence of order effects before the efficacy of any intervention can be determined. To assess for order effects, MANOVAs were conducted using the dependent variables of intensity and unpleasantness from the first and second pressure tasks (before any interventions had been delivered). Difference scores from the two pressure tasks were calculated for each

participant and compared to 0 in the MANOVA; if order effects were present, then these difference scores would be expected to be nonzero. No other predictors were included in the model. The multivariate analysis revealed no overall significant difference between pressure tasks 1 and 2, Wilks' $\Lambda = 0.99$, $F(2,107) = 0.40$, $p = .6714$. Univariate ANOVAs similarly showed no specific order effect for intensity, $F(1,108) = 0.41$, $p = .5254$, or unpleasantness, $F(1,108) = 0.03$, $p = .8591$. Given this result, it appears unlikely that differences between ratings given before and after the intervention period can be attributed to order effects.

Further analyses were conducted to determine whether the positive mood induction had significantly elicited an increase in positive mood. Intervention group was used as a predictor in a MANOVA with the difference between the second and third mood ratings given on the mood VAS (positive and negative) as the set of outcomes. These analyses failed to reveal a significant change in positive or negative mood between these two time points (positive mood: $F(2,108) = 2.15$, $p = .1216$; negative mood: $F(2,108) = 2.54$, $p = .0839$). Furthermore, a repeated-measures ANOVA predicting all four mood VAS ratings indicated that time of assessment significantly predicted mood VAS ratings for both positive mood ($F(3,324) = 14.51$, $p < .0001$) and negative mood ($F(3,324) = 8.32$, $p < .0001$) with mood becoming more negative and less positive immediately after cold pressor testing regardless of group, whereas intervention group did not predict either positive mood ($F(2,108) = 0.31$, $p = .7308$) or negative mood ($F(2,108) = 1.02$, $p = .3639$). These findings would suggest that the cognitive skills intervention was differentiated from the positive mood induction primarily by the introduction of coping strategies and the instructions to use them in the subsequent tasks, without an additional

difference in mood. In addition, although the positive mood and neutral mood groups watched different movie clips, one may infer from this analysis that differences between these groups should not be attributed solely to changes in positive mood. Whenever possible, a series of analyses was conducted to allow for both a comparison of all three groups independently as well as a specific contrast between the cognitive skills intervention group and the other two groups together. This analytical approach would be most appropriate if the positive mood group experienced a change in mood no different than that of the neutral mood group.

Additional pilot testing was conducted to determine whether the instructions developed to invoke additional CAT prior to the cold pressor tasks was necessary to elicit sufficient CAT, and if so, whether this procedure was successful in evoking more CAT. When data had been collected from the first 21 participants (19% of the sample), their initial CAT-VAS ratings from the pre-intervention pressure tasks were compared to the one they gave at the start of the pre-intervention cold pressor task using a repeated-measures 3x2 MANOVA model, using task (1, 2 or 3) and instruction set as predictors. Of these participants, 12 had been given the instructions aimed at eliciting CAT and 9 had been given a neutral set of instructions. The model revealed no significant differences between the two groups based on instruction set, $F(1,19) = 0.15$, $p = .6985$. Still, as expected, participants gave substantially higher initial CAT-VAS ratings pre-intervention for the cold pressor tasks than the pressure tasks, $F(2,38) = 13.94$, $p < .0001$. Given the lack of difference in CAT for cold pressor by instruction set, the neutral instruction set was given to all participants from this point forward in the study.

Analysis Strategy for Main Hypotheses

For the analyses of the core hypotheses of the study, in addition to gender, race and PCS scores from the first visit, predictors of pain included two variables derived from the CAT-VAS ratings each participant made for that task. These predictors were the Bayes estimates of the slope and intercept (at the start of the task) of the regression line representing that individual's CAT-VAS ratings for that task. These values were calculated using PROC MIXED in SAS, using only participant ID and time of the observation (in seconds elapsed) as predictors of CAT-VAS ratings. This approach is superior to calculating only a mean of all CAT-VAS ratings or the area under the curve of the CAT-VAS ratings because it captures both the pattern of change in ratings over time (slope) and the relative amount of CAT each participant reported (intercept). CAT-VAS slopes and intercepts are reported in Table 4.

Before the central analyses were conducted, models were constructed using possible covariates individually as predictors of pain outcomes (intensity, unpleasantness, tolerance) for the pre-intervention pain tasks. The potential covariates included demographic variables (gender, race, and age of participants) as well as baseline questionnaire scores from the PCS, CSQ, CES-D and PANAS. Results of these analyses appear in Tables 5, 6, and 7. For self-report pain outcomes (intensity and unpleasantness), MANOVAs or MANCOVAs were carried out. Briefly, the variables that appeared to significantly predict pain outcomes included gender (being male was associated with giving lower ratings), PCS total score from the first visit (more CAT was related to higher ratings), and race (participants identifying as Asian reporting less pain). Significant relationships were not observed for participant age, PANAS subscores, CES-D scores, or most subscales of the CSQ, with the exception of the CAT subscale. Thus,

gender, PCS score from the pre-experimental visit, and race were included as covariates in the primary analyses of self-report pain. Covariates were determined for analyses of pain tolerance with a similar process (Table 8), and only gender and race were retained to be used as covariates if group differences in pain tolerance by intervention group were observed.

Hypothesis 1: Efficacy of Interventions for Reducing CAT

To test whether the cognitive skills intervention was more successful than other interventions in reducing CAT, a multilevel model was constructed using intervention group as a predictor and CAT-VAS ratings as a repeated outcome (up to 7 observations per task, with observation number [0 through 6] entered as a predictor as well). To test whether intervention group successfully predicted CAT-VAS scores in the presence of other potential explanatory variables, gender, race, and scores from the PCS completed at the pre-experimental visit also were included as predictors. Furthermore, a contrast was included comparing the cognitive skills intervention group to the other two groups to determine whether the cognitive skills intervention successfully reduced CAT compared to the positive or neutral mood groups. The outcome variable for these analyses was CAT-VAS ratings for the post-intervention pain tasks (third pressure task, second cold pressor task). No covariance structure was assumed for the repeated CAT-VAS ratings. Given that individuals could be expected to differ both in their initial amount of CAT as well as their rate of change in CAT over time, both a random intercept and a random effect for observation number were estimated. Regression coefficients for race/ethnicity were estimated as the difference between one group and each other group, and an overall

F test was conducted to determine whether there were any group differences by race in addition to these direct comparisons.

An example of one of these multilevel models is given below, in a case where White is the comparison group for race. In these models, *i* represents an individual participant and *j* represents an individual observation (i.e., a CAT-VAS rating).

Level 1 Equation:

$$\text{CAT-VAS Rating}_{ij} = \beta_{0j} + \beta_{1j}(\text{Observation Number})_{ij} + \beta_{2j}(\text{Group})_{ij} + \beta_{3j}(\text{Male})_{ij} + \beta_{4j}(\text{PCS Total Score})_{ij} + \beta_{5j}(\text{Black or African American})_{ij} + \beta_{6j}(\text{Asian})_{ij} + \beta_{7j}(\text{American Indian/Alaskan Native})_{ij} + \beta_{8j}(\text{Native Hawaiian or Other Pacific Islander})_{ij} + \beta_{9j}(\text{Other Race})_{ij} + r_{ij}$$

Level 2 Equations:

$$\beta_{0j} = \gamma_{00} + u_{0j} \qquad \begin{pmatrix} u0j \\ u1j \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \tau 00 & \\ \tau 10 & \tau 11 \end{pmatrix}\right]$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50}$$

$$\beta_{6j} = \gamma_{60}$$

$$\beta_{7j} = \gamma_{70}$$

$$\beta_{8j} = \gamma_{80}$$

$$\beta_{9j} = \gamma_{90}$$

Reduced Form Equation:

$$\text{CAT-VAS Rating}_{ij} = (\gamma_{0j} + u_{0j}) + (\gamma_{1j} + u_{2j})\,(\text{Observation Number})_{ij} + \gamma_{2j}(\text{Group})_{ij} +$$
$$\gamma_{3j}(\text{Male})_{ij} + \gamma_{4j}(\text{PCS Total Score})_{ij} + \gamma_{5j}(\text{Black or African American})_{ij} +$$
$$\gamma_{6j}(\text{Asian})_{ij} + \gamma_{7j}(\text{American Indian/Alaskan Native})_{ij} +$$
$$\gamma_{8j}(\text{Native Hawaiian or Other Pacific Islander})_{ij} + \gamma_{9j}(\text{Other Race})_{ij} + r_{ij}$$

As predicted, for the post-intervention pressure task, intervention was a significant predictor of CAT-VAS ratings ($F(2,534) = 4.27$, $p = .0145$). Tests of differences between least squares means revealed that the cognitive skills intervention group gave significantly lower CAT-VAS ratings than the neutral mood group ($\beta = -7.6$, $t(534) = -2.66$, Bonferroni adjusted $p = .0242$) but not the positive mood group; the overall contrast between the cognitive skills intervention group and the other groups combined revealed no statistically significant difference ($\beta = -8.77$, $t(534) = -1.71$, $p = .0873$). Two other significant predictors of CAT-VAS ratings emerged. First, the observation number of the CAT-VAS rating had a significant positive relationship with CAT-VAS ratings predictor, suggesting that CAT increased over time ($\beta = 5.04$, $t(110) = 9.21$, $p < .0001$, The other significant predictor of CAT-VAS ratings was race/ethnicity ($F(4,534) = 3.40$, $p = .0092$); this analysis suggested that participants who identified as Asian tended to give lower CAT-VAS ratings than other participants. Gender and PCS total score did not reach significance.

For the post-intervention cold pressor task, as predicted, intervention group was also significant predictor of CAT-VAS ratings ($F(2,311) = 5.61$, $p = .0040$). Tests of differences between least squares means revealed that individuals receiving the cognitive skills intervention group again showed significantly lower CAT-VAS ratings than the those in the neutral mood group ($\beta = -17.0$, $t(311) = -3.34$, Bonferroni adjusted $p = .0028$.

The difference between the cognitive skills intervention group and positive mood group was not statistically significant after a Bonferroni adjustment was applied (β = -10.8, t(311) = -2.02, Bonferroni adjusted p = .1340), and no significant differences between positive mood and neutral mood groups was observed. However, unlike the results for the pressure task, the overall contrast between the cognitive skills intervention group and the other groups combined did reveal a substantial and statistically significant difference, with the cognitive skills intervention group giving lower CAT-VAS ratings than the combination of other two groups (β = -27.71, t(311) = -3.04, p = .0026). Other significant predictors of CAT-VAS ratings for cold pressor 2 were observation number (β = 9.61, t(110) = 8.62, p < .0001), suggesting that CAT-VAS scores again increased over time, and gender (β = 8.8, t(311) = 2.02, p = .0440), suggesting that male participants gave lower CAT-VAS ratings than female participants. Race/ethnicity and PCS total score did not significantly predict CAT-VAS ratings for the cold pressor task.

To control for pre-intervention levels of CAT, further analyses were conducted adding estimated CAT-VAS slopes and intercepts from the prior tasks of the same type (pressure or cold) as predictors of CAT-VAS scores. The results of these analyses, summarized in Table 9, were greatly similar to the prior models. Intervention group remained a significant predictor of CAT-VAS ratings for both the post-intervention pressure and cold tasks. The overall contrast between the cognitive skills intervention group and other groups was now significant for both the pressure and cold tasks. The cognitive skills intervention group showed significantly lower CAT-VAS ratings compared to the neutral mood group only for pressure and compared to each of the other groups for cold pressor. The only other significant predictors of CAT-VAS ratings for

either task were the CAT-VAS slope and intercept from pre-intervention pain tasks, each of which were positively associated with CAT-VAS ratings.

To summarize, as predicted, intervention group significantly predicted post-intervention CAT-VAS ratings even when other predictors including observation number, gender, race, PCS total score, and prior CAT-VAS ratings were included in the model. The cognitive skills intervention group gave significantly lower CAT-VAS ratings compared to the neutral mood group for both pressure and cold and compared to the positive mood group for cold pressor.

Hypothesis 2: CAT as a Predictor of Pain

The hypothesis was that higher CAT would predict higher pain self-report ratings and lower observed pain tolerance. For self-report, outcome variables were maximum pain intensity and maximum pain unpleasantness from the pre-intervention pain tasks; these two variables were tested with a MANCOVA approach. Using a multivariate approach takes into account the expected correlation between the intensity rating and unpleasantness rating each individual gave for a given pain task, allowing for a more reliable test of a variable's predictive utility on the entire set of outcomes (i.e., the omnibus test) before additional exploration of its association with individual outcome variables through univariate tests. For pain tolerance, a single outcome variable, time elapsed in the task, was used in a survival analysis approach. This approach was necessary given the nature of the outcome variable; because the amount of time before quitting for a participant who tolerated the full task only is known to be greater than 3 minutes, the variable is "right censored," potentially leading to erroneous conclusions if an individual's pain tolerance is said to be only the 180 seconds that were observed.

Analyses were conducted on the pre-intervention pain tasks (pressure 1 and 2, cold pressor 1) given the expected influence of intervention on pain report.

Self-reported pain. Results of the MANCOVA are summarized in Tables 10 and 11. Omnibus tests evaluated whether variables significantly predict self-reported pain outcomes (intensity and unpleasantness) as a set. The MANCOVA, which included all of the above predictors, accounted for 54%-56% of the total variance in intensity and unpleasantness for pressure tasks 1 and 2 and 38-43% of the variance in intensity and unpleasantness for cold pressor task 1. The omnibus tests indicated that, when all predictors were included in the model, only CAT-VAS slope (all $p < .0001$) and CAT-VAS intercept (all $p < .05$) significantly predicted subjective pain report; no other predictors returned statistically significant results. In all cases, the estimated regression coefficients for CAT-VAS slope and intercept were positive, indicating that higher levels of CAT as determined by the CAT-VAS were associated with higher pain self-report.

Observed pain tolerance. To determine the predictive value of CAT-VAS slope and intercept for determining how much time would elapse before a participant would terminate the pre-intervention pain tasks, survival analyses were conducted in SAS using PROC LIFEREG. The approach used, an accelerated time to failure model, aims to estimate the likelihood of a participant's terminating the task at a given time point by fitting the log of failure times into a parametric regression model using an iterative, maximum likelihood estimation approach. The regression coefficients generated by PROC LIFEREG indicate whether the time to failure is accelerated or decelerated by the predictor variable; positive coefficients indicate that positive values on the variable are associated with longer times before failure, whereas negative values indicate that higher

values of the predictor are associated with shorter times before failure. In other words, these values can be interpreted in the same way as conventional multiple regression coefficients for predictors.

For example, the model constructed to test for differences in failure times using CAT-VAS slopes, CAT-VAS intercepts and male gender as predictors of failure time on a pain task would be:

$$\log(\text{Time To Failure}) = \beta_1(\text{CAT-VAS Slope}) + \beta_2(\text{CAT-VAS Intercept}) + \beta_3(\text{Male}) + \varepsilon$$

Inspection of the observed frequency distributions of time elapsed (e.g., Figure 3) suggested that the likelihood of terminating a pain task varied over time; for example, for pre-intervention cold pressor pain, participants appeared to be most likely to quit the task within the first 10 to 60 seconds of the task and much less likely after that point. Thus, when possible, a generalized gamma distribution was used to estimate the underlying probability distribution function (odds at any time that a participant would quit), in an effort to avoid the assumption that the likelihood of participants quitting was always increasing or decreasing. Inspection of fit statistics (e.g., -2 log likelihood and AIC) indicated that using a generalized gamma distribution provided the best fit to the data for cold tasks. However, because the failure rate for pressure tasks was generally very low (a maximum of 16% of participants asked to stop or removed their hand for any pressure pain task), a solution frequently could not be estimated for pressure tasks using the generalized gamma distribution. This difficulty necessitated some restriction of the model, namely that some aspects of the shape of the underlying probability distribution would be assumed rather than estimated from the data, to reach a solution. Thus, for

pressure tasks, a Weibull probability distribution function (i.e., a specific case of the gamma distribution) was assumed.

For all three pre-intervention pain tasks, when entered as the sole predictor, higher CAT-VAS slopes predicted significantly shorter times before quitting the pain task at hand (pressure 1: β = -8.08, $X^2(1)$ = 13.19, p = .0003; pressure 2: β = -2.97, $X^2(1)$ = 54.22, p < .0001; cold 1: β = -4.02, $X^2(1)$ = 49.32, p < .0001). Similarly, higher CAT-VAS intercepts were associated with significantly shorter times before termination of the task (pressure 1: β = -0.508, $X^2(1)$ = 4.66, p = .0308; pressure 2: β = -0.04, $X^2(1)$ = 6.25, p = .0124; cold 1: β = -0.02, $X^2(1)$ = 28.57, p < .0001). However, tests of the interaction between CAT-VAS slope and intercept did not significantly predict pain tolerance for any of the three pre-intervention pain tasks.

When gender and race were included as covariates, higher CAT-VAS slope remained a significant predictor of lower pain tolerance for all three pre-intervention pain tasks (pressure 1: β = -2.79, $X^2(1)$ = 16.07, p < .0001; pressure 2: β = -4.32, $X^2(1)$ = 46.06, p < .0001; cold 1: β = -4.32, $X^2(1)$ = 63.65, p < .0001). CAT-VAS intercept again had a similar negative association with pain tolerance times, but this association was not statistically significant for pressure task 2 (pressure 1: β = -0.03, $X^2(1)$ = 4.70, p = .0302; pressure 2: β = -0.01, $X^2(1)$ = 1.55, p = .2139; cold 1: β = -0.04, $X^2(1)$ = 26.79, p < .0001). Race significantly predicted pain tolerance only for cold pressor 1, with White participants showing higher pain tolerance than other groups (β = 0.59, $X^2(1)$ = 7.04, p = .0080). Gender did not predict pain tolerance for any pre-intervention pain task.

Hypothesis 3: Impact of Interventions on Pain

The third hypothesis was that, in addition to experiencing a reduction in CAT, individuals who received the cognitive skills intervention would show both the greatest decrease in subjective pain ratings and the most improvement in pain tolerance. The statistical approaches to evaluating this hypothesis were highly similar to the assessment of the efficacy of the cognitive skills intervention in reducing CAT, with some alterations. First, intervention group was added to the predictors for each of the models (gender, race, PCS score from the pre-experimental visit, estimated CAT-VAS slope and intercept for that task). Second, because the analysis was aimed at describing change in pain due to intervention, the outcome variables for pain self-report used were difference scores between pre- and post-intervention ratings (e.g., the difference between intensity scores from the first cold pressor and second cold pressor). Difference scores for intensity and unpleasantness for pressure and cold are reported in Table 12; negative scores indicate that unpleasantness scores decreased after the intervention period for that task. Third, for pain tolerance, survival analyses were conducted only using the post-intervention pain tasks (pressure 3 and cold pressor 2), as difference scores for time elapsed before the end of the task would be inappropriate outcome variables for survival analysis.

Self-reported pain: cold pressor. For the difference between cold pressor tasks 1 and 2 (pre- and post-intervention), omnibus tests revealed that, as predicted, the intervention did have a statistically significant relationship with the set of two self-report pain variables (Wilks' Λ =.85, $F(4,198) = 4.33$, $p = .0022$). In addition, each of the variables derived from the CAT-VAS also accounted for statistically significant portions of the variance in self-reported pain outcomes (slope: Wilks' Λ =.85, $F(2,99) = 8.63$, $p = .0004$;

intercept: Wilks' Λ =.88, F(2,99) = 6.45, p = .0023). Of the other covariates, PCS scores from the pre-experimental visit did not achieve statistical significance for predicting self-report pain outcomes (Wilks' Λ =.94, F(2,99) = 0.54, p = .0553). No significant relationships were observed between pain outcomes and gender (Wilks' Λ =.99, F(2,99) = 0.74, p = .4783) or race/ethnicity (Wilks' Λ =.92, F(8,198) = 1.14, p = .3392).

Univariate tests revealed that the set of predictors accounted for 27% of the variance in the difference in reported maximum pain intensity between pre- and post-intervention tasks (F(10,100) = 3.66, p = .0003, R^2=.27). Each of the predictors found to be significantly associated with pain outcomes in the omnibus tests also significantly predicted intensity in the univariate test, including intervention (F(2,100) = 3.60, p = .0308) and CAT-VAS slope (F(1,100) = 11.05, p = .0012) and intercept (F(1,100) = 10.00, p = .0021). Other covariates did not significantly predict change in intensity rating for the cold pressor task. The planned contrast between the cognitive skills intervention group and the other two groups returned a significant result, F(1,100) = 4.27, p = .0413. Statistical comparison between each of the group means indicated that the mean difference in reported intensity was significantly lower for the cognitive skills intervention group than the positive mood group, t(100) = -2.63, p = .010, but no other significant group differences were observed.

The combination of predictors accounted for 38% of the variance in unpleasantness ratings (F(10,100) = 6.16, p < .0001). Similarly to intensity ratings, univariate tests revealed that the significant predictors for the omnibus were each significant predictors of unpleasantness specifically; these predictors were intervention group (F(2,100) = 7.41, p = .0010), CAT-VAS slope (F(1,100) = 14.54, p = .0002), and CAT-VAS intercept

($F(1,100) = 9.26$, $p = .0030$), whereas gender and race failed to reach significance. It may be noted that PCS scores from the pre-experimental visit, which the omnibus tests did not reveal as predictors of the set of pain self-report outcomes, were significant predictors of pain unpleasantness in the univariate tests, ($F(1,100) = 5.46$, $p = .0215$). Higher CAT-VAS slope, CAT-VAS intercept, and PCS scores each were associated with more positive difference scores in unpleasantness ratings between cold pressor 1 and 2 (in other words, relatively higher unpleasantness scores for the second cold pressor task, even if an overall decrease was observed). With regard to the interventions, the contrast between the cognitive skills intervention group and the other two groups was again significant, $F(1,100) = 14.63$, $p = .0002$. In this case, further group comparisons revealed individuals receiving the cognitive intervention reported significantly greater decreases in unpleasantness than individuals from either the positive mood group ($\beta = -11.47$, $t(100) = -3.58$, $p = .0005$) or the neutral mood group ($\beta = -9.94$, $t(100) = -3.16$, $p = 0021$).

Self-reported pain: pressure. The models constructed to test for changes in pressure pain outcomes due to the intervention were identical to the models for cold; difference scores were calculated subtracting intensity or unpleasantness ratings from the third and final pressure task from those of the second pressure task. (No significant differences were observed between pressure tasks 1 and 2; ratings from pressure 2 were preferred as they were the most recent pain test to calculate difference scores.) For the difference between pressure tasks 2 and 3, omnibus tests revealed that only CAT-VAS slope was a significant predictor of the set of self-report pain outcomes (Wilks' $\Lambda = .88$, $F(2,98) = 6.59$, $p = .0021$). Intervention had no significant effect on subjective pain report (Wilks' $\Lambda = .95$, $F(4,196) = 1.25$, $p = .2898$), nor was CAT-VAS intercept associated with any

difference in pressure pain self-report (Wilks' Λ =.95, F(2,98) = 2.49, p = .0882). No other covariates showed significant associations with self-reported pain. Univariate tests similarly demonstrated that CAT-VAS slope was again the lone significant predictor of both maximum pain intensity (F(1,99) = 11.78, p = .0009) and unpleasantness (F(1,99) = 4.89, p = .0293). Only for difference in pain intensity was the overall univariate model significant (intensity: (F(10,99) = 2.07, p = .0344, R^2=.17; unpleasantness: F(10,99) = 1.40, p = .1912, R^2=.12). Planned contrasts revealed no significant differences between the cognitive skills intervention group and other groups for pressure pain self-report outcomes (intensity: (F(1,99) = 1.81, p = .1820; unpleasantness: F(1,99) = 1.02, p = .3151).

In summary, intervention group significantly predicted change in pain self-report variables for cold pressor pain but not pressure pain. The group receiving the cognitive skills intervention experienced significantly better pain self-report outcomes for the cold pressor task; these individuals had greater decreases in intensity and unpleasantness post-intervention than those in the positive mood group and lower relative unpleasantness scores than those in the neutral mood group. For both pain modalities, individuals with higher CAT-VAS slopes had higher relative self-report of pain after the intervention period; for cold, CAT-VAS intercept also maintained a significant positive association with both intensity and unpleasantness ratings, and higher PCS scores were associated with higher difference scores for unpleasantness.

Time to withdrawal from stimulus (pain tolerance). Tests to determine the effect of the interventions on pain tolerance were largely similar to the survival analyses conducted for CAT-VAS slope and intercept as predictors. However, difference scores

for time elapsed before the task ended would not be appropriate for use as outcome variables and thus were not calculated. It is important to note that preliminary analyses of the effect of intervention group on time elapsed revealed no differences between groups for the pre-intervention pain tasks (pressure 1: $X^2(2) = 0.94$, $p = .6238$; pressure 2: $X^2(2) = 0.58$, $p = .7464$; cold 1: $X^2(2) = 3.25$, $p = .1974$).

When intervention group was entered as the sole predictor of pain tolerance on the post-intervention pressure task, no significant effect for intervention was found ($X^2(2) = 0.71$, $p = .7000$). However, as the sole predictor of post-intervention cold pressor pain tolerance, intervention group significantly predicted time elapsed before withdrawal ($X^2(2) = 21.55$, $p < .0001$). Survival estimates (likelihood of survival over time) for each group on the post-intervention cold pressor tasks are illustrated in Figure 4. Group comparisons revealed that participants in the cognitive skills intervention group showed significantly higher pain tolerance than either those in the positive mood group ($\beta = 0.85$, $X^2(1) = 13.95$, $p = .0002$) or neutral mood group ($\beta = 1.07$, $X^2(1) = 21.31$, $p = .0002$), but the difference observed between the neutral mood and positive mood groups was not significant ($\beta = -0.22$, $X^2(1) = 1.74$, $p = .1877$).

If CAT significantly predicts pain tolerance, then CAT-VAS ratings should be predictors of pain tolerance even when intervention group is taken into account. Thus, in follow-up analyses, CAT-VAS slope and intercept were added as covariates predicting time to withdrawal from the stimulus. Under these conditions, intervention group no longer significantly predicted pain tolerance ($X^2(2) = 5.81$, $p = .0549$). However, two other findings from this analysis were notable. First, both CAT-VAS slope and intercept remained significantly negatively related to pain tolerance (slope: $\beta = -3.67$, $X^2(1) =$

113.96, p < .0001; intercept: β = -0.02, $X^2(1) = 15.03$, p = .0001). Second, group comparisons revealed that with CAT-VAS variables present as predictors, the neutral mood group showed significantly lower pain tolerance than the positive mood group (β = -0.48, $X^2(1) = 5.52$, p = .0187).

To summarize, as predicted, the cognitive skills intervention group showed greater pain tolerance on the post-intervention cold pressor task compared to the other two groups, in addition to the improved self-report pain outcomes. When CAT-VAS ratings were added as predictors, the cognitive skills intervention group did not differ from the other groups in pain tolerance, although those who received the positive mood induction showed better pain tolerance than those in the neutral mood group. These findings suggest both that the intervention improved participants' tolerance of the stimulus and that CAT remained an important predictor of pain tolerance even when group was taken into account. These analyses may also suggest that the positive mood induction had some effect on pain tolerance that the neutral mood clip did not.

CAT-VAS: Validity Tests

To assess the convergent and divergent validity of the CAT-VAS, multilevel linear regression analyses were conducted using CAT-VAS scores from pre-intervention pain tasks as the dependent variable. Independent analyses were conducted using scores and subscores from the pre-experimental visit questionnaires (PCS, CSQ, PANAS, and CES-D) as predictors; observation number was also included to account for the repeated measurement of CAT over the course of the pain tasks. Convergent validity of the CAT-VAS would be supported if significant relationships emerged between the CAT-VAS and the PCS or CAT subscale of the CSQ; a relationship between CAT-VAS scores and

negative affect would also suggest the CAT-VAS is a valid measure of CAT, given the relationship between CAT and both negative mood and depression. However, significant relationships should not be observed between CAT-VAS scores and either positive affect or the subscales of the CSQ that account for behavioral coping strategies.

Results from these analyses appear in Table 13. The convergent and divergent validity of CAT-VAS ratings was mostly supported by these analyses. Regarding convergent validity, CAT-VAS scores showed significant positive associations with PCS total scores from all three pain tasks and either reached or approached significance for CAT subscores from the CSQ. Interestingly, when PCS subscores were used as predictors rather than total score, the Rumination subscore held a significant positive relationship with CAT-VAS scores whereas Magnification and Helplessness did not. CES-D scores showed a significant positive relationship with CAT-VAS ratings as well across all three pain ratings, but the Negative Affect subscale of the PANAS only showed a positive relationship with CAT-VAS ratings from the first pressure task.

Regarding divergent validity, no relationships were observed between CAT-VAS scores from any of the first three pain tasks and Positive Affect from the PANAS. Few relationships were observed between CAT-VAS scores and any coping strategies from the CSQ other than CAT; Pain Behaviors exhibited a positive relationship with CAT-VAS ratings for cold pressor task 1 and Activity Level for pressure task 1, but no other relationships were statistically significant. These analyses appear to indicate that the CAT-VAS indeed measures CAT, does not show strong associations with other constructs relevant to CAT, and may most accurately represent the ruminative aspect of CAT.

Face validity of the intervention was also assessed by means of the survey participants completed after all of the experimental pain tasks had been completed. Group comparisons on the Likert scale questions (range 0 to 10) appear in Table 14. Briefly, participants who received the cognitive skills intervention gave significantly higher ratings than either other group of how logical the intervention was, how helpful it was in reducing their CAT, and how likely they were to recommend what they did during their intervention (i.e., the cognitive techniques) to friends undergoing similar tasks. However, no group differences were observed for participants' confidence that their intervention would help them to complete the second cold pressor task or for whether the intervention had helped them to have less pain during the post-intervention pain tasks.

Discussion

Several theoretical models of the relationship between pain and cognition hypothesize that CAT increases an individual's suffering in response to pain due to a combination of ruminating about the pain, magnifying its subjective intensity, and feeling helpless to alter or diminish its severity (e.g., Sullivan et al., 2001). Prior research has indicated that CAT indeed serves as an important predictor of both individuals' subjective evaluation of pain and their avoidance of or withdrawal from pain (e.g., Severejins et al., 2001). In addition, CAT appears to have a considerable impact on pain in both an immediate and long-term sense; CAT is considered a key component of a cognitive cycle that promotes both the intensification of acute pain and its development into a more chronic state of disability.

The present study aimed to determine whether brief cognitive skills training could be more efficacious than alternative interventions at changing both CAT and pain in response to an experimental pain stimulus. a positive finding as hypothesized would indicate that the intervention could disrupt the cycle by which short-term pain is intensified and, perhaps, by which acute pain becomes a more chronic problem. Furthermore, a self-report, in-the-moment instrument for assessing CAT was developed and its predictive utility evaluated in the present study; given prior research (e.g., Campbell et al., 2010), it was expected that this in-the-moment measure would predict pain more completely and accurately than retrospective self-report.

The findings of the present study provide substantial support both for these hypotheses and for conceptual models that highlight the predictive utility of CAT in pain. Individuals who received the cognitive skills intervention showed a greater decrease in CAT, tolerated a painful stimulus longer, and reported that painful stimuli were less intense and unpleasant after the intervention compared to those who underwent a different procedure. This finding is consistent with other studies that have suggested that brief cognitive skills training for pain can have a significant impact on pain perception and tolerance (e.g., Gil et al., 1996). This study additionally demonstrates that these benefits can span pain stimuli of different modalities and intensities, extending the potential generalizability of the intervention to encompass other types of pain.

The cognitive skills training differed from the other intervention group procedures in a number of ways that may illuminate its efficacy. The idea that reducing CAT could lead directly to improved pain outcome has been advanced not only in theoretical models (e.g., Asmundson et al., 2004), but also in prospective research (e.g., Riddle et al., 2009) and experimental research (e.g., Smeets et al., 2006). Thus, the findings suggest that the cognitive skills training may have been efficacious because of its explicit targeting of CAT thoughts that the participant earlier indicated were the most frequent and relevant for themselves. Each intervention procedure involved interaction with one of the experimenters including generation of thoughts/mood words relevant to oneself; thus, even though prior research has included dialogue with an experimenter as an intervention component (e.g., Berg et al., 2008), it is unlikely that differences in pain outcomes can be ascribed to these aspects of the cognitive skills intervention. In addition, participants in this study had the opportunity and instruction to practice the cognitive skills in response

to a mild to moderate stimulus (pressure) prior to engaging in a more taxing pain task (cold pressor). Prior studies support the idea that practicing cognitive-behavioral coping skills in the context of an experimental pain stimulus can facilitate learning and application of coping strategies to future pain (e.g., Gil et al., 1996).

This study also provided support for using an in-the-moment measurement approach to CAT in the context of acute pain. CAT-VAS scores significantly predicted a substantial amount of variance in self-report pain; these scores represented not only an individual's general level of CAT during a trial (intercept), but also its relative increase or decrease over time (slope), an advantage over questionnaire that is afforded by its in-the-moment repeated-measures design. Concurrent and divergent validity testing suggests that CAT-VAS scores significantly correlate with existing measures of CAT; however, the CAT-VAS appears to offer significant additional utility in predicting both subjective pain report and pain tolerance. The slope of CAT-VAS ratings appeared to provide the greatest value in predicting experimental pain (i.e., was a significant predictor of pain throughout almost every analysis). This result speaks to the unique utility of this novel measure. Existing CAT questionnaires have been improved with adaptation to assess CAT in response to a specific painful event (Campbell et al., 2010); however, such measures still do not capture change in CAT over time. Both the repeated measurement design of the CAT-VAS and the rich analytical approach applied to it in the current study allow for a much sharper assessment of the influence of CAT at the moment of pain.

Although CAT-VAS scores showed a significant positive association with the total score from the PCS, the only PCS subscale related to CAT-VAS scores was Rumination. This finding is particularly interesting given that the most powerful predictor of

subjective pain report and observed tolerance of the painful stimulus was the estimated slope of the CAT-VAS ratings; when CAT-VAS ratings increased more steeply, pain outcomes tended to be worse. Taken together, these findings suggest that the CAT-VAS most successfully captures not only ruminative thinking about pain, as the PCS might, but also escalation in the intensity of rumination over time. Consider that the fear-avoidance model of pain proposes a cycle of escalating pain-related distress and disability, a key component of which is negative thinking and rumination. This model suggests both that subjective pain report and observable pain behavior (e.g., removal of hand from the stimulus) would be positively associated with greater rumination and that this rumination would escalate distress and pain.

The observed relationships between rate of change in CAT-VAS ratings over time, rumination, and pain outcomes appear to provide some measure of empirical support for the cycle described in this theoretical model. A more rapid escalation of CAT would imply a more rapid increase in pain over time; although the current design collected pain ratings only once per trial to minimize distraction, a study that assessed both pain and CAT multiple times per painful event could illuminate further their positive association with each other. Fortunately, both the design of the CAT-VAS and the rich statistical approach it afforded for the current study offer the potential for such fine-grained analysis of these temporal relationships.

Overall, the findings for the relationship between pain tolerance, CAT, and intervention were encouraging and consistent with initial hypotheses. Individuals who showed more CAT were more likely to quit the task earlier; however, even though the cognitive skills intervention did appear to have some utility in predicting cold pressor

pain tolerance, the effect of intervention group on pain tolerance was less pronounced than anticipated and was reduced to nonsignificance when CAT-VAS variables were added as predictors. A potential and unanticipated reason for this result is that fewer people terminated the experiments prior to the 3-minute cutoff than had been expected for both pressure and cold pressor tasks. In essence, fewer observations were collected than expected, given that individuals who completed the full 3 minutes of a task never produced the event under observation (i.e., termination of the task).

Participants' responses on the open-ended questionnaire may shed some light on this result. On this form, nearly all of the participants indicated that they used some form of distraction or another cognitive strategy to complete the pain tasks prior to the intervention period. Interestingly, a substantial number of participants (34 of 111, or about 31%) reported that making pain ratings on the CAT-VAS specifically made them more likely to try to persist for longer on the task, either to the next rating or to the very end, because they knew how much longer the pain could last. The nature of the CAT-VAS then may have made these participants more likely to set a personal goal and to try to reach that goal; in previous research, individuals prompted to set a personal quota for cold pressor pain (i.e., trying to double their time tolerating the stimulus on a second run of the task) have shown improvements in pain tolerance (e.g., Dolce, Doleys, Raczynski, Lossie, Poole, & Smith, 1986). However, other participants (12 of 111, or about 11%) reported that making ratings increased their attention to the pain, increased their pain, or made them less likely to complete the task; it is possible that for these participants, making ratings resulted in an increase in CAT. Further adjustments to the cognitive skills intervention could address this difficulty in participants who report it, perhaps by

discussing a specific application of the cognitive skills for the moment after a CAT thought enters the mind during a painful experience.

The unique design of this study allowed for several new contributions to the current knowledge on the influence of CAT on pain. The cognitive skills intervention was compared to more generic approaches to reducing experimental pain, allowing one to better hone in on the key ingredients of cognitive interventions for pain. Participants examined their own most frequent CAT thoughts, rated these in such a way that moment-by-moment change in CAT could be quantified, and in the cognitive skills group, practiced techniques for mitigating and reducing these in the context of particular painful stimuli (Gil et al., 1996). Changes were observed across two experimental pain modalities as well as across self-report and behavioral indicators of pain level. Finally, the statistical and measurement approaches employed permitted the key role of change in CAT over time (i.e., CAT-VAS slope) in predicting pain to be explored.

Limitations of the Current Study

A primary limitation of the current study is the population sampled. Although the results of the present study are encouraging, all participants were pain-free young adults. This aspect of the study limits generalization of these results to a clinical pain population, particularly to individuals with chronic pain; however, some aspects of the design mitigate this limitation. As discussed previously, young adults are at an age when levels of CAT are likelier to be elevated (Sullivan & Neish, 1998). It is important to note that the mean pre-experimental PCS total score actually is greater than the means reported for certain clinical samples, such as TMD patients (e.g., Campbell et al., 2010). Still, the

level of CAT in these healthy participants is likely to be lower than that of clinical pain patients in this age group.

Although all participants were randomized to one of the three intervention groups, Chi-square tests revealed a discrepancy in race across groups; a significantly higher proportion of participants in the cognitive skills group identified themselves as White whereas more participants in the positive mood induction group identified themselves as Black or African American. The unfortunate failure of the randomization leaves questions about whether the interventions have the same utility across racial groups. It should be noted that cognitive skills interventions have proven helpful for reducing pain and improving adjustment both in samples mostly comprised of Black or African American individuals (e.g., Gil et al., 1996) and in primarily White samples (e.g., Emery et al., 2006). In addition, although relatively few participants from other racial/ethnic groups participated, some differences by race in pain perception were observed; most notably, participants identifying as Asian gave lower pain ratings as a group compared to other groups.

Future studies should consider including psychological measures of aspects of racial and ethnic identity to allow for exploration of which of these aspects would underlie group differences. In particular, participants might respond differently to testers of their own racial/ethnic group versus another group, much in the way that the interaction of participant and experimenter gender predicts experimental pain response (Levine & De Simone, 1991). On a similar note, the interaction of experimenter and participant gender was not controlled for as a predictor of pain outcomes in the current study. To ensure a sufficiently large sample, no participants were excluded based on gender. However,

matching experimenter and participant gender for experimental visits proved logistically infeasible. It is possible that gender, race and other experimenter characteristics influenced participants' pain report; subsequent research should compare the relative importance of these demographic factors to that of the intervention in modifying pain responses.

Although cold pressor is thought to be one of the best experimental analogues for clinical pain, exposure to this pain was acute and time-limited; due to the informed consent process, participants were aware of these limits to the stimuli they would experience during the visit, a luxury which individuals with clinical pain rarely have. This aspect of the study limits generalization of the findings for clinical conditions with more continuous or unpredictable pain, but this limitation would be less restrictive for time-limited and predictable clinical pain such as pain resulting from medical procedures (e.g., Haythornthwaite et al., 2001). In addition, very few participants failed to complete a pressure task whereas relatively few (about 60%) did not finish the cold pressor tasks. To explore further the generalizability of the benefits of the intervention, one could examine whether a more intense pressure stimulus, likelier to prompt participants to end the task, or another intense stimulus of a different modality such as thermal pain, generates a similar pattern of findings to the cold pressor tasks in this study.

Perhaps the most substantial limitation of this study was an unexpected one; the positive mood intervention did not create a significant effect on positive or negative mood between the first and second administrations of the cold pressor task. Indeed, no group differences at all were observed for positive or negative mood between these two time points (Table 15; Figures 5 and 6). This failed manipulation is surprising given the

success of past brief interventions in reducing cold pressor pain and distress (Bruehl et al., 1993) as well as the empirical support for the positive mood induction procedure used in the current study (Rottenberg et al., 2007).

The lack of a detected change in positive mood due to intervention is somewhat supported by the mood VAS and questionnaire data. Follow-up univariate analyses indicated that individuals' PANAS positive and negative mood scores were not significantly correlated with their ratings on the first mood VAS, a measure that participants completed before any pain testing took place. Given this lack of continuity in mood across visits, it is possible that the context of the experiment, particularly the anticipation of additional testing after the intervention period, had a global negative effect on mood that could have disrupted the impact of the mood induction. Repeated-measures ANOVA did reveal that positive and negative mood significantly changed over the course of the experimental visit, with mood becoming more negative and less positive immediately after cold pressor testing.

Although the many differences in pain outcome observed between the cognitive skills intervention and the other two interventions still suggest that cognitive skills training had a particular benefit, but the failed manipulation of positive mood unfortunately leaves unclear whether a more powerful positive mood intervention would have elicited a change in CAT or pain. The mood induction implemented by Bruehl and colleagues (1993) involved an experimenter guiding participants through creating a mental image of a pleasant memory, whereas the current study used a more passive approach (watching a clip, then interacting with the experimenter on a task). A positive mood induction based on interaction with another individual might improve pain coping and provide a better

comparison group for the cognitive skills intervention; however, such an intervention might also be considered to be targeting CAT directly from the perspective of the communal coping model (Thorn, 2003). Still, if participants cannot be brought into a more positive mood state because of anticipation of more pain, this factor could limit the potential utility of interventions targeting mood beyond a temporary experience of pain that will likely remit relatively quickly.

Participants in the cognitive skills intervention group expressed a greater belief that the skills training intervention was logical, likely to help reduce CAT, and worth recommending to a friend in a similar situation. Notably, groups did not show any differences in belief that the intervention would help them to reduce the pain; however, these findings unfortunately leave the possibility that the cognitive skills intervention succeeded in reducing pain and CAT because it was more believable, not more efficacious. To provide some evidence to bear on this question, a follow-up study could aim to improve the credibility of the positive mood induction as a means of pain reduction. For example, Bruehl and colleagues (1993) used a set of instructions that both asked participants to try to maintain their mood during the cold pressor task and provided a rationale to communicate to participants that the intervention was likely to relieve pain; they observed success for their positive mood induction in improving outcomes on cold pressor tasks. The positive mood induction used in the current study could be enhanced with a similar focus on therapeutic rationale by, for example, establishing a relationship between mood and CAT and explaining that the goal of the exercise was to reduce CAT through a change in mood state. Steps like these could help to eliminate this confounding variable in determining the elements that made the cognitive intervention efficacious.

Future Directions

The cognitive skills training in this study showed utility in helping participants to cope with discrete pain stimuli, the onset and offset of which they could anticipate. The training as described would most easily generalize to similar painful situations involving acute, temporary painful events. Several studies have explored psychological interventions that aim to help individuals cope with pain and discomfort resulting from specific medical procedures that they were about to undergo, including injections and immunizations (Uman, Chambers, McGrath, & Kisely, 2008), burn debridement and dressing change (Haythornthwaite et al., 2001; Hoffman, Chambers, Meyer, Arceneaux, Russell, Seibel, et al., 2011), and intracardiac catheterization (Argstatter, Haberbosch, & Bolay, 2006). The current study provides evidence that skills practice in the context of one type of pain (pressure) could generalize to another type of pain experienced soon thereafter (cold pressor). If patients about to undergo a painful medical procedure are given the opportunity beforehand to learn and practice coping skills using a mild pain stimulus, as in the current study, both CAT and pain related to the procedure might be mitigated.

Prior research has suggested that higher CAT predicts worse outcomes for injury, including the development of a chronic pain state. For example, postoperative pain in patients undergoing knee arthroscopy was predicted by pre-operative CAT but not depression, anxiety disorders, or self-efficacy (Riddle et al., 2009). Given this relationship, these authors suggest that an intervention to reduce CAT would help minimize the development for ongoing pain and disability in the knee. Similarly, among those with back injuries, fear-avoidance and catastrophizing beliefs were significant

prospective predictors of which individuals went on to experience chronic low back pain (Linton et al., 2000). To determine the usefulness of the current cognitive skills intervention in disrupting the development of a chronically painful condition, one would first need some follow-up measurements to determine for how long after the intervention the decrease in CAT was sustained; such an investigation would be highly appropriate now given the success of the intervention in the current study.

The cognitive skills intervention in the present study also could be adapted for use among individuals with chronic or repeated episodic pain. The current intervention combined a number of aspects of other successful cognitive-behavioral treatments for these individuals. Cognitive restructuring and distraction techniques have been included in treatments of chronic headache (Thorn et al., 2007) and SCD (Gil et al., 1996), among others, and exploration of the usefulness of mindfulness techniques in pain reduction is expanding (Chiesa & Serretti, 2011). Furthermore, both the current intervention and longer-term cognitive skills trainings (e.g., Thorn et al., 2007) have included examination of individuals' own automatic CAT thoughts and negative evaluations of pain. However, these interventions rarely include practice of cognitive techniques in the context of controlled pain stimuli. In adapting the current intervention for use among individuals with chronic or repeated episodic pain, offering multiple opportunities for practice of skills in this context could help to consolidate and maintain treatment gains (e.g., Gil et al., 1996). Anecdotally, several participants reported on the open-ended exit questionnaire that the added intensity of the cold pressor task challenged and motivated them to apply coping strategies that they otherwise would not have considered; perhaps

practice with experimental pain stimuli would help individuals with pain to try new strategies with the hope of achieving new success in pain management.

Regarding measurement, the CAT-VAS showed promise in this study as both a powerful indicator of CAT levels in the moment and a valuable predictor of an individual's evaluation of their pain and ability to tolerate pain. However, to put the CAT-VAS to use measuring CAT within clinical pain populations may require some adjustment. The CAT-VAS was used in this study to measure a pain response to a discrete stimulus over a specific, brief period of time, using an experimental paradigm that allowed for an observable indicator of pain tolerance (withdrawal from the stimulus), whereas clinical pain can be substantially more diffuse, without a clear end in sight and with no way to remove the source of the pain. The CAT-VAS provides a means to measure both CAT at a specific moment within a person's pain experience and the direction and magnitude of change in their CAT over time. A possible clinical application of the CAT-VAS would be to determine whether the CAT-VAS held additional predictive utility for the development of a chronic disability by measuring an individual's level of and rate of change in CAT in response to an acute injury, similar to Linton and colleagues' prospective study of the development of chronic low back pain after injury.

Adjustments to the implementation of the CAT-VAS would be necessary to accurately assess an individual's cognitive response to a more ongoing pain state as opposed to pain a stimulus with a known onset. A particularly promising means of assessing change in coping strategy use over time has been the use of daily diaries (e.g., Gil et al., 2001); applying this methodology to the CAT-VAS could allow one to assess change in CAT over time in a more chronic pain condition and to use this change over

time as a predictor of pain outcomes. In particular, using in-the-moment assessments prompted by electronic alerts (e.g., Smyth et al., 1998) could provide an interesting means to elicit in-the-moment CAT ratings from individuals with ongoing pain; this approach could help one to determine whether in-the-moment CAT ratings serve as better predictors of change and psychological adjustment in ongoing pain than retrospective recall of pain and CAT by conventional daily diary. Further testing would be needed to determine whether the current time interval between CAT-VAS ratings (30 seconds) is appropriate for use among individuals with ongoing pain, as the current study enrolled only healthy individuals.

In terms of other theoretical models of CAT, the study protocol limited the capacity for participants to use a communal coping approach by soliciting help from others. Experimenters were not permitted to offer responses to participants' utterances during the pain tasks, which may have limited the likelihood that solicitous comments would be reinforced (Thorn, 2003). This aspect of the pain tasks may have influenced participants away from solicitation of assistance and toward selecting a coping strategy that was targeted more directly at pain relief (Sullivan et al., 2001). It is unclear whether allowing the possibility of soliciting help or distraction from others during this protocol would mitigate the utility of the cognitive skills intervention.

A particularly interesting pattern within the analyses suggests the possibility of mediation of pain outcomes through a reduction in CAT. For cold pressor pain tolerance, intervention group was a significant predictor of an individual's likelihood of terminating the pain tasks before 180 seconds when entered as the sole predictor but no longer reached significance when CAT-VAS variables were added as predictors to the model.

Prior research has suggested that changes in perceived pain intensity, as well as pain-related disability, are mediated through CAT for low back pain (Smeets et al., 2006). Furthermore, CAT appears to mediate of the relationships between gender and pain (Edwards et al., 2004) and between depression and pain (Geisser et al., 1994). Further research explicitly examining these relationships could determine whether change in CAT is a necessary component of successful psychological interventions for pain reduction.

In closing, CAT appears to be a vitally important element linking psychosocial variables to pain outcomes including subjective pain experience, pain behavior and adjustment to pain. Given these strong relationships, cognitive-behavioral interventions targeting CAT appear highly promising for alleviating pain through psychological means. In particular, interventions that allow for practice of coping skills in response to a specific painful event may show improved efficacy. Lastly, by examining CAT closely, both at the moment that pain is experienced and as its intensity and frequency change over time, one can obtain richer and more useful information about these relationships; this information may lead to further innovations in the application of cognitive skills to improve individuals' response to pain within a variety of clinical and nonclinical contexts.

Table 1

Differences between Intervention Groups, Study Completers and Non-Completers

	Intervention Groups		Completers vs. Non-Completers	
	X^2	df	X^2	df
Race	13.3	8	1.03	4
White vs Others	7.46*	2	0.00	1
Black vs Others	9.23***	2	0.00	1
	F	df	F	df
Gender	0.87	2,108	0.00	1,115
Age	0.23	2,108	0.34	1,115
Current Pain	1.35	2,108	8.87**	1,115
PCS (pre-exp.)				
Total	0.61	2,108	0.29	1,115
Magnification	1.30	2,108	0.06	1,115
Rumination	0.23	2,108	0.78	1,115
Helplessness	0.50	2,108	0.17	1,115
PANAS				
Positive Affect	0.20	2,108	0.80	1,115
Negative Affect	0.06	2,107	0.64	1,114
CES-D	1.48	2,106	1.27	1,113
CSQ				
Total	1.15	2,108	0.27	1,115
Diverting Attention	1.03	2,108	0.04	1,115
Reinterpreting Sensations	0.10	2,108	0.69	1,115
Coping Self-Statements	1.10	2,108	0.03	1,115
Ignoring Sensations	0.19	2,108	0.73	1,115
Praying/Hoping	0.36	2,108	1.02	1,115
Catastrophizing	0.69	2,108	0.36	1,115
Activity	2.17	2,108	0.02	1,115
Pain Behaviors	0.58	2,108	0.61	1,115
Pain Control	0.11	2,108	3.64	1,115
Pain Decrease	4.09	2,108	0.13	1,115

*p < .05.

**p < .01.

***p < .001.

Table 2
Descriptive Statistics for Pre-Experimental Visit Questionnaires

	Mean (SD)	Observed Range	Possible Range
PCS			
Total	16.3 (9.0)	0 to 39	0 to 52
Helplessness	6.0 (4.2)	0 to 20	0 to 24
Magnification	2.9 (2.2)	0 to 11	0 to 12
Rumination	7.4 (4.1)	0 to 16	0 to 16
PANAS			
Positive	33.7 (6.5)	15 to 50	10 to 50
Negative	18.3 (5.0)	10 to 32	10 to 50
CES-D	12.3 (8.1)	0 to 38	0 to 40
CSQ			
Diverting Attention	15.2 (7.5)	0 to 32	0 to 36
Reinterpret Sensation	7.4 (7.1)	0 to 30	0 to 36
Coping Self-Statements	22.3 (7.1)	3 to 36	0 to 36
Ignoring Sensations	15.1 (8.2)	0 to 36	0 to 36
Praying/Hoping	12.4 (8.5)	0 to 35	0 to 36
CAT	6.1 (5.7)	0 to 25	0 to 36
Increase Activity Level	15.8 (6.1)	1 to 29	0 to 36
Pain Behaviors	18.0 (6.0)	4 to 33	0 to 36
Pain Control	4.0 (1.0)	1 to 6	0 to 6
Pain Decrease	3.5 (1.1)	0 to 6	0 to 6

Table 3
Descriptive Statistics for Pain Tasks, All Groups

	Mean Intensity	Mean Unpleasantness	Mean seconds before STOP	Percent reaching 180 seconds
Cold 1	70.0	76.3	38	40%
Cold 2[A]	64.9	69.7	42	47%
Pressure 1	38.8	46.6	65	91%
Pressure 2	40.0	46.8	88	84%
Pressure 3[A]	31.1	33.9	102	92%

[A]Post-intervention task.
[B]Mean seconds applies only for tasks that were ended; that is, tasks that reached 180s are excluded from this calculation.

Table 4

Means and Standard Deviations of Estimated CAT-VAS Variables

	CAT-VAS Slopes			
	All Groups	Cognitive	Positive Mood	Neutral Mood
Cold 1	0.39 (0.24)	0.41 (0.27)	0.43 (0.26)	0.34 (0.20)
Cold 2[A]	0.38 (0.31)	0.34 (0.32)	0.44 (0.33)	0.37 (0.28)
Pressure 1	0.27 (0.18)	0.29 (0.20)	0.26 (0.17)	0.27 (0.16)
Pressure 2	0.30 (0.27)	0.34 (0.29)	0.28 (0.27)	0.30 (0.26)
Pressure 3[A]	0.17 (0.18)	0.15 (0.18)	0.13 (0.14)	0.22 (0.22)

	CAT-VAS Intercepts			
	All Groups	Cognitive	Positive Mood	Neutral Mood
Cold 1	46.7 (17.4)	44.9 (17.0)	42.9 (14.4)	52.1 (19.5)
Cold 2[A]	42.0 (18.6)	34.9 (17.9)	42.7 (15.0)	47.7 (20.6)
Pressure 1	16.3 (14.8)	18.1 (13.9)	12.2 (12.5)	18.7 (17.0)
Pressure 2	10.5 (11.6)	11.6 (11.0)	8.2 (9.6)	12.0 (13.8)
Pressure 3[A]	9.5 (12.1)	7.7 (9.2)	6.7 (9.2)	14.0 (15.4)

[A]Post-intervention task.

Table 5
Omnibus Tests of Relationships between Covariates and Pain Self-Report

	Pressure 1		Pressure 2		Cold 1	
	Wilks' Λ	F (df)	Wilks' Λ	F (df)	Wilks' Λ	F (df)
Male	0.93	3.96* (2,107)	0.93	4.04* (2,107)	0.94	3.31* (2,107)
Age	0.97	1.52 (2,107)	0.99	0.36 (2,107)	1.00	0.26 (2,108)
Race	0.81	2.83** (8,208)	0.83	2.54* (8,208)	0.89	1.55 (8,210)
PCS (pre-exp.)	0.92	2.54* (2,107)	0.95	2.62 (2,107)	0.91	5.18** (2,108)
PANAS						
Positive	0.97	1.46 (2,104)	1.00	0.25 (2,104)	0.97	1.38 (2,105)
Negative	0.98	0.93 (2,104)	1.00	0.03 (2,104)	0.98	0.89 (2,105)
CES-D	0.95	2.82 (2,105)	0.98	1.05 (2,105)	0.96	2.32 (2,106)
CSQ						
CAT	0.94	3.31* (2,98)	0.99	0.47 (2,98)	0.96	2.23 (2,99)
Reinterpret	0.94	3.08 (2,98)	0.97	1.47 (2,98)	0.97	1.37 (2,99)
Sensations						

No other CSQ subscales showed significant relationships with pain self-report ($p > .20$).
*$p < .05$.
**$p < .01$.

Table 6

Univariate Tests of Relationships between Covariates and Maximum Pain Intensity

	Pressure 1		Pressure 2		Cold 1	
	β	t (df)	*β*	t (df)	*β*	t (df)
Male	-11.66	-2.47* (109)	-11.89	-2.41* (109)	-10.09	-2.59* (110)
Age	-0.96	-1.75 (109)	-0.49	-0.77 (109)	0.32	0.70 (110)
PCS (pre-exp.)	0.71	2.71** (109)	0.58	2.12* (109)	0.67	3.13** (109)
PANAS						
Positive	-2.43	-1.70 (105)	-0.74	-0.49 (105)	-0.84	-0.70 (106)
Negative	-3.02	-1.29 (105)	-0.17	-0.07 (105)	-0.69	-0.34 (106)
CES-D	0.63	2.14* (105)	0.44	1.43 (105)	-2.43	2.09* (106)
CSQ						
CAT	1.32	2.58* (99)	0.47	0.85 (99)	0.92	2.07* (100)
Reinterpret	-0.95	-2.48* (99)	-0.71	-1.72 (99)	-0.54	-1.63 (100)
Sensations						
	β	F (df)	*β*	F(df)	*β*	F (df)
Race	NA	4.59** (4,105)	NA	3.71** (4,105)	NA	1.17 (4,106)
	R^2		R^2		R^2	
Overall model	.24		.20		.14	

No other CSQ subscales showed significant relationships with pain self-report.

R^2 is calculated from models predicting unpleasantness from only the retained covariates (gender, race, PCS total from the pre-experimental visit).

* $p < .05$.

** $p < .01$.

*** $p < .001$.

**** $p < .0001$.

Table 7
Univariate Tests of Relationships between Covariates and Maximum Pain Unpleasantness

	Pressure 1		Pressure 2		Cold 1	
	β	t (df)	*β*	t (df)	*β*	t (df)
Male	-14.11	-2.82** (109)	-15.00	-2.85** (109)	-8.66	-2.22* (110)
Age	-0.83	-1.41 (109)	-0.53	-0.85 (109)	0.24	0.53 (110)
PCS (pre-exp.)	0.86	3.07** (109)	0.68	2.29* (109)	0.65	3.09** (109)
PANAS						
Positive	-2.37	-1.54 (105)	-0.32	-0.20 (105)	0.14	0.12 (106)
Negative	-3.38	-1.34 (105)	0.13	0.05 (105)	-0.64	-0.32 (106)
CES-D	0.39	1.22* (107)	0.38	1.12 (107)	0.38	1.52* (108)
CSQ						
CAT	1.12	2.02* (99)	0.58	0.97 (99)	0.68	1.52 (100)
einterpret Sensations	-0.90	-2.18* (99)	-0.69	-1.55 (99)	-0.41	-1.24 (100)
	β	F (df)	*β*	F(df)	*β*	F (df)
Race	NA	1.99 (4,105)	NA	2.32 (4,105)	NA	1.52 (4,106)
	R^2		R^2		R^2	
Overall model	.18		.17		.14	

No other CSQ subscales showed significant relationships with pain self-report.
R^2 is calculated from models predicting unpleasantness from only the retained covariates (gender, race, PCS total from the pre-experimental visit).
* $p < .05$.
** $p < .01$.
*** $p < .001$.
**** $p < .0001$.

Table 8
Covariates for Pain Tolerance (Time Elapsed Before Task Ended)

	Pressure 1		Pressure 2		Cold 1	
	β	X^2	β	X^2	β	X^2
Male	0.81	1.35	0.87	3.52	0.52	8.92**
Age	0.00	0.00	0.03	0.27	-0.06	3.16
Race		†		†	NA	11.48*
Black - White					-0.65	9.32**
PCS (pre-exp.)	-0.01	0.08	-0.00	0.01	0.00	0.00
PANAS						
Positive	0.03	0.42	0.01	0.40	-0.00	0.06
Negative	0.03	0.17	0.02	0.27	0.00	0.00
CES-D	0.01	0.14	0.12	0.26	0.00	0.07
CSQ						
Diverting Attention	0.06	0.78	-0.04	1.73	0.08	10.03**
Praying/hoping	-0.09	2.74	-0.04	2.70	-0.05	6.32*

df for X^2 tests = 1 for all tests except overall effect of race, where df = 4.
No other CSQ subscores were significant predictors of pain tolerance in the model.
†A maximum likelihood solution could not be converged upon for these tests.

Table 9
Predictors of Post-Intervention CAT-VAS Ratings

	Pressure 3		Cold 2	
	β	t (df = 534)	*β*	t (df = 311)
CAT-VAS				
Slope	0.23	2.84**	18.0	3.17**
Intercept	0.61	5.72****	1.11	11.93****
Male	-0.49	-0.51	-1.64	-0.55
PCS (pre-exp.)	-0.07	-0.71	-0.25	-1.55
	F (df)		F (df)	
Race	0.94 (4,534)		0.54 (4,311)	
Intervention Group	5.51** (2,534)		6.33** (2,311)	
	β	t (df = 534)	*β*	t (df = 311)
Contrasts				
Cognitive – others	-5.1	-2.87**	-10.2	-3.41***
Cognitive – Neutral	-6.5	-3.32**	-8.4	-2.45*
Cognitive – Positive	-3.6	-1.73	-12.0	-3.47**

[B]Slope/intercept for the second pre-intervention pressure task; slope and intercept from the first pre-intervention pressure task were included in model but NS (p>.75).
* p < .05.
** p < .01.
*** p < .001.
**** p < .0001.

Table 10
Omnibus Tests of CAT-VAS and Covariates Predicting Pain Intensity and Unpleasantness

	Pressure 1		Pressure 2		Cold 1	
	Wilks' Λ	F (df)	Wilks' Λ	F (df)	Wilks' Λ	F (df)
CAT-VAS Slope	0.62	30.13**** (2,100)	0.57	37.61**** (2,100)	0.74	17.53**** (2,101)
CAT-VAS Intercept	0.84	9.60*** (2,100)	0.94	3.41* (2,100)	0.76	16.10**** (2,101)
Male	1.00	0.23 (2,100)	0.99	0.32 (2,100)	1.00	0.04 (2,101)
Race	0.89	1.46 (8,200)	0.91	1.27 (8,200)	0.92	1.11 (8,202)
PCS (pre-exp.)	0.99	0.37 (2,100)	0.98	0.28 (2,100)	0.98	0.78 (2,101)

*p < .05.
**p < .01.
***p < .001.
****p < .0001.

Table 11

Univariate Tests of CAT-VAS and Covariates Predicting Subjective Pain Report

	Maximum Pain Intensity					
	Pressure 1		Pressure 2		Cold 1	
	β	t (df = 101)	β	t (df = 101)	β	t (df = 102)
CAT-VAS Slope	72.82	6.58****	59.12	7.93****	33.81	4.81****
Intercept	0.54	4.17****	0.45	2.62**	0.60	5.44****
Male	2.56	0.67	2.37	0.12	-0.28	-0.08
PCS (pre-exp.)	0.17	0.81	0.21	1.03	0.24	1.20
	F (df = 4, 101)		F(df = 4, 101)		F (df= 4, 102)	
Race	1.32		1.20		1.04	
	R^2		R^2		R^2	
Overall	.55		.56		.39	
	Maximum Pain Unpleasantness					
	Pressure 1		Pressure 2		Cold 1	
	β	t (df = 101)	β	t (df = 101)	β	t (df = 102)
CAT-VAS Slope	89.55	7.55****	67.89	8.38****	40.27	5.95****
Intercept	0.54	3.89***	0.38	2.04*	0.57	5.36****
Male	1.48	0.36*	0.50	0.12	0.34	0.10
PCS (pre-exp.)	0.17	0.76	0.50	0.12	0.34	1.18
	F (df = 4, 101)		F(df = 4, 101)		F (df= 4, 102)	
Race	0.50		0.49		0.68	
	R^2		R^2		R^2	
Overall	.54		.56		.43	

*p < .05.
**p < .01.
***p < .001.
****p < .0001.

Table 12

Means and Standard Deviations of Difference Scores for Self-Reported Pain

	Intensity			
	All Groups	Cognitive	Positive Mood	Neutral Mood
Pressure 2 – Pressure 1	0.9 (15.0)	1.8 (15.7)	-0.1 (17.4)	1.1 (12.0)
Pressure 3[A] – Pressure 2	-9.6 (17.8)	-12.6 (18.5)	-11.0 (17.5)	-5.4 (17.0)
Cold 2[A] – Cold 1	-4.2 (12.9)	-9.8 (14.0)	0.5 (12.5)	-3.7 (10.2)
	Unpleasantness			
	All Groups	Cognitive	Positive Mood	Neutral Mood
Pressure 2 – Pressure 1	0.2 (13.5)	-0.8 (14.4)	1.5 (14.4)	-0.2 (11.8)
Pressure 3[A] – Pressure 2	-13.6 (21.4)	-17.2 (21.7)	-17.4 (19.4)	-6.5 (21.9)
Cold 2[A] – Cold 1	-5.4 (15.1)	-14.3 (19.5)	-1.2 (11.9)	-1.4 (8.7)

[A]Post-intervention task.

Table 13
Regression Coefficients for Measures Predicting CAT-VAS Ratings

	Pressure 1		Pressure 2		Cold 1	
	β	t (df)	*β*	t (df)	*β*	t (df)
PCS (pre-exp.)						
Total	0.50	2.73** (521)	0.35	2.33* (507)	0.84	3.73*** (263)
Helplessness	-0.25	-0.41 (520)	-0.20	-0.40 (506)	0.31	0.41 (263)
Magnification	-0.28	-0.32 (520)	-0.40	-0.57 (506)	-0.90	-0.85 (263)
Rumination	1.52	2.52* (520)	1.17	2.36* (506)	2.01	2.72 (263)
CES-D	0.62	3.06** (511)	0.34	2.06* (497)	0.72	2.74** (253)
PANAS						
Positive	-0.41	-1.56 (516)	-0.35	-1.60 (505)	-0.24	-0.67 (258)
Negative	0.84	2.48* (516)	0.40	1.42 (505)	0.63	1.42 (258)
CSQ[A]						
CAT	0.92	2.60** (521)	0.57	1.89 (507)	0.90	2.00* (263)
Activity level	0.78	2.16* (521)	0.55	1.78 (507)	0.23	0.50 (263)
Reinterpret sensations	-0.50	-1.88 (521)	-0.16	-0.70 (507)	-0.33	-1.00 (263)
Pain behaviors	0.14	0.41 (521)	-0.29	-1.00 (507)	0.88	2.08* (263)
Pain control	-1.13	-0.53 (521)	0.01	0.01 (507)	-3.85	-1.47 (263)

[A]Aside from reported subscales, no other CSQ subscores had p <.25.
*p < .05.
**p < .01.
***p < .001.

Table 14
Means and Standard Deviations for Exit Questionnaire Responses

Question	All Groups	Cognitive	Positive Mood	Neutral Mood	Group Differences[A]
1. Logical	6.4 (2.5)	7.9 (1.5)	5.7 (2.5)	5.5 (2.4)	Overall***, C>N****, C>P****
2. Confident	5.1 (2.8)	5.5 (2.8)	4.8 (2.8)	5.0 (2.9)	None
3. Lower CAT	5.3 (2.7)	6.4 (2.3)	5.1 (2.6)	4.5 (2.9)	Overall**, C>N** C>P*
4. Lower pain	5.0 (2.8)	5.6 (2.6)	4.8 (2.7)	4.6 (2.9)	None
5. Recommend	5.5 (3.0)	7.5 (1.9)	4.9 (2.8)	4.1 (3.0)	Overall***, C>N****, C>P****

1. *" How logical did the things you did with the trainer between cold water tasks seem to you?*
2. *"How confident were you that what you did with the trainer after the first cold water task would help you to get through the second one?"*
3. *"Think about what you did with the trainer between cold water tasks. How successful do you think this was in helping you manage your CATASTROPHIZING?*
4. *"Again, think about what you did with the trainer between cold water tasks. How successful do you think this was in helping you manage your PAIN?"*
5. *How confident would you be in recommending the things you did with the trainer to a friend who would be going through a similar set of tasks?"*

[A]Group differences were assessed using ANOVA.
* $p < .05$.
** $p < .01$.
*** $p < .001$.
**** $p < .0001$.

Table 15
Mood VAS Ratings by Time and Intervention Group

	Positive Mood VAS			
	All Groups	Cognitive	Positive Mood	Neutral Mood
T1: before pain tasks	70.7 (16.2)	66.9 (16.5)	72.8 (20.5)	72.2 (16.2)
T2: before Cold 1	63.7 (21.2)	60.8 (23.0)	65.2 (20.6)	64.8 (20.4)
T3: before Cold 2[A]	66.7 (21.8)	66.3 (23.2)	69.6 (21.8)	64.0 (20.6)
T4: after Cold 2[A]	60.6 (23.6)	61.4 (23.1)	61.3 (26.1)	59.3 (21.9)

	Negative Mood VAS			
	All Groups	Cognitive	Positive Mood	Neutral Mood
T1: before pain tasks	23.7 (19.6)	24.7 (19.8)	20.5 (17.4)	26.0 (21.5)
T2: before Cold 1	30.6 (20.8)	34.1 (23.4)	27.4 (19.1)	30.7 (20.1)
T3: before Cold 2[A]	25.2 (20.8)	24.2 (20.4)	21.5 (20.9)	29.9 (20.9)
T4: after Cold 2[A]	31.4 (23.7)	28.5 (22.0)	29.9 (24.2)	35.6 (24.6)

[A]Post-intervention task.

Figure 1
Study Design Flow Chart

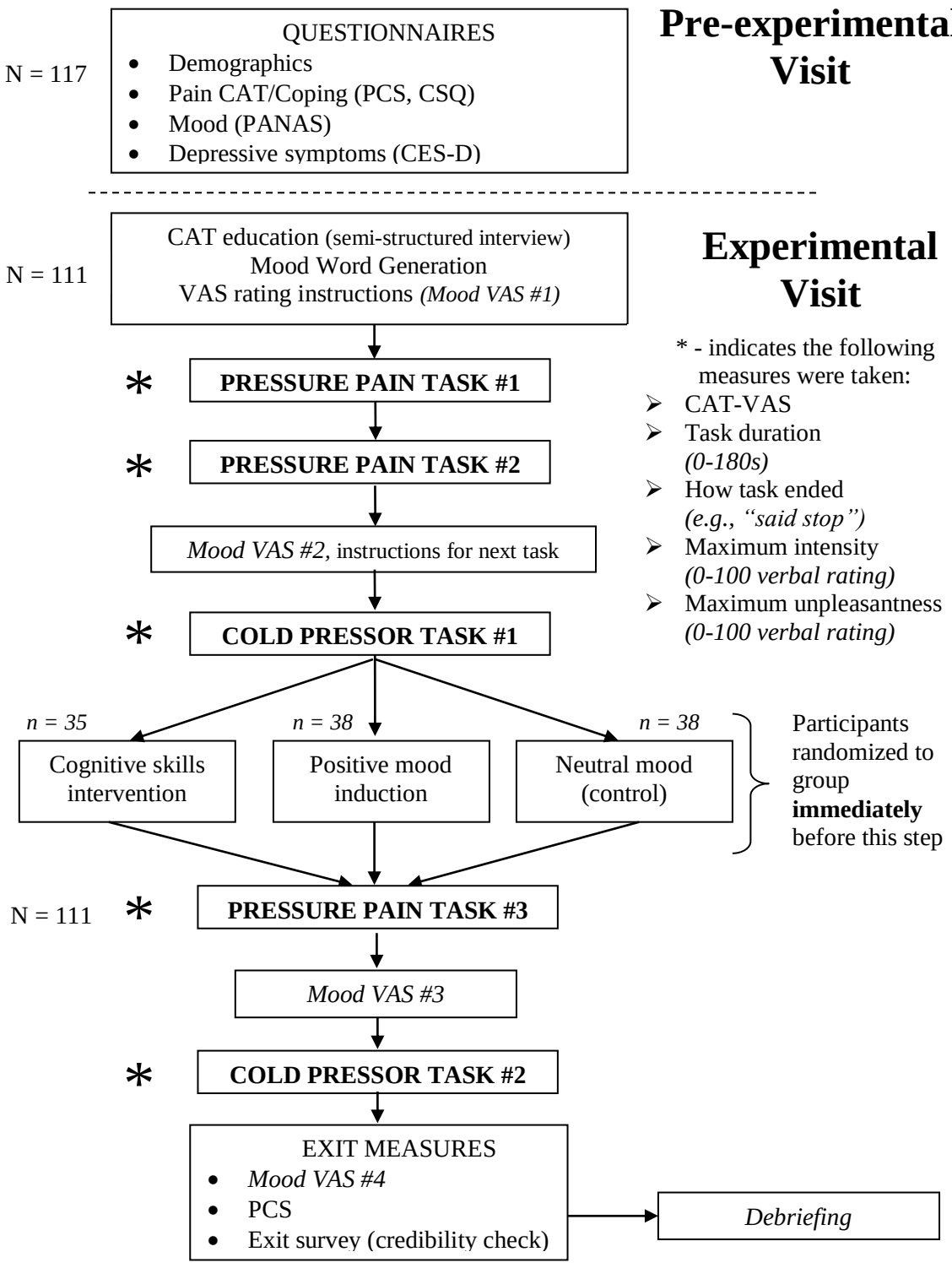


Figure 2

Maximum Pain Intensity and Unpleasantness by Task, All Groups

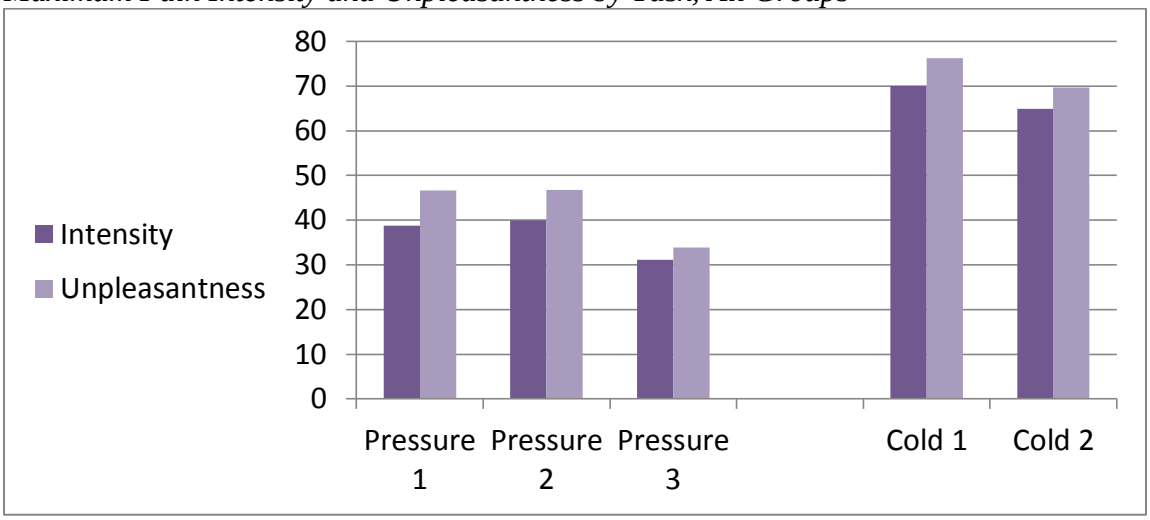


Figure 3
Histogram of Pre-Intervention Cold Pressor Pain Tolerance

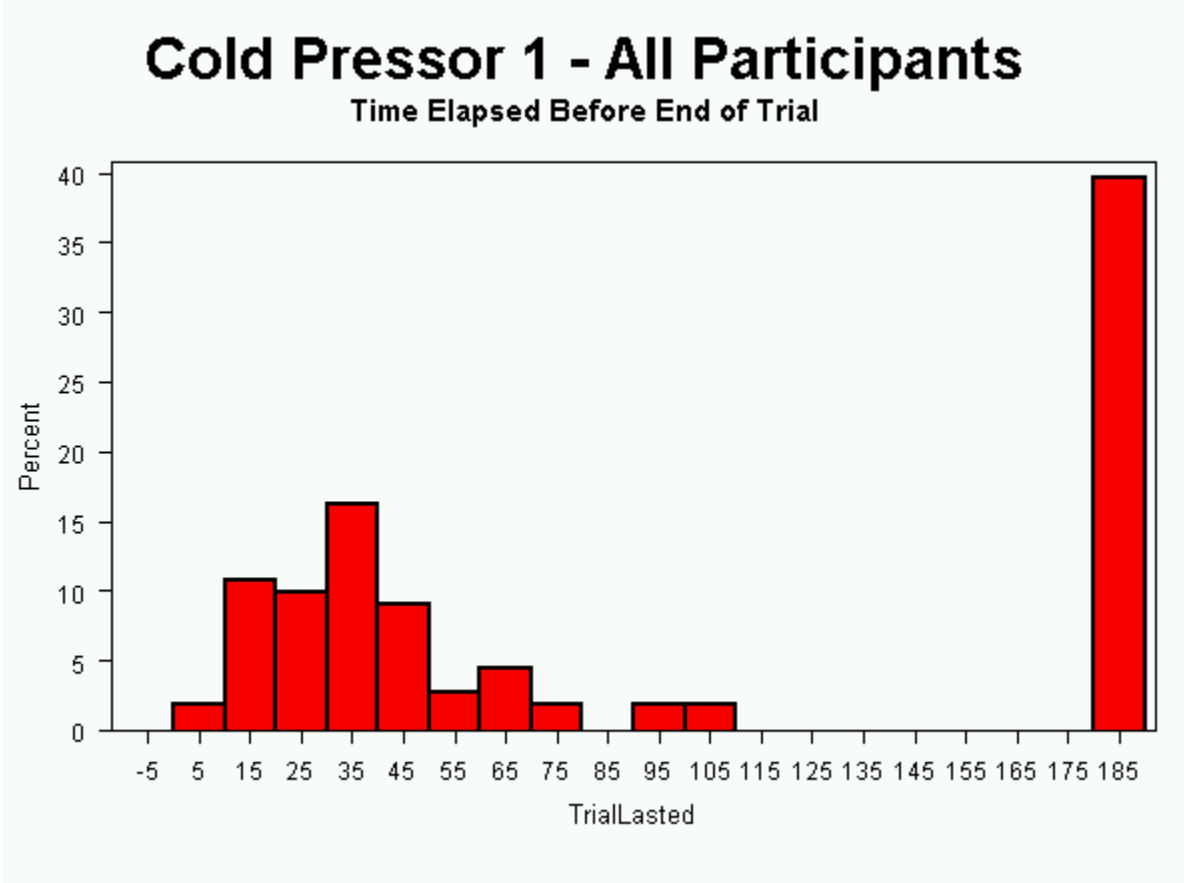


Figure 4

Survival Estimates for Post-Intervention Cold Pressor Task

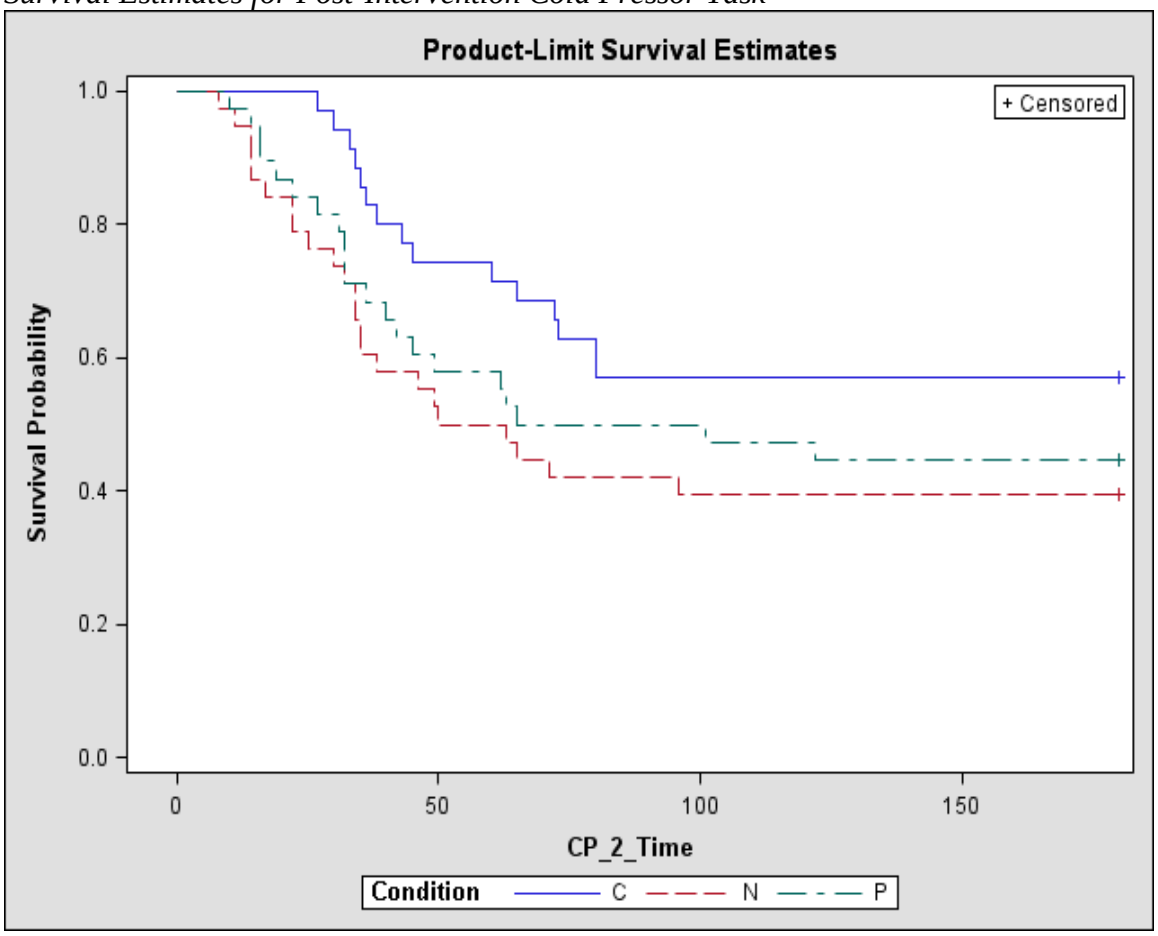


Figure 5

Positive Mood VAS Ratings by Time and Intervention Group

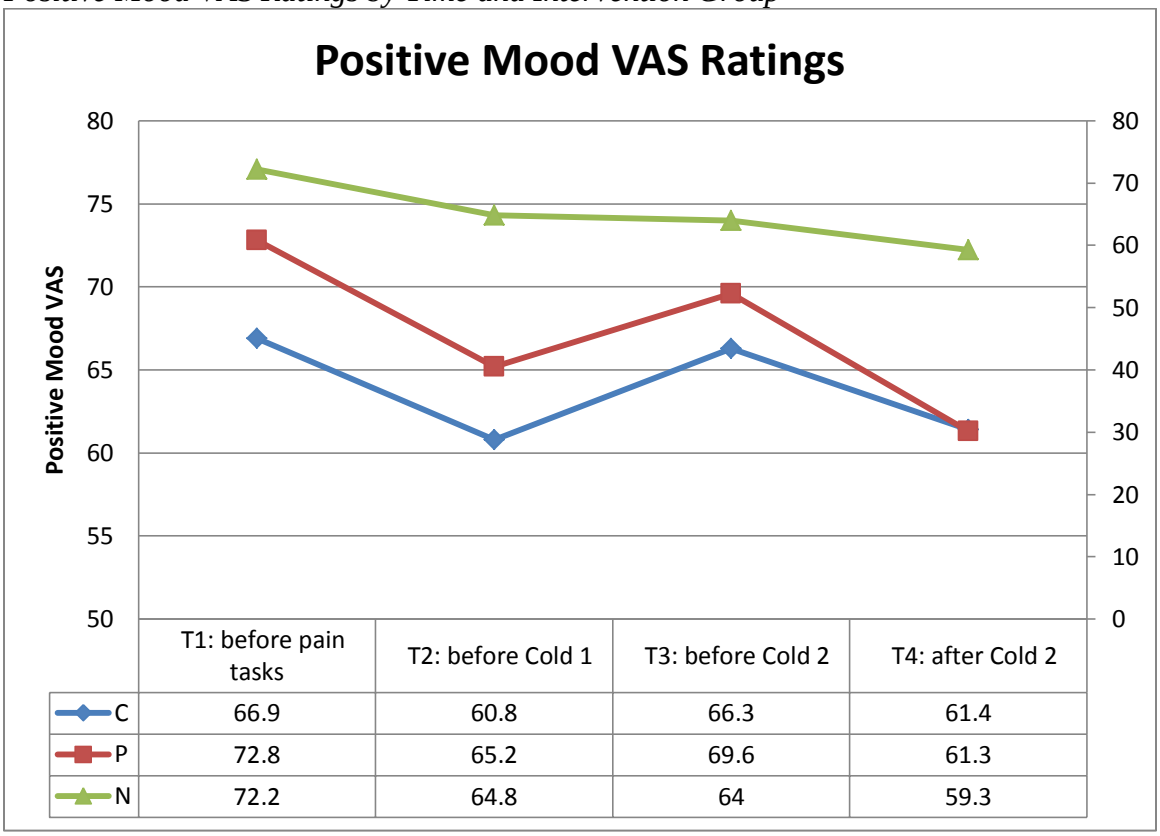
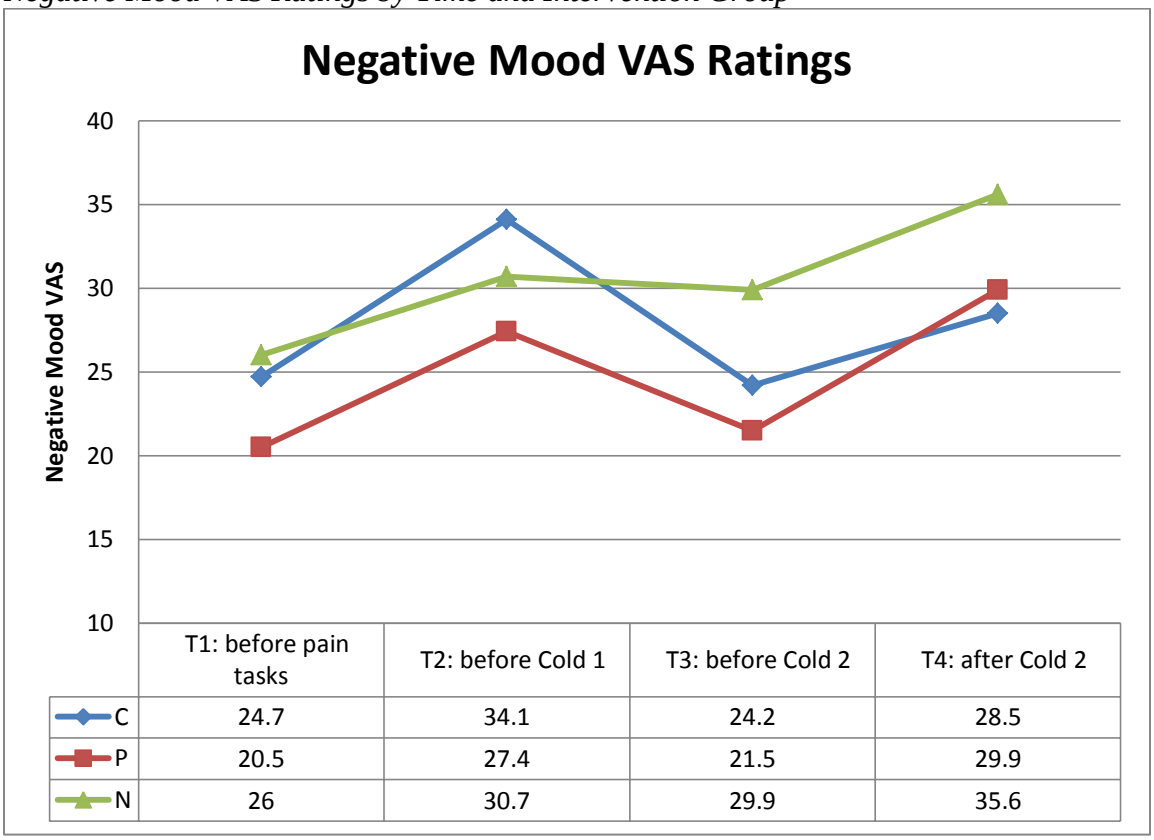


Figure 6

Negative Mood VAS Ratings by Time and Intervention Group



	T1: before pain tasks	T2: before Cold 1	T3: before Cold 2	T4: after Cold 2
C	24.7	34.1	24.2	28.5
P	20.5	27.4	21.5	29.9
N	26	30.7	29.9	35.6

Appendix 1
Demographics and Exclusion Criteria Questionnaire

Welcome to our study and thank you for participating!

Please answer the following questions about yourself. If you wish to skip questions, you are free to do so – please **put an X through any questions you wish to skip**. If you have questions, **please ask.**

1. What is your date of birth? _____

2. What is your gender? _____

3. Are you right or left handed? Please circle one: Left Right Both

4. How do you identify in terms of ethnicity/race? Please circle all that apply, or describe below:

American Indian/Alaskan Native
Asian
Native Hawaiian or Other Pacific Islander
Black or African American
White

Other *(please describe):*

5. Do you identify as Hispanic or Latino/a?
Circle one: Yes No

6. Are you in pain today?
Circle one: Yes No
If you answered "yes": What kind of pain? Where is it? _____
_____
How intense is the pain on a 0-10 scale (10 = worst possible pain)? _____

7. Have you taken any pain medication today?
Circle one: Yes No
If "yes": please specify the medication and, if possible, the dosage: _____
_____

8. Do you have any chronic, painful conditions (e.g., migraines, arthritis), **OR** any condition that would affect your ability to sense temperature or pressure?
Circle one: Yes No
If "yes": Please specify as best you can. _____
_____

9. Do you have Reynaud's disease, prior frostbite, or any medical condition that indicates that part or all of your body should not be exposed to very cold temperatures?
If "yes": Please specify as best you can. _____
_____

10. Have you ever been in a study in which you were exposed to cold temperatures?
Circle one: Yes No
If "yes": Please describe it as best you can: _____
_____

THANK YOU!

Appendix 2
Additional Information Concerning Pain Testing

Pressure tasks:
The Forgione-Barber device is operated as follows. First, the participant inserts the index or middle finger from his or her nondominant hand into a small chamber and leaves it resting there. The participant's arm rests parallel to the floor; the chamber reduces the range of horizontal movement of the finger. A plastic wedge with a dull Lucite edge is then lowered onto the finger between the first and second phalanges by means of a hinged door-like apparatus. The device alone exerts a force of approximately 1 Newton (N) on the finger; to increase the amount of stimulation, an additional weight of 6 ounces was applied onto the flat surface on the hinged door above the wedge.

Cold pressor tasks:
The cold pressor apparatus consisted of an insulated container, sufficiently deep to accommodate a participant's hand up to the wrist, a small motor to circulate water (i.e., to avoid local warming of the water by the hand), and a thermometer that could be submerged underwater. Cold water and ice were used to establish and maintain a temperature between 1 and 2 degrees Celsius before the beginning of a task; prior research has suggested that stimuli that vary within a range of greater than 2 degrees Celsius can increase considerably the range of pain tolerances one observes (Mitchell et al., 2004). This temperature range was selected because it was considered intense enough that a substantial portion of participants would end the task early, giving sufficient variability for analysis of pain tolerance. Submersion of the hand in room temperature water prior to cold pressor was employed because both ambient temperature of the environment and participants' own arm temperatures impact the reliability of the cold pressor task (Meagher et al., 2001; Sullivan et al., 1995; Sullivan et al., 2000). The tester retrieved the cold water bath from the adjacent room while the participant had his or her hand submerged in room temperature water; during pressure tasks, the trainer prepared the cold water bath and assured that the temperature was within the range needed for the experiment. After returning to the main room, the tester first gave instructions for the cold pressor task, then prompted participants to remove their hand from the room-temperature water, to ensure that the participant's hand had been in the room temperature water for a sufficient duration.

Both tasks:
During each pain task, the tester asked the participant to rate their level of catastrophizing on the CAT-VAS every 30 seconds. The task duration and rating intervals were selected as a compromise for several considerations in designing this study, including minimizing the distraction from pain built into the experiment, ensuring that amounts of and variation in pain intensity and unpleasantness allow for sufficient power for statistical analyses, and balancing intensity of pain with likelihood of withdrawal from the painful stimulus for both the pressure tasks and the cold pressor tasks.

Appendix 3
Instructions for Cold Pressor Task 1

Tester:
"Instead of using pressure, the next task involves putting your hand into freezing cold water. Before we do this, you need to be aware that a lot of people find this one to be much worse than the pressure, and sometimes participants from the participant pool have said that it is overwhelming.[1]

Once the task begins, try to keep your hand in the water as long as possible. Remember that you can stop at any time by saying "STOP" or pulling your hand out of the water. If you do that, remember to rate your catastrophizing right away on the next line. Once the task is over, I'll ask you to rate the intensity and unpleasantness of this sensation from zero to 100. Do you understand?

Alright. When I say, 'NOW', put your hand in the water and rate your catastrophizing at the same time. Ready? NOW."

[1]Underlined sections were only read for participants randomized to the CAT induction procedure, which was dropped after the first 21 participants and did not significantly change CAT ratings.

Appendix 4
Trainer Script for Cognitive Skills Intervention Group

Trainer:
"We are going to have a short rest time now to let your hand warm up again before we do the second cold water trial. In the meantime, we are going to look at your catastrophizing thoughts again and talk about ways to reduce them when you are having pain or unpleasant sensations. When we are done talking about this, we'll do another trial of the pressure to give you a chance to practice those. Okay?

"Alright, let's go over some ways that people reduce catastrophizing. I'll introduce two, then we'll work together on the third, but what they all share in common is that they change what you are thinking. Do you understand so far? Okay.

"The first way that people reduce catastrophizing is by paying close attention to something else. Some people do this with distraction – paying very close attention to things in their physical surroundings like sights or sounds, or to their breathing. But in any case, they pay close attention to something different from their thoughts about the pain. Make sense so far? Okay.

"The second kind of tactic that people use is different – it's sometimes called mindfulness or acceptance. When people try this, they try to just accept the pain they are experiencing without worrying about it. Sometimes they will notice thoughts or worries going through their minds, but they just try to let the thoughts go through their minds without holding onto them at all. So, instead of focusing on how bad pain is, they either try to accept the pain just as it is, or they just try to let the thoughts about how bad the pain is pass through without dwelling on it. Does that make sense?

"The third tactic is called cognitive restructuring. Here's how it works. When people catastrophize about pain, they can think the pain is really terrible, when in reality it may not be as bad as it seems. But, if people look closely at what they're thinking, there is often a way to reframe that thought into something more realistic or positive – or a more realistic or positive thought they can substitute in for the original thought. If they change or restructure their thoughts that way, they can reduce their catastrophizing. (Make sense? Let's try it out.)

"Let's look at your list of thoughts together. What was the first one you wrote? *[Wait for participant to read thought aloud.]* If you were going to restructure that thought – to reframe it in a more realistic or positive way, what would the thought be instead? (What about a different, more positive thought you could substitute for that one?)

If participant (P) reports that they can't think of a restructured thought, say:
"It's okay, this can be hard. I'm sure there's a way to do it, though. Let me show you a couple of examples." *[Show list of thoughts/responses to P]*

Once they have a restructured thought, say:
"Alright, so that's how you can change that one. Can you please write that new thought down underneath or next to the original one?"

Trainer goes through the list of thoughts with P and asks P to write counterthoughts as they are generated until the list is exhausted.

"Alright! Great, thank you. For the rest of the trials in the study, I want you to try to use some of those strategies to reduce your catastrophizing. Can you name them for me?"

T restates the names of the strategies if P cannot name them all.

"Thank you! I'll let the other researcher know we're done for now."

Appendix 5
Restructuring Thoughts

If you have the troublesome thought:	Try to substitute these thoughts:
I can't deal with this.	*A little fear is okay, I can live with that and I can manage it.* *I can manage this.* *I need to try out some of the new techniques I just learned.*
It's never going to get better. *It's never going to end.*	*Even though this feels bad, it will be over soon.* *I can make it through this.* *It's only temporary.* *I am in control over what happens to me.*
I can't stop thinking about this.	*It is okay to think about this. That doesn't mean it's the end of the world.* *I can put my attention wherever I want to put it.*

Appendix 6
Trainer Script for Positive and Neutral Mood Groups

Trainer:
"You're going to have a short rest time now to let your hand warm up again before we do the cold water task again. In the meantime, there is a video clip for you to watch. I'm going to watch it together with you, then ask you a couple of questions before we start up again. When the video is done, you'll do another trial of pressure before the cold water task. Okay?"

After the video clip:
"Alright, now I'd like to ask you questions about the mood words we talked about at the start of your visit today. Let's take a look at that. What was the first word you wrote?

After participant reads the word aloud:
"Could you say how much you are feeling that (are feeling [word #1]), on a scale from 0-5? Zero means 'don't feel that at all.' Five means 'feel that completely.'

After participant rates the mood word:
"Alright, please write that down next to the first word you wrote. Now, can you think of another way of saying [word #1] – a synonym for it? What is it?

"Okay, write that word next to the original word as well. Now, let's do that again for the other two words.

"The second word was [word #2]. How much are you feeling that [or, are you feeling [word #2]], from 0-5? Alright, write that down. And can you think of a synonym for [word #2]? Okay, write that down.

"The third word was [word #3]. How much are you feeling that [or, are you feeling [word #3]], from 0-5? Alright, write that down. And can you think of a synonym for [word #3]? Okay, write that down. Thank you!

"Thanks! I'll let the other researcher know we're done for now."

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