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Title of Dissertation: An Exploration of Dispositional Mindfulness and the Mechanisms of Pain Processing in Children

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ABSTRACT

Title of Document: AN EXPLORATION OF DISPOSITIONAL MINDFULNESS AND THE MECHANISMS OF PAIN PROCESSING IN CHILDREN

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Cognitive load has been shown to affect subjective pain experiences for adults, however the current study is the first to examine the effect of cognitive load on distraction effectiveness for children. Additionally, dispositional mindfulness was examined as a part of this study as it is increasingly examined in adult and child samples with regard to the affective processing of pain. To examine these hypotheses fifty-seven children (9-13 years old) experienced three randomly presented heat levels (not painful, slightly painful, moderately painful) during two distraction conditions involving different levels of cognitive load (a high load 'working memory' task and a low load 'motor' control task) in counter-balanced order. Children completed measures of dispositional mindfulness. As predicted, children's pain intensity and pain unpleasantness ratings were lower in the high load condition compared to the low load condition. These differences were amplified in the moderately painful heat trials. In contrast to predictions, dispositional mindfulness was not a significant predictor of the effectiveness of distraction. Dispositional mindfulness was significantly related to measures of children's attentional and emotional control abilities, however a serial mediation model did not produce

significant indirect or overall effects to suggest a strong influence of mindfulness on the effectiveness of distraction. Results demonstrate that distraction that places high demand on executive resources is more effective for acute pain management for children. Further research is needed to examine the potential effects of dispositional mindfulness on the effectiveness of distraction in children.

AN EXPLORATION OF DISPOSITIONAL MINDFULNESS AND THE

MECHANISMS OF PAIN PROCESSING IN CHILDREN

By

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Introduction

Although pain associated with medical procedures is often considered to be routine and ordinary, it is frequently distressing to children and families. As pain is known to be naturally attention capturing for critical evolutionary reasons (Crombez, Van Damme, & Eccleston, 2005), this makes it a challenging negative experience to ameliorate using behavioral and psychological interventions. Researchers have studied effective interventions for acute pain for decades, and have developed theories to explain their effectiveness along the way (Eccleston & Crombez, 1999; Melzack & Wall, 1965). More recently, neuroimaging methods have allowed researchers to examine the underlying mechanisms of pain and of interventions for pain management (Bantick et al., 2002; Bilevicius, Kolesar, & Kornelsen, 2016; Frankenstein, Richter, McIntyre, & Remy, 2001; Zeidan et al., 2015). This has created a surge of evidence that is available for positing new research questions and theories to guide ongoing exploration of pain mechanisms and effective interventions.

Distraction is a widely studied intervention that has significant evidence to support its effectiveness in pediatric and adult acute pain management (Buhle & Wager, 2010; Cohen et al., 1997; Dahlquist, Weiss, et al., 2002; Dahlquist, Pendley, et al., 2002; Legrain, Crombez, Plaghki, & Mouraux, 2013). Distraction is thought to function by limiting the attentional resources available for pain stimuli to capture (McCaul & Malott, 1984). As such, it is thought that distraction tasks that capture more cognitive, or attentional, resources may decrease the amount of attention that is available to process pain stimuli. Evidence for the ideal amount of attentional load has been inconclusive in adult samples (Buhle & Wager, 2010), and has not been experimentally examined in pediatric samples. Therefore the proposed study aims to examine the impact of cognitive load on the effectiveness of distraction in a sample of healthy children.

In addition to studying the effectiveness of distraction at a broader level, researchers have worked to identify key moderators of the effectiveness of distraction, as distraction is known to not be equally effective for all individuals (Verhoeven, Goubert, Jaaniste, Ryckeghem, & Crombez, 2011). For example, research has found that pain catastrophizing moderates the effectiveness of distraction, such that individuals higher on pain catastrophizing benefit less from distraction compared to their peers lower on pain catastrophizing (Verhoeven, Goubert, et al., 2011). However, few studies have examined moderators that may predict improved effectiveness of distraction for children.

Recently, mindfulness meditation has seen significant growth in interest in the field of chronic pain as an intervention, and as a predictor of positive pain outcomes (Chiesa & Serretti, 2011; Kingston, Chadwick, Meron, & Skinner, 2007; Schutze, Rees, Preece, & Schutze, 2010). Research suggests that mindfulness practice results in increases in critical executive functioning skills such as attentional control and emotion regulation (Lyvers, Makin, Toms, Thorberg, & Samios, 2014; Teper & Inzlicht, 2013) and may reduce the negative affective experience of pain. As executive functioning skills are also highly implicated in the experience of acute pain and the mechanisms of distraction, it is hypothesized that mindfulness may moderate the effectiveness of distraction in acute pain management. However, this has not been examined in acute pain research with adults or children.

The proposed study aims to examine the effectiveness of distraction in a controlled laboratory setting to examine dispositional mindfulness as a potential moderator of the effectiveness of distraction. This study aims to inform clinical practice by illuminating valuable, and measureable individual characteristics that may indicate the potential effectiveness of distraction in pediatric acute pain settings.

Literature Review

Standard medical care for children often involves uncomfortable or painful procedures (e.g., immunizations). In the United States, the national childhood immunization schedule recommends upwards of 30 intramuscular immunizations by the time a child is 6 years old, and at a minimum, yearly immunizations for influenza for children and adolescents ages 7 to 18 (CDC, 2016). Children with chronic or acute medical conditions are regularly exposed to more frequent painful medical procedures as a part of diagnosis, monitoring and treatment. For example, children experiencing childhood cancer typically undergo multiple blood draws, port placements, injections, lumbar punctures and bone marrow aspirations. Children following a Children's Oncology Group (COG) treatment protocol experience 8 to 15 invasive procedures in the first month of treatment alone. Children have difficulty coping with these painful experiences, and therefore frequently show signs of emotional and behavioral distress including anxiety, crying, screaming and flailing before and during painful procedures (Dahlquist, Pendley, et al., 2002). Given the necessity of these procedures, children are often subjected to procedures regardless of their willingness to participate, and therefore medical procedures can become distressing to children and parents, as well as disruptive to the functioning of medical clinics and inpatient hospital units.

Impact of Pediatric Acute Pain

Child outcomes. For children who are distressed before and during painful medical procedures, the consequences can be significant. Research suggests that past negative experiences with medical procedures is associated with elevated fear and avoidance of medical care in adulthood (Pate, Blount, Cohen, & Smith, 1996). The impact of the distress associated with painful medical procedures has significant consequences that can impact children's healthcare utilization during childhood as well as their utilization in adulthood.

Parent outcomes. In one study that surveyed parents of children who were at least six months overdue for one or more immunizations, 35% of parents reported that their concern about their child's pain/crying/anxiety relating to the immunization was a factor in their delay in the recommended schedule (Luthy, Beckstrand, & Peterson, 2009). Research with children undergoing cancer treatment shows that parent distress during invasive procedures remains stable throughout the course of treatment, which can be up to several years, suggesting that children and parents likely do not adapt to procedural anxiety and pain without intervention (Kazak, Boyer, Brophy, Johnson, & Scher, 1995).

Medical provider outcomes. The impact of distress associated with pediatric procedural pain on healthcare providers, nursing and child life resources is understudied. In one study, researchers noted that a video distraction intervention that included a nurse coach to encourage attention to the video was a cost-effective intervention for 4- to 6-year-olds during immunizations in reducing distress (Cohen et al., 1997). Another study found that a family-centered preparation protocol had significant cost-saving benefits in a sample of children undergoing surgery (Kain et al., 2006). Although these studies are potentially informative, little research has been conducted on long-term cost-effectiveness of various interventions of pediatric acute pain compared to no intervention. However, extensive anecdotal evidence does suggest that poorly managed procedural pain results in increased nursing time, child life resources, and other costly medical resources.

Pain Processing

Pain is defined by the International Association for the Study of Pain (IASP) as an unpleasant sensory and emotional experience associated with actual or potential tissue damage. Pain is by nature an attention-capturing experience. It serves a critical purpose of interrupting attention when the body senses threat to allow the individual to react quickly and effectively to minimize potential damage to the tissue. Therefore, vigilance to pain is a natural process that serves a positive role in preservation of an individual's health and safety (Crombez et al., 2005). Despite the natural and important aspects of pain, it is clear that pain can occur regardless of actual threat to the individual, and can therefore cause unpleasant sensory and emotional experiences of no functional benefit to the health and safety of the individual. Examples of this include neuropathic pain, phantom-limb syndromes, as well as relatively benign events such as immunizations. Throughout recorded history, pain has been studied with a primary aim of developing interventions to reduce the unpleasantness of pain in settings where behavioral and emotional reaction to pain stimuli is not functional.

Early theories. Early theories of the nature of pain were developed to describe how sensory pain signals throughout the body are transmitted to the brain. Specificity theory proposed that body tissue contains specific pain receptors, which only respond to pain stimuli, and when stimulated send impulses through A-delta and C fibers that travel to the spinal cord and then to a pain center in the brain. Given that this theory had some strong physiological evidence, but did not adequately capture psychological components of pain processing, the Pattern theory was subsequently posited (Melzack & Wall, 1965). Pattern theory held that instead of having unique receptors that respond only to painful stimuli, patterns of stimulation of non-specific receptors were necessary to create the experience of pain. Although both of these theories laid the groundwork for research in pain, they were too simplistic to fully describe pain processes.

Gate control theory. Melzack and Wall (1965) developed the gate control theory of pain to fills gaps in the previous, and comparatively simplistic, theories. Melzack and Wall theorized that pain involves interacting systems within the spinal cord and the brain. The authors describe that pain sensation begins with stimulation of nerve endings in body tissue, which results in signals being sent up to the dorsal horn of the spinal cord through two different types of fibers. The quicker nerve fibers send signals of non-painful stimulation of the tissue, whereas the slower nerve fibers send signals of painful (i.e., nociceptive) stimulation. Therefore, the non-painful stimulation can reach the gate first, and essentially “close” the gate off so that the painful stimulation signals do not reach their destination. Alternatively, if the gate is left open due to lack of non-painful stimulation, the pain stimulation signals are allowed to influence central transmission (T) cells that activate neural mechanisms in the brain associated with pain processing. Similarly, information can originate in supraspinal regions and modulate the gate from the other direction, suggesting that pain can occur without stimulation of nerves in tissue (Melzack & Wall, 1965). The gate theory of pain remains the most widely researched theory and is still considered to explain much of the sensory components of pain.

Neuroanatomical Pain Systems

As the definition of pain involves both unpleasant sensory and emotional components, this has been subject to ample research. Research has shown that attention and affect contribute distinct effects on pain perception that are evident in individuals' ratings of pain experience (i.e., pain intensity versus pain unpleasantness), as well as neuropsychological findings. It is well established that two distinct neuroanatomical projection systems process attention and affect associated with pain. These systems are called the lateral and medial pain systems, which appear to operate in parallel. Empirical support for the separate activation of brain regions associated with ratings of pain intensity (attention) versus pain unpleasantness (affect) originates from several neurophysiological research groups (Bentley et al., 2004; Kenntner-Mabiala, Andreatta, Wieser, Muhlberger, & Pauli, 2008; Villemure & Bushnell, 2009).

Lateral. The lateral pain system is thought to be responsible for sensory-discriminative components (e.g., location, intensity, and duration of pain) and is associated with activity in the primary somatosensory cortex and the prefrontal cortex (Bentley et al, 2004). Bentley and colleagues (2004) found a unique effect of brain activity in lateral pain areas in response to a pain localization task compared to a pain unpleasantness rating task. To test this, the researchers utilized a laser heat stimulator during three experimental conditions: a pain localization task, a pain unpleasantness rating task and a control pain detection task. During all conditions electroencephalogram (EEG) data were collected. During the pain localization task, participants' view of the location of the stimulus on their arm was shielded. Pain stimuli were directed at two different locations on their arm, which participants were instructed to identify during the trial. During the pain unpleasantness task, participants were asked to rate the pain unpleasantness during stimulus presentation. In the control task, participants simply reported when they detected pain. The EEG data confirmed that brain activity in areas associated with the localization of pain (i.e., somatosensory cortex/insula) evidenced significant increases in activation during localization task, but not in the other two tasks. This evidence suggests that affective processes of pain are somewhat distinct from brain areas that assist with localization of pain stimulation.

Medial. The medial pain system is involved in affective, motivational, and evaluative components of pain processing (Bentley et al., 2004) and is associated with increased brain activity in the anterior cingulate cortex and parts of the insular cortex. In their influential paper, Rainville, Duncan, Price, Carrier, and Bushnell (1997) reported experimental evidence to support the unique role of the anterior cingulate cortex in pain affect encoding. The experiment included three female and five male adult participants who were screened for high hypnotic suggestibility. Given the participants' high suggestibility, the experimenters were able to manipulate unpleasantness of pain stimuli while holding pain intensity constant. Participants underwent positron emission tomography (PET) and magnetic resonance imaging (MRI) scans during which they experienced two levels of water temperature (neutral and painfully hot) during conditions of 1) alert control, 2) hypnosis control, and 3) hypnotic suggestion for increased unpleasantness and 4) hypnotic suggestion for decreased unpleasantness. The researchers found that hypnotic conditions altered pain affect in the participants' rating of unpleasantness. Further, the change in perceived unpleasantness of painful stimuli was highly correlated with activation in the anterior cingulate cortex (ACC), but not in other pain-related cortical structures (e.g., primary somatosensory cortex). This suggests that the ACC modulates emotional aspects of pain processing, while leaving the sensory components of the pain experience unchanged. This study further provides evidence for some degree of independence of the two components of pain processing.

Limited attention theory. Decades after Melzack and Wall (1965) posited the gate control theory of pain, Eccleston and Crombez (1999) noted that the extant theories of pain focused too heavily on the sensory aspects of pain experience, to the neglect of the emotional and motivational components of pain. The authors therefore proposed a cognitive-affective model focused on the limited attentional capacity of cognition that contributes to pain processing. In their influential theoretical paper the researchers explored how pain is evolutionarily predisposed to capture attention for survival reasons. Therefore since pain by nature demands attention there ensues a process of switching attention back and forth between pain stimuli and competing stimuli (the distractor, in this case). The model thus proposes that effective pain interventions must require central attentional control to compete with pain stimuli for processing resources.

Distraction and Pain Management

Research has shown that distraction can be an effective acute pain-management technique for children and adults in clinical and laboratory settings. The effectiveness of distraction has been shown in healthy children undergoing experimentally-induced (cold pressor) pain (Dahlquist, Weiss, et al., 2002) and immunizations (Cohen, Blount, Cohen, Schaen, & Zaff, 1999; Manimala, Blount, & Cohen, 2000) as well as in samples of children with cancer undergoing intramuscular and subcutaneous portacatheter access (Dahlquist, Pendley, et al., 2002), and in burn wound debridement (Sil, Dahlquist, & Burns, 2013). In one study with 244 healthy children and adolescents, researchers found that participants who reported using behavioral and cognitive distraction coping strategies more often when confronted with general pains rated experimental pain stimuli as less unpleasant than children who reported that they use fewer behavioral and cognitive distraction coping strategies in typical pain situations (Lu, Tsao, Myers, Kim, & Zeltzer, 2007). Although the researchers did not measure in-the-moment coping strategies during experimental pain presentations, this finding indicates that children who tend to cope using distraction methods may experience the negative affective components of pain less strongly than their peers.

An early experimental study by Miron, Duncan, and Bushnell (1989) explored the effects of a visual distraction task on pain intensity and unpleasantness and found that participants' performance (e.g., response speed and accuracy) in detecting changes in noxious heat levels was reduced during the distraction task suggesting that distraction limited participants' attention to the sensory aspects of pain stimuli. Further, the researchers noted that pain intensity and unpleasantness were reduced by the distraction task in parallel manner, suggesting that distraction affects both sensory and affective components of pain to a similar degree.

Various recent studies have examined the neuroanatomical areas associated with the modulation of pain using distraction. Frankenstein and colleagues (2001) conducted an fMRI study to examine the role of the anterior cingulate gyrus (ACG) in pain processing and in distraction in adults. The researchers examined neural activity in the

ACG during a verbal attention task alone, a cold pressor task alone, and during a combined cold pressor and visual attention task (i.e., distraction intervention). The researchers found activation in sub-regions of the ACG for each of the three tasks, both during the pain task and the attention task alone, and together, suggesting that the ACG may be involved with the autonomic and/or affective dimensions common to both nociceptive stimulation and distraction. The researchers further found that pain ratings significantly decreased during distraction, and that pain intensity ratings were highly correlated with neural activations. The authors noted that this evidence suggests that distraction and affective processing of pain are likely related due to the overlap of brain regions that process distraction tasks and pain stimuli.

A seminal paper by McCaul and Malott (1984) proposed the underlying principles of effectiveness of distraction, which laid the groundwork for much of the subsequent research in distraction for pain management. The authors reviewed evidence that supported that distraction works by reducing the attention available to process acute pain stimuli. This conceptualization came before much neuroimaging data was available, however it outlined the basic assumption that cognition mediates the experience of pain through attentional resources and one's ability to direct their attention toward a non-painful stimulus in the presence of a painful stimulus. The attentional mechanisms of distraction are considered to be consistent with the gate control theory of pain as well. More specifically, it is thought that distraction may function by sending non-nociceptive signals via descending pathways to interfere with ascending nociceptive pain signals from nerves in the body tissue (DeMore & Cohen, 2005; Melzack & Wall, 1965). The origin, production, and mode of delivery of these non-nociceptive signals are not fully understood. However, researchers have hypothesized various cognitive processes that are thought to modulate pain processing and are therefore thought to play a role in blocking pain signals using attention.

Executive Functions and Distraction

Although distraction has been shown to be an effective intervention, and various theories for its effectiveness have been posited, the exact mechanisms are not yet fully understood, and it is clear that distraction is not effective for all individuals equally (McCaul, Monson, & Maki, 1992; Verhoeven et al., 2010). As components of both pain and distraction are associated with attention, it has been theorized that distraction requires the use of executive functions. Executive functions are the cognitive processes that largely occur in the frontal lobes of the brain and modulate use of skills such as sustained attention, organization, monitoring, shifting between tasks, inhibiting behavior and holding information in ones mind to engage in purposeful, future- and goal-oriented problem-solving behavior (Gioia, Isquith, Kenworthy, & Barton, 2002).

To further explain how executive functioning plays a role in distraction for pain management, Legrain, Crombez, Verhoeven and Mouraux (2011) expanded upon Eccleston's model of cognitive-affective components of pain and distraction by elaborating the concepts of 'bottom-up' and 'top-down' processes. Bottom-up processes refer to stimuli that involuntarily capture attention, such as pain stimuli. Top-down processes include those in which attention is purposefully directed or captured, such as a goal-oriented task. Legrain and colleagues propose that bottom-up processing can by modulated by top-down processing and therefore intentional tasks that capture attention can affect processes that unintentionally capture attention. In a more recent study that examined this concept further, Legrain and colleagues (2013) found that a working memory task modulated cortical processing of painful stimuli (as measured by EEG), such that nociceptive stimuli were not able to capture attention during a working memory distraction task. Further, the researchers found that working memory suppressed early cortical responses to nociceptive stimuli suggesting that working memory may work by closing the gate by sending non-nociceptive signals down through pathways to block the ability for nociceptive signals to reach the brain and initiate processing of pain stimuli.

Because effective distraction is thought to engage executive functions, it has been hypothesized that individuals who have a higher ability to engage in top-down processes would benefit most from tasks that attempt to capture attention away from pain stimuli. More specifically, researchers have hypothesized that better executive functioning abilities would predict greater effectiveness of distraction for reducing pain intensity (Verhoeven, Van Damme, et al., 2011). The rationale for this expectation was that effective distraction requires use of executive functions, and therefore higher levels of skill in executive functions would increase the ability for an individual to engage attention and therefore benefit from the distractor with regard to their pain perception. However, researchers have failed to detect these direct effects (Verhoeven, Van Damme, et al., 2011). More specifically, Verhoeven and colleagues (2011) found in one study that various executive functioning abilities (i.e., inhibition, switching and working memory) were not related to the effectiveness of distraction as expected.

Despite the findings by Verhoeven and colleagues (2011), other researchers suggest that some executive functioning abilities may be more related to the effectiveness of distraction than others (Frankenstein et al., 2001). In the proposed study, specific executive functions that are considered critical for the effectiveness of distraction in reducing both the sensory and affective components of pain include the ability to: 1) sustain attention to the distraction task while inhibiting shifts in attention to painful stimuli and 2) regulate emotional responses to the affective components of pain stimuli (Moore, Keogh, & Eccleston, 2012).

Attention. Attention is a critical modulator of cognitive processing, as it enables individuals to focus on a particular stimulus that is relevant to performance or a specified goal, while ignoring irrelevant information, allowing the individual to sustain focus on a given cognitive task (Posner & Jones, 1971). Although early researchers studied attention as a singular process (Broadbent, 1958), more recently theorists have proposed that three separate attentional networks function to enable the ability to sustain attention (Posner & Jones, 1971; Raz & Buhle, 2006). These networks include the *orienting* network, which helps with identification of relevant information, the *alerting* network, which helps to decide how intently to focus attention while inhibiting awareness to external stimuli, and finally the *executive attention* network, which helps to resolve any conflicts that arise during a given task (i.e., any interruptive stimuli).

Each of these components of attention is critical to the use of distraction for pain management. For example, the orienting network allows an individual to select the information relevant to the task, which is a necessary first step to engaging in the task, as well as throughout the duration of the task. Secondly, the alerting network enables the individual to focus a certain amount of cognitive resources to the distraction task, thus limiting the amount of attention available to be captured by pain stimuli. Finally, the executive attention network is activated when the painful stimulus is presented and requires a brief shift in attention to resolve which stimulus requires attentional resources and enables the individual to return to the distraction task quickly. The executive attention process is often found to be related to parental reports of children's effortful control and is thought to be highly related to constructs of emotion-regulation and inhibitory control; further, brain studies have found that the executive network of attention is highly related to activity in the ACC (Raz & Buhle, 2006). Therefore, it is possible that previous researchers have focused on singular components of executive functioning as predictors of distraction effectiveness (i.e., switching or inhibition), but have missed critical elements of attentional control that capture more variance in the effectiveness of distraction (e.g., stimulus conflict resolution).

Attention and cognitive load. Although distraction has been shown to be an effective intervention in most individuals overall, due in part to use of cognitive resources, researchers have found that some distractors that utilize attentional resources to block pain signals are more effective than others in reducing pain (Buhle & Wager, 2010). Multiple researchers therefore suggest that the level of executive demand, or cognitive load, may impact the effectiveness of distraction. This may function by way of the alerting network of attention, such that higher cognitive load increases the intensity of the focus on the non-painful stimuli, thus leaving fewer cognitive resources available to be captured by painful stimuli.

Distraction tasks that place continuous, high demand on executive resources have been shown to more effectively interfere with or inhibit pain processing than tasks that are intermittent or lower in cognitive load (Buhle & Wager, 2010; Legrain et al., 2013, 2011). For example, Buhle and Wager (2010) manipulated the level of cognitive load to examine the impact on behavioral effects of pain. Participants were asked to complete a control task (passive viewing of numbers, “low load”) and an experimental task deemed to be high in cognitive load (a working memory 3-back task, “high load”) while being exposed to three different levels of thermal pain. Results indicated that the higher cognitive load task decreased pain intensity ratings, as expected, and that the effect was most notable at higher levels of heat pain compared to lower levels of heat pain, although higher load distraction was effective at all levels of nociceptive stimulation.

Conversely, Seminowicz and Davis (2007) found evidence to suggest that task load does not affect pain intensity or unpleasantness ratings. The researchers examined the effects of cognitive load on pain at four different levels of cognitive load and at three levels of pain (i.e., no pain, mild and moderate), using transcutaneous electoral nerve stimulation (TENS) pain. More specifically, the researchers used three levels of difficulty (i.e., cognitive load) in a modified version of the multisource interference task (MSIT), which requires participants to identify a number of the screen that was different from the other two stimuli that are concurrently presented on the screen. The difficulty of the task was manipulated using various features of the task (e.g., location, size and position of the number). The fourth task was a motor control (i.e., tapping) task that required minimal cognitive effort. The participants rated pain intensity levels after three of four trials within each of the 12 (four task by three pain) conditions. Contrary to their hypotheses however, the researchers found that pain ratings collected at the end of each block of trials were not significantly different at the different levels of task difficulty. However, this study had some design flaws including that the participants completed the same experimental tasks in an MRI scanner several days prior to the laboratory-based study rather than completing pain ratings following each trial in the scanner. Therefore it is possible that the tasks may have become easier (i.e., requiring lower cognitive load and therefore less attention) due to practice. Further, the pain ratings were gathered at the end of a block of six trials with a consistent pain level throughout the block, rather than after each pain stimulus presentation, thus the intensity and/or unpleasantness ratings may have reflected habituation effects.

Despite these possible limitations, it is clear that there is inconsistency in the literature regarding the relation between cognitive load and the effectiveness of distraction in adults. In children the role of cognitive load in distraction has not been explored to date. However, in a recent unpublished study by our research team conducted with a sample of children (ages 6 to 12) we found that a higher cognitive load (1-back, high working memory) distraction task improved cold pressor pain tolerance significantly from baseline, but did not significantly improve pain tolerance more than a lower cognitive load (visual discrimination, low working memory) task. However, our study had low power to detect expected effects in the repeated measures analysis due to low rates of the task mastery in the high cognitive load task; therefore replication of this study method is needed to verify how cognitive load impacts the effectiveness of distraction in children.

In a published dialogue regarding some evidence to argue against the effectiveness of distraction, McCaul and colleagues (1992) and Leventhal (1992) both noted the often-ignored influence of emotional aspects of pain in distraction, and encouraged future research to further examine the effects of affective components of distraction. Howard Leventhal (1992) in particular noted in his commentary that researchers too heavily focus on attentional components of distraction to the exclusion of affective functions of distraction. He wrote that although attention is clearly involved in the mechanisms of effectiveness of distraction, it "cannot fully explain" why distraction works for some individuals and not others. As pain involves affective components, the emotional processing of pain is typically studied in terms of coping (McCaul & Malott, 1984). However, as research in the acute pain literature is moving toward understanding neural mechanisms, it is important to examine how a more basic form of affect regulation, namely emotion regulation, impacts pain processing and the effectiveness of distraction.

Emotional control. Traditionally, emotion regulation has been defined as the processes by which one influences which emotions one experiences and how they are experienced (Gross, 1998). Most research has focused on how emotional responses can be regulated at various points between the initial emotional cue and the emotional response, by manipulating the regulatory strategies used. For example, an emotion can be consciously ignored or suppressed to the extent that an individual can attend to something other than the negative (or positive) emotion, effectively distracting themselves from experiencing some aspect of the emotion that was cued. Alternatively, at the same point in time the individual can ruminate on the emotion, which would have the opposite effect, via a similar process of regulating the attention given to the emotion. Another example of a process of emotional control is that of explicit cognitive change, which ascribes meaning to the emotion. This includes any strategies such as cognitive reframing, or re-appraisal, which is meant to transform the emotional impact without ignoring the emotional aspects altogether (Gross, 1998).

A more recent framework encapsulates the complexity of emotion regulation by proposing a dual-process framework. Gyurak, Gross, and Etkin (2011) propose that although research has historically focused on obvious parts of emotion regulation (i.e., effective effortful strategies), new advances in technology allow researchers to examine more automatic components of emotion regulation. Therefore, in their proposed framework, the authors suggest that there are two types of emotion regulation processes: explicit and implicit. Although they propose that explicit and implicit processes are distinct processes, the authors emphasize that they are not mutually exclusive categories, but that emotion regulation processes my vary in explicitness and implicitness.

Explicit processes. Much of the extant literature in emotion regulation has focused on cognitive processes (e.g., reappraisal) that require individuals to translate their neural reactivity into subjective reports of their experience, thereby supposedly making emotional processes measureable. These studies are thought to capture *explicit* emotion regulation processes, which are defined as processes that require some level of insight and awareness to consciously regulate emotional impact of a stimulus (Gyurak et al., 2011). The mechanisms of explicit emotion regulation processing can be examined using self-report or neuroimaging studies, and can be easily manipulated by researchers. Imaging studies have found that attempts to reappraise negative emotional stimuli result in increased activity in ventromedial and dorsolateral prefrontal cortex (PFC) areas, while working in parallel to reduce activity in limbic emotion-reactivity related areas including the amygdala and insula (Gyurak et al., 2011). This suggests that brain activity associated with explicit emotion regulation strategies occurs largely in areas associated with executive functioning, and effectively reduces the typical physical experiences (e.g., heart rate) associated with negative emotional responses.

In one EEG study (Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011) found that distraction and reappraisal were equally effective emotion-regulation strategies following a negative image presentation, but that differences in effectiveness occurred in terms of time elapsed from stimulus presentation to emotional reactivity using measures of the late positive potential (LPP), which is an amplitude using EEG technology that is highly sensitive to emotional stimuli and has correlated with subjective reports of arousal level in previous research. The researchers found that distraction acts significantly more quickly in the unfolding of a negative emotion compared to reappraisal. Distraction produced the LPP approximately 300ms earlier than reappraisal. This pattern suggests that distraction and reappraisal intervene at separate stages of the unfolding of an emotion to aid with regulation of the impact of the stimulus (Thiruchselvam et al., 2011).

Various researchers have examined explicit emotion regulation processes and the effects on the experiences of affective components of pain. McRae and colleagues (2009) conducted brain imaging during an experimental paradigm to compare the effectiveness of distraction and cognitive reappraisal on reducing participants' negative affect following presentations of negatively-valenced emotion images. The researchers found that both the distraction task and the cognitive reappraisal task reduced self-reported negative affect compared to a control condition, and that both interventions decreased amygdala activity. Behavioral and fMRI data in this study showed that reappraisal resulted in greater decreases in self-reported negative affect and increased activity in areas of the brain associated with affective meaning. Distraction resulted in greater decreases in activation in the amygdala and areas associated with selective attention. This study indicates that distraction and explicit emotion regulation strategies may function using some overlapping neural pathways, but may have distinct effects. This study did not examine any possible amplified benefit to reducing negative affective components of pain when distraction and emotion regulation strategies are combined. Due to the difficulty of having individuals engage in both an effortful emotion-regulation strategy and a distraction task at the same time, added value may be possible by using more automatic emotion-regulation abilities during effortful distraction.

Implicit processes. It is clear that emotion regulation processes occur consistently throughout daily experiences, without conscious awareness, or effortful use of strategies to change emotional experiences (Gyurak et al., 2011). Recent research has begun to examine the early experience of emotion and emotion regulation by capturing electrocortical activity, which can be captured within milliseconds of stimulus presentation, as affective processes are known to begin unfolding within milliseconds of a given stimulus presentation. This type of research allows researchers to explore what is known as *implicit* emotion regulation. Implicit emotion regulation is defined as any process that operates without conscious intent, which has the goal of modifying the quality, intensity or duration of an emotional response (Koole & Rothermund, 2011). It is argued that implicit emotion regulation strategies may occur in the brain without any conscious intention on the part of the individual, or they may occur in parallel with explicit emotion-regulation strategies.

In one of the few experimental studies that examined neurocognitive correlates of children's implicit emotion regulation, Lewis and colleagues (2006) found a consistent effect of negative emotion on response inhibition using EEG technology. More specifically, they found that during an inhibitory control task (go/no-go), children evidenced higher response inhibition, as measured by event-related potential (ERP) amplitudes, during instances of negative mood induction compared to positive mood induction. Negative mood inductions were induced by showing that the child was losing points from the game. The researchers found that children's ERP amplitudes were greater during the no-go (inhibiting button presses) condition, compared to the go (pressing a button) condition. Overall, this study suggests that early neural responses to negative affective stimuli are mediated by the anterior cingulate cortex, which the same area that is known to be part of the medial, or affective, pain processing network.

It is important to note here that emotion regulation is conceptually distinct from the actual initial phases of the emotional experience itself (Gross, 2015). In addition to the innate difficulty in differentiating between implicit and explicit emotion regulation, some research methodologies that appear at first glance to measure implicit emotion regulation in fact measure the unfolding of the emotion itself. It is arguable however that if one learns to regulate emotions by regulating attention in such a way that prohibits the emotional stimuli to be processed during the initial phases of the emotion, the ability to reduce the initial unfolding of the emotion substantially or entirely would be categorized as implicit (or possibly explicit) emotion regulation. Also importantly, emotion-regulation is thought to comprise of three distinct stages (Gross, 2015). The identification stage occurs first and is the stage when the individual selects either implicitly or explicitly to engage in emotion-regulation efforts, the selection stage follows, which is the stage during which one makes the decision as to what strategy to use to regulate the emotion. Finally, the implementation stage occurs during which the selected strategy is actively being used. Therefore, an emotional response can arguably by manipulated at any of the three stages in either explicit or implicit emotion regulation.

As noted, it can be difficult to differentiate between explicit and implicit emotion-regulation processes. Therefore, some researchers measure emotion regulation in novel ways, which appear to measure both emotion regulation processes together. In one such study, researchers asked participants to continuously rate their discomfort on a VAS while looking at emotional images and following exposure (for 25 s). They found that higher self-reported attentional control abilities (i.e., focusing and shifting) predicted faster emotional down-regulation (i.e., quicker improvements in discomfort levels) following exposure to aversive emotional stimuli (Morillas-Romero, Tortella-Feliu, Balle, & Bornas, 2015). Therefore, the findings suggest that higher attentional abilities may facilitate more automatic and effective down-regulation of the affective components of pain processing. However, the type of emotion regulation process is less clear given that participants did not self-report how they were able to down-regulate, and if these processes were conscious efforts or not.

A study by Cohen, Henik, and Mor (2011) showed that activation of attention, and the executive network in particular, has effects on negative emotional stimuli. In the study, the participants were presented with the Attentional Network Task (ANT), which specifically measures each of the three attentional networks (i.e., orienting, alerting and executive) individually. As such, the authors were able to detect that once executive processes are activated, as measured by subtracting response times from congruent trials from response times for incongruent trials, they diminish the effects of negative emotional stimuli on task performance. This has implications for the use of distraction for pain management, as it suggests that attention-capturing tasks that involve some conflict-resolution between stimuli may have positive effects on negative affective components of external stimuli.

Given that researchers are beginning to study the affective components of pain in relation to distraction, there are two possible lines of research. One line focuses on integrating affective components into a distraction task, to attempt to modulate the pain experience using the combination of attention and affect. However, another mode of researching the affective components of pain, similarly to the intent of Rainville and colleagues (1997) who manipulated the unpleasantness of pain using hypnosis, is to conduct research in which the unpleasant processing of the affective component of pain is altered in its valence. In this framework of emotion-regulation with regard to pain processing, the distractor is not manipulated to engage emotion-regulation strategies, instead it suggests that individuals can modulate the valence, or judgment of unpleasantness of the affective components of pain, and therefore attention can be more fully directed toward the distractor. Multiple studies have found that mindfulness meditation is a practice that encourages this type of shift in perceiving unpleasant stimuli.

Dispositional Mindfulness

Research in mindfulness meditation and its applications to pain and psychological wellbeing in adults and children is burgeoning (Sanger & Dorjee, 2015). Mindfulness refers to the non-judgmental awareness of present experiences (Kabat-Zinn, 1994) and has been promoted for its role in health and wellbeing in the Western world for decades, and in Buddhist contexts for centuries. Less studied to date is the construct of dispositional, or trait, mindfulness. Dispositional mindfulness reflects the *overall tendency* to non-judgmentally attend to present experiences and sensations. Dispositional mindfulness is therefore considered to be a measureable trait rather than a state. To demonstrate its function as a trait, as well as to explore the genetic underpinnings of the construct, one large adolescent twin study (N = 2,118), showed that 32% of dispositional mindfulness is heritable and 66% of the variance is due to non-shared environmental factors, with no significant influence of shared environment. The study further found shared genetic liability underpinning co-occurrence of low mindfulness, depression and anxiety sensitivity (Waszczuk et al., 2015).

Research has found that dispositional mindfulness is related to psychological functioning, day-to-day pain, and lower experimental pain intensity ratings and higher pain tolerance (Petter, Chambers, McGrath, & Dick, 2013). In adult samples, dispositional mindfulness has been found to fully mediate the relation between actual practice of mindfulness meditation and perceived stress and to partially mediate the relation between mindful practice and psychological well-being (Carmody & Baer, 2008). One meta-analysis with adult studies found that dispositional mindfulness is consistent with the theorized role of improvements resulting from mindfulness-based interventions (MBIs) (Quaglia, Braun, Freeman, McDaniel, & Brown, 2016). Therefore, dispositional mindfulness is thought to be a product of ongoing use of the basic tenets of mindfulness meditation, which includes non-judgmentally attending to present experiences and sensations. As further evidence of the construct of dispositional mindfulness, the most widely used measure of dispositional mindfulness in adults, the Mindful Attention and Awareness Scale (MAAS) has been validated extensively, and has been shown to negatively correlate with behavioral indicators and self-reported measures of mind-wandering, which is thought to be a construct in direct opposition to mindfulness (Mrazek, Smallwood, & Schooler, 2012).

Dispositional mindfulness and executive functioning. No known studies to date have examined the role of dispositional mindfulness and the effectiveness of distraction. However, research has shown relations between mindfulness and executive functions associated with distraction. Lee and Chao (2012) found that college students who scored higher on dispositional mindfulness showed higher inhibition abilities during an experimental task than their peers lower on dispositional mindfulness suggesting that with higher ability to attend to present goal-oriented tasks, individuals are better able to inhibit competing stimuli. Similarly, with a sample of fourth- and fifth-graders, Oberle, Schonert-Reichl, Lawlor and Thomson (2012) found that after controlling for gender, age, and cortisol levels, higher dispositional mindfulness predicted greater accuracy on an inhibitory control task.

Research has consistently linked mindfulness meditation and overall improved executive functioning skills. In one mindfulness intervention study with adolescents and adults with Attention Deficit Hyperactivity Disorder (ADHD), results showed that after an 8-week mindfulness training program, participants performed significantly better on multiple cognitive tasks including an Attention Network Test (ANT), which measures attention, alerting, orienting and attentional conflict, as well as a Stroop task, which measures attentional conflict, and the Trail Making Tests A and B, which assess set-shifting and inhibition (Zylowska et al., 2008). In another study that included a group of experienced meditators and a group of non-meditators, Moore and Malinowski (2009) found that dispositional mindfulness was moderately to highly correlated with multiple attention measures in adults. In their study, participants who scored higher on mindfulness also scored higher on processing speed, attentional and inhibitory control and higher accuracy (e.g., fewer errors and more correct responses) (Moore & Malinowksi, 2009).

Emotional control. Researchers have also found that mindfulness meditation practice is associated with better emotional control, which is a primary executive function (Lyvers et al., 2014; Teper & Inzlicht, 2013). Further, researchers have found that several well-known measures of dispositional mindfulness have been associated with better emotion regulation abilities (Brown, Ryan, & Creswell, 2007).

The mechanism underlying the relation between mindfulness and emotional control is not fully understood. A recent empirical review by Chiesa, Serretti, and Jakobsen (2013) found that in short-term practitioners of mindfulness, the impact of mindfulness on emotion-regulation may be best described as a "top-down" process, such that the individual effortfully reinterprets emotional stimuli in a way that modifies their impact, essentially using a cognitive shift to interpret the emotional stimuli as less interfering. Alternatively, the authors note that in long-term practitioners of mindfulness, a "bottom-up" process may transpire such that there is reduced activity in the emotional areas of the brain at emotional stimulus presentation without the effortful process of evaluating the emotional draw of the stimulus at all.

Brown and colleagues (2013) revealed a direct relation between dispositional mindfulness and neural responses in response to emotional stimuli. Specifically, the researchers measured the Late Positive Potential (LPP) using EEG. Brown and colleagues (2013) found that when presented with highly arousing unpleasant images, participants high in dispositional mindfulness showed smaller immediate neural responses than participants low in dispositional mindfulness. Even after statistically controlling for trait attentional control, this effect remained significant, suggesting that the mindfulness is more than simple attentiveness. In a different experimental paradigm, Teper and Inzlicht (2013) found that during an executive function task (Stroop), experienced meditators more intensely noticed their own performance errors (error-related negativity measured by EEG) and performed better on the task than non-meditators, suggesting that meditators were able to notice their errors without emotional judgment and thus were able to return their attention to the task quickly. Both of these studies suggest that dispositional mindfulness may impact neural pathways such that negative emotional stimuli are processed less negatively in individuals with higher dispositional mindfulness.

Dispositional mindfulness and pain. Little research has been conducted to examine the relation between dispositional mindfulness and acute pain. However, one study recently compared the impact of the practice of Open Monitoring meditation, which is a practice that encourages nonjudgmental and nonreactive awareness of sensory experience, on pain ratings between novice and long-term meditators (Perlman, Salomons, Davidson, & Lutz, 2010). The researchers found that long-term meditators had significant reductions in self-reported pain unpleasantness, but not pain intensity when presented with a noxious stimulus. This implies that long-term use of mindfulness meditation may specifically impact the affective components of pain processing. In terms of sensory processing of pain, Petter, Chambers, MacLaren and Chorney (2013) found that after controlling for the effects of sex and situational catastrophizing, dispositional mindfulness did not predict pain intensity during a cold pressor immersion. The researchers did not examine pain unpleasantness in this study.

Given these recent findings it is likely that dispositional mindfulness is not as highly related to pain intensity as it is to pain unpleasantness. This is due to the fact that if dispositional mindfulness effectively reduces the affective impact of pain, the sensory impact of pain not only remains, but also could be subject to increased awareness. For example, if an individual is able to experience pain non-judgmentally, pain is likely to be experienced as more purely a sensory experience. In line with the three networks of attention, the individual experiencing the pain is likely to more efficiently switch back and forth between the distraction task and the pain stimulus in order to assess the sensory aspects of the stimulus, without spending resources on assessing the affective, or affective components of the stimulus. Although ratings of pain intensity and pain unpleasantness are highly correlated (Pearson r = .62)(Verhoeven, Van Damme, et al., 2011), they are thought to measure slightly different processes in the pain experience (Miron et al., 1989) and thus examining them separately adds value to the literature.

Summary

Despite the large body of research that suggests that distraction is an effective acute pain management technique for some children, it is also notable that distraction is not effective for all children. This gap in the literature requires that distraction continue to be systematically studied to determine factors that moderate the effectiveness of distraction as a pain management technique in medical settings. Understanding of potential moderators in a controlled laboratory setting is necessary to experimentally manipulate key active ingredients of an intervention and therefore reveal factors of clinical importance. As such, the current study aimed to inform the development of useful screening protocols for clinicians and medical providers to enable appropriate selection of effective pain management techniques for all children during routine, and medically necessary painful procedures.

Although pain is known to be an experience with both sensory and affective properties, many researchers and theorists choose to focus on one aspect or another in relation to distraction. Although experimental researchers often measure both sensory and affective properties of pain in a single study, they fail to examine these distinct, yet overlapping, components using an organizing framework. With new and exciting research findings that offer insight into critical neural processes, it is now reasonable to study the interaction between attention and affect in the effectiveness of distraction for acute pain. Given this review of the literature, it was anticipated that distraction may be a particularly effective intervention for individuals who are skilled in early, and likely implicit (i.e., dispositional mindfulness) emotion-regulation processes that enable one to better attend to the distractor (via modulation of attention intensity and via skill in conflict negotiation), which will in turn increase the effectiveness of the distractor in terms of reducing the intensity and unpleasantness of painful stimuli.

Dispositional mindfulness is a relatively new construct in Western research. In adults it has been found to directly affect emotional control and attentional control abilities. Therefore a sample that includes individuals with higher and lower levels of dispositional mindfulness is expected to offer adequate variance to detect differences.

Finally, most research in pain is conducted with adults, and most commonly with college students, which limits their generalizability to children due to the clear differences in cognitive abilities and other critical factors. As children often have difficulty managing painful procedures, and constitute a portion of the population that faces painful medical procedures, it is critical to study pain processing and the effectiveness of distraction with children. Further, the extant research in pain processing, distraction, executive functioning and mindfulness suggest that there is much to explore in the experience of pain in children and adolescents. Although researchers have examined these components of acute pain management separately, no study to date has examined a model designed to explore the relations concurrently.

Study Aims

Aim 1. The current study aimed to address gaps in the literature by examining cognitive load as a predictor of the effectiveness of distraction for acute pain management in children.

Aim 2. The current study also aimed to evaluate dispositional mindfulness as a moderator of the effectiveness of distraction for acute pain management in children.

Aim 3. The current study aimed to examining the role of dispositional mindfulness in the sensory as well as affective valence of children's experience of acute pain.

Study Design Overview

To accomplish these aims, a sample of 9- to 13-year-old children who varied in terms of dispositional mindfulness was recruited. During the experimental procedure, the children experienced three randomly presented heat levels (not painful, slightly painful, moderately painful) while performing two distraction tasks involving different levels of cognitive load (a high load 'working memory' task and a low load 'motor' control task) in counter-balanced order.

Hypotheses

Cognitive load and distraction effectiveness hypotheses

1. I predicted that all children would benefit from the high load 'working memory' distraction intervention, reporting lower pain intensity and unpleasantness during the high load 'working memory' condition relative to the low load 'motor' control condition for both slightly painful and moderately painful stimuli, but not for the not painful stimuli. This was expected because past research has shown that tasks of higher cognitive load cause participants to rate pain intensity and pain unpleasantness lower than tasks of lower cognitive load.
    a. I predicted that dispositional mindfulness would moderate response to distraction with children higher in dispositional mindfulness showing greater benefit from the high load task relative to the control task, compared to children lower in dispositional mindfulness. This was expected due to the extant literature that suggests that distraction is not effective for all children equally, as well as the literature that suggests that dispositional mindfulness may have implications for the affective processing of pain.

Dispositional mindfulness and pain ratings hypotheses

2. I expected that a serial mediation model would show that emotional control, attentional control and task performance mediate the relation between

dispositional mindfulness and distraction effectiveness (i.e. pain unpleasantness change) during the high load ‘working memory’ condition for moderately painful stimuli. Based on the literature, the following effects were hypothesized:

a. I expected that children who were higher in dispositional mindfulness would evidence greater benefit from distraction (i.e. greater pain unpleasantness reductions) than children who are lower in mindfulness during the high load distraction condition (i.e., total effect) (hypothesis 2a). These effects were expected due to the extant findings that dispositional mindfulness is related to the affective components of pain and this total effect was expected to be mediated by the subsequent predictors added to the model.
b. I expected that dispositional mindfulness would be positively related to emotional control (hypothesis 2bi), that emotional control would be positively related to distraction effectiveness during the high load distraction condition (hypothesis 2bii), and further that emotional control would mediate the relation between dispositional mindfulness and distraction effectiveness (hypothesis 2biii). These effects were expected because the literature suggests that dispositional mindfulness training results in increased emotional control abilities, and therefore it was expected that children with higher dispositional mindfulness would evidence higher emotional control abilities than children with lower dispositional mindfulness. Further, higher emotional control is associated with better pain outcomes.

c. I expected that dispositional mindfulness would be positively related to attentional control (hypothesis 2ci), that attentional control would be positively related to distraction effectiveness during the high load distraction condition (hypothesis 2cii), and further that attentional control would mediate the relation between dispositional mindfulness and distraction effectiveness (hypothesis 2ciii). These effects were expected because the literature suggests that dispositional mindfulness training results in increases in attentional abilities, and therefore it was expected that children with higher dispositional mindfulness would evidence higher attentional control abilities than children with lower dispositional mindfulness. Further, higher attentional control is associated with better pain outcomes.

d. I expected that children who were higher on dispositional mindfulness would show better performance on the high load distraction task than children who were lower on dispositional mindfulness (hypothesis 2di), that better performance would be positively related to distraction effectiveness during the high load distraction condition (hypothesis 2dii), and further that task performance would mediate the relation between dispositional mindfulness and distraction effectiveness (hypothesis 2diii). These effects were expected because research suggests that mindfulness practice is associated with improvement in attention-related task performance. Further, better task performance has been shown to be associated with pain outcomes.

3. I expected that children who were higher in dispositional mindfulness would rate pain stimuli as less unpleasant than children who were lower in mindfulness during the control (low load task) condition. This was expected because children who are higher in dispositional mindfulness are expected to notice pain sensations less negatively/less judgmentally than children who are lower in dispositional mindfulness.
4. I expected that dispositional mindfulness would also be negatively related to pain intensity ratings, but to a lesser degree than pain unpleasantness, during the control (low load task) condition. This was expected because pain intensity and pain unpleasantness rating are highly correlated with one another, but dispositional mindfulness is thought be to more predictive of the affective mechanisms of pain processing, whereas it is not expected to predict pain intensity as strongly.

Method

Participants

Children were recruited from the UMBC Summer Day Camp, from the surrounding community via hardcopy and online flyers, as well as from an internal lab list of families who previously participated in our research studies and indicated interest in participating in later studies. Although it was proposed that children would be prescreened for dispositional mindfulness to recruit a sample that included children high and low on dispositional mindfulness, the sample recruited through the summer camp and community revealed a normal distribution of dispositional mindfulness scores that included children across the spectrum. Therefore, no additional recruitment was necessary.

Measures

Demographic questionnaire. Parents completed a demographic questionnaire that included information regarding their child's age, sex, and race. See Appendix A for a sample of the demographic questionnaire.

Past pain experience. Parents completed questions about the frequency of their child's history of painful medical experiences (e.g., surgeries, injuries, medical procedures) in addition to rating their child's typical reactions from 1 = *very positive* to 7 = *very negative* for each type of medical experience. Average reaction scores across all categories were calculated to capture overall past pain experience.

Pubertal development. Parents also completed a brief 4-to-5-item (4 for girls and 5 for boys) questionnaire assessing their child's pubertal development, in order to indicate pubertal status. The parent version of the Pubertal Development Scale

(Carskadon & Acebo, 1993; Petersen, Crockett, Richards, & Boxer, 1988) was modified for parent-report by Menseh and colleagues (2013). The measure has been found to be highly reliable (Carskadon, Vieira, & Acebo, 1993; Petersen et al., 1988) and to have satisfactory predictive validity of sexual activity as shown by correlations between .17 and .31 for several types of heterosexual sexual activities (Robertson et al., 1992). Parents will be asked about external puberty indicators: skin changes, changes in height/growth spurt, body hair, breast growth (girls only), voice deepening (boys only), and facial hair (boys only). For each item, the parent will rate their child's development on a four-point Likert type scale, as either " (1) *has not started yet*," " (2) *has barely started*," " (3) *has definitely started*," or " (4) *seems complete*." Scores for each item are then averaged to obtain a mean Pubertal Development Scale (PDS) score. Boys and girls were grouped as pre-pubertal (average scores below 2), early pubertal (average score between 2 and 3) and pubertal (average scores above 3). Any children who were in the pubertal stage of development were considered for exclusion from analyses.

Behavior Rating Inventory of Executive Function (BRIEF-2). The BRIEF-2 Parent Form (Gioia, Isquith, Guy, & Kenworthy, 2015) was used to measure children's level of executive functioning. The BRIEF-2 is an 86-item measure that takes approximately 15 to 20 minutes to complete. The BRIEF-2 assesses eight clinical executive functioning subscales: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor and has demonstrated adequate reliability and validity using a standardization sample of 1,400 children aged 5-18 years.

For the purposes of this study the raw scores from the Emotional Control subscale were used for analyses. The Emotional Control subscale consists of eight items that measure children's ability to modulate emotional responses. Examples of items include: "small events trigger big reactions," and "mood is easily influenced by the situation" (see Appendix B to view items on the BRIEF-2). The developers of the BRIEF-2 found good internal consistency of the parent-report Emotional Control subscale (.89) in their sample. They also found adequate 3-week test-retest reliability on the Emotional Control subscale ($r = .79$). The validity was assessed by the developers as well. They found that the Emotional Control subscale was moderately correlated with the CBCL-parent and youth-report Total Problems Composite (Pearson Correlation coefficients of .40 and .53, respectively), and was also moderately correlated with the BASC-2 parent and self-report Internalizing Problems Composite (Pearson Correlation coefficients of .56 and.54, respectively). Adequate internal consistency for the Emotional Control subscale was also found in the present study, with Cronbach's α of .87 for the 8-item scale.

Attentional Control Scale for Children (ACS-C). Children completed the ACS-C between the two experimental trials. The ACS-C is a child adaptation of the adult version of the 20-item Attentional Control Scale (ACS) by Derryberry & Reed (2002), which has been shown to have adequate reliability and validity with numerous adult samples. The ACS-C was developed by Muris, de Jong, and Engelen (2004) using adapted language for children ages 8-13. It is composed of 20 items measuring two types of attentional control: nine items measure focusing (e.g., "When concentrating, I do not notice what happens around me") and the remaining 11 items measure shifting (e.g., "I can easily write or read while I am talking on the phone"). Items are scored on a 4-point Likert scale from 0 = *never*, 1 = *sometimes*, 2 = *often*, and 3 = *always*. After recoding reverse-scored items, a total score is computed; higher scores indicate higher levels of attentional control. The developers of the ACS-C report adequate internal consistency (α range from .72 to .75) in two independent samples. The developers of the scale also report positive correlations with perceived control (Pearson r = .22) and negative correlations with trait anxiety (r = -.38) and neuroticism (r = -.40) as measured by the Screen for Child Anxiety (SCARED) suggesting adequate construct validity (Muris et al., 2004) (see Appendix C to view items on the ACS-C).

Recent research provides reliability and validity evidence for the adult version of the ACS. Specifically, researchers have shown that in college students the ACS is highly correlated with various attentional and executive control measures including the Cognitive Failures Questionnaire (CFQ) (r = -.68), which measures executive functioning "errors" that occur in daily life, the distraction subscale of the Thought Control Questionnaire (TCQ) (r = .40), as well as performance on the Wechsler Adult Intelligence Scale (WAIS) letter-number sequencing task (r = .27) (Judah, Grant, Mills, & Lechner, 2014). Further, in their validation efforts of the ACS using bipolar electro-oculography, which measures eye movements, Judah and colleagues (2014) found that participant's prosaccade (eye movement toward a stimulus) latency showed a moderate positive correlation with the ACS focusing subscale, (r = .35), which suggests that participants were effortfully delaying automatic eye movements to a stimulus in order to verify their accuracy prior to responding. Additionally, the researchers found that the ACS Focusing subscale was significantly correlated with participant's antisaccade (eye movement away from the stimulus) performance (r = .32), suggesting that participants who scored higher on attentional control were better able to maintain their focus on the goal-directed task and inhibit prepotent responses.

Together, these results provide strong evidence of the validity of the adult version of the ACS. Although comparable research has not yet been conducted with the ACS-C it is expected that since the child version was not altered in substantial ways beyond simplifying the language for comprehension, that the relations with constructs of attentional control would likely be similar for the child version of the measure. Adequate internal consistency for the Focus subscale scores was found in the present study, with Cronbach's α of .75. However, the Shift subscale revealed low internal consistency with Cronbach's α of .10. Therefore only the focus subscale was used for main analyses.

Child and Adolescent Mindfulness Measure (CAMM). Children completed the 10-item Child and Adolescent Mindfulness Measure (CAMM) to assess present-moment awareness and non-judgmental, non-avoidant responses to thoughts and feelings. The CAMM was administered in interview format. Children were asked to rate how often each item is true for them using a 5-point Likert scale from 0 = *never true,* to 4 = *always true* (see Appendix D to view items on the CAMM). The final scale yields scores ranging from 0 to 40, with higher scores indicating higher levels of dispositional mindfulness. Previous research has shown that on average, children in US samples score with a mean of 22.74 (SD = 7.33) on the CAMM, with boys and girls between the ages of 10 and 12 reporting equal levels of dispositional mindfulness (de Bruin, Zijlstra, & Bogels, S.M., 2014; Greco et al., 2011).

The CAMM was originally developed by Greco, Bear, and Smith (2011). In their original publication the developers conducted four studies (total N = 1,413) to describe the process of item development and reduction and to preliminarily validate the scale with a sample of children and adolescents (aged 10-17). During this process the authors reduced the initial item pool from 25 to 10 items through exploratory factor analysis. Subsequent validation efforts have been conducted with nonclinical samples by de Bruin, Zijlstra and Bogels (2014), with a sample of 275 Dutch children aged 10 to 12 and a sample of 560 Dutch adolescents aged 13-16, and by Kuby, McLean and Allen (2015) with a sample of 562 children aged 12 to 15 years.

The CAMM has shown adequate internal consistency (between .70 and .80) across the multiple samples. Principal factor analysis (PFA) and confirmatory factor analysis (CFA) conducted by two of the research groups (de Bruin et al., 2014; Kuby et al., 2015) have confirmed the one-dimensional factor structure of the CAMM.

To assess the validity of the scale, researchers have examined the relation between scores on the CAMM and various other measures thought to measure related constructs. To provide evidence of divergent validity, researchers found that CAMM scores have been found to negatively correlate with child-reported somatic complaints (Pearson Correlation $r = -.40$), internalizing symptoms ($r = -.50$) and externalizing behavior problems ($r = -.37$) as measured by the Children's Somatization Inventory (CSI), as well as thought suppression ($r = -.58$) as measured by the White Bear Suppression Inventory (WBSI), and psychological inflexibility as measured by the Avoidance and Fusion Questionnaire for Youth (AFQ-Y) (Greco et al., 2011). Divergent validity is further evidenced by negative relations between CAMM scores that scores on the Negative Affect (NA) scale from the Positive and Negative Affect Scale for Children (PANAS) ($r = -.43$) and the Penn-State Worry Questionnaire for Children (PSWQ-C) ($r = -.54$) (Kuby et al., 2015).

To provide evidence of convergent validity researcher found that CAMM scores have been found to positively correlate with expected factors including overall quality of life (Pearson Correlation coefficients ranging from .25 to .55) as measured by the Youth Quality of Life Inventory (YQOL) and the Pediatric Quality of Life Inventory Scale (PedsQL), respectively. Further, CAMM scores were found to be positively related to healthy self-regulation ($r = .32$), as measured by the Healthy Self-Regulation Subscale (HSR; West, 2008) (de Bruin et al., 2014).

Given that the literature suggested that average scores of dispositional mindfulness on the CAMM were 23, for randomization procedures children were considered ‘higher’ if they score at or above 23 on the CAMM, and will be randomized accordingly. Similarly, children were considered ‘lower’ on mindfulness if they score below 23 on the CAMM and randomized accordingly.

However, the purposes of analyses, dispositional mindfulness was dichotomized at the mean of the current sample ($M = 25.68$), and children were considered ‘high’ on dispositional mindfulness if they scored above the mean ($n = 32$), and ‘low’ if they scored below the mean ($n = 24$). Adequate internal consistency for the CAMM was also found in the present study, with Cronbach’s α of .76 for the 10-item scale.

Pain intensity Visual Analog Scale (VAS). Children’s subjective ratings of pain intensity were measured using a visual analogue scale (VAS) following each trial. Data were recorded within the eprime computer program. At the end of the trial an onscreen rating bar appeared, along with a cue, “how painful?” The VAS was anchored with numbers 0 “*no pain at all”* to 10 “*the worse pain I have ever felt*.” A vertical cursor was located at the far left of the screen, on the number 0. Participants were instructed to use the “1” and “2” keys on the numerical keypad to move a vertical cursor along the line to select the location on the line that best described the intensity of pain that they felt on their arm. The “2” key advanced the vertical cursor toward the right side of the screen toward higher pain ratings, and the “1” key moved the cursor back toward the left side of the screen toward lower pain ratings. The experimenter verbally verified with the participant that they were finished rating the intensity of the pain. The computer program recorded pain ratings for each trial and adjusted pain ratings to range from 1 to 11 for purposes of calculating change scores (see Table 4 for complete descriptives).

Pain intensity change scores were calculated by subtracting average pain ratings in the control condition from average pain ratings in the 1-back condition for each of the three heat levels separately. Therefore, negative pain intensity change scores indicated lower pain ratings during 1-back distraction (compared to control); positive change scores indicated that pain intensity increased during the 1-back condition relative to the control condition (i.e. the 1-back distraction was not effective). See Table 3 for descriptive statistics of change scores.

Pain unpleasantness Visual Analog Scale (VAS). Children’s subjective ratings of pain unpleasantness were measured using a visual analogue scale (VAS) following each trial, immediately after rating the pain intensity, within the e-prime program. An onscreen rating bar appeared, along with a written an experimental verbal cue, “how unpleasant?” The VAS was anchored with numbers 0 “*not at all unpleasant”* to 10 “*the most unpleasant pain I have ever felt*.” A vertical cursor was located at the far left of the screen, on the number 0. Participants were instructed to use the “1” and “2” keys on the numerical keypad to move a vertical cursor along the line to select the location on the line that best described the unpleasantness of pain that they felt on their arm. The “2” key advanced the vertical cursor toward the right side of the screen toward higher pain ratings, and the “1” key moved the cursor back toward the left side of the screen toward lower pain ratings. The computer program recorded pain ratings for each trial and adjusted pain ratings to range from 1 to 11 for purposes of calculating change scores (see Table 4 for complete descriptives).

Pain unpleasantness change scores were calculated by subtracting average pain ratings in the control condition from average pain ratings in the 1-back condition for each of the three heat levels separately. Therefore, greater negative scores indicated greater distraction effectiveness (i.e. change from control to 1-back) with regard to pain unpleasantness ratings, and greater positive change scores indicated higher pain unpleasantness ratings in the control condition than in the 1-back condition (i.e. the distraction was not effective). See Table 3 for descriptive statistics of change scores.

Equipment

Pain stimulus. Heat was delivered to the volar of the individual’s non-dominant arm using the FDA-approved Medoc Pathways system (Medoc Systems, Israel). The MEDOC Pathway system is a pain research system that measures sensory thresholds for warm and heat-induced pain (see Figure 1 for a photograph of the MEDOC). The MEDOC is widely used in experimental research with adults and children for the purposes described in the proposed study (Birnie, Caes, Wilson, Williams, & Chambers, 2014; Buhle & Wager, 2010; Hashmi & Davis, 2009; Lutz, McFarlin, Perlman, Salomons, & Davidson, 2013). An Advanced Thermal Stimulator (ATS) thermode was used in this study, which is connected to the main MEDOC station by two thermistors (electronic thermal sensors) and one water thermistor. The surface contacting skin of participants is aluminum coated, and is 16 x 16 mm in size (see Figure 2 for a photograph of the ATS termode). The thermode is connected to the system's cooling unit, which circulates coolant designed for the system to rapidly decrease the temperature of the thermode to baseline (32 °C) at a rate of 8 °C per second. For safety, a maximum temperature limit of 50 °C was strictly enforced for initial threshold and tolerance trials (up to one second duration of heat exposure), following the procedures conducted in the majority of thermal pain research studies with adults and children (Buhle & Wager, 2010; Lu et al., 2007). A maximum temperature limit of 49 °C was enforced for the 6-11 seconds at peak during experimental trials.

Software. Both the control and the 1-back tasks were programmed and conducted using E-prime 2.0 software (Psychology Software Tools, Inc.). Data from each trial was collected and stored within the E-prime program.

Computer monitor. Experimental tasks were presented on a 24-inch Dell LCD flat panel display.

Laptop computer. A 64-bit operating system on a Dell Latitude E7240 with an Intel® Core™ i7-5600U CPU @ 2.60GHz 2.59 GHz was used to program and run the E-prime program.

Keyboard. A numerical keyboard was used for responses on the experimental tasks, the number 1 had a "yes" indicator and the number 2 had a "no" indicator placed on top of the letters. The keyboard was connected to the laptop computer with a USB cord.

Procedure

All procedures were conducted by graduate or advanced undergraduate students who have experience interacting with children. Children were pre-screened for level of dispositional mindfulness using the CAMM prior to being randomized into experimental order.

Setting. Child assent and questionnaire procedures took place in the Pediatric Psychology Lab at UMBC. Parents were not present for child assent or experimental procedures. Experimental procedures occurred in an experimental room (approximately 10 ft by 10 ft in size) in the Quiton Lab, located on the same floor of the same building at UMBC. Children sat in a comfortable chair with armrests. A standard size bed pillow was placed under the child's non-dominant arm to increase comfort of keeping the arm in the correct position on the armrest or on the child's lap depending on comfort. One experimenter sat on the dominant-hand side of the child. The other experimenter stood directly behind the child to manipulate the MEDOC system and to adjust the thermode on the child's arm. A small desk was placed on the child's dominant side to allow for placement of the response mouse (see Figure 3 for a photograph of the response mouse) near the child's dominant hand (see Figure 4 for a photograph of the experimental room arrangement). The experimental room was maintained at a room temperature between 73 and 75 °F. The entire procedure last approximately one hour.

Parental consent and child assent. Parental consent and child assent was obtained according to procedures approved by the Institutional Review Board (IRB). During the consent and assent process, parents and children were informed that the heat delivered during the experiment would not reach limits that could result in lasting damage to the skin. Parents and children were informed that the location where the heat thermode was placed on their skin may appear pink for a short period of time following participation, but that safety settings on the equipment will ensure that children cannot obtain a burn from the thermode. Assent forms were read out loud to all children prior to participating in the study, with the child following along with their own copy.

The consenter also informed participants that they were allowed to stop participation at any time with the following verbal assurance during the assent process and prior to the experimental trials: "*If at any time you do not want to keep playing any of the games you may stop. When you do the heat test, after a while, the heat might feel uncomfortable or your arm may start to hurt. You can say, 'stop' and we will immediately stop the heat test whenever you want.*"

After the procedures were described, the parent and child were encouraged to ask any questions that they had prior to signing the informed consent or child assent form. Families had the option of withdrawing from the study at any point during the study procedures.

Parents were asked to complete the demographic questionnaire and the BRIEF-2. Parents of children in the UMBC summer camp who participate completed questionnaires at home and returned them to the researchers prior to the child's participation. Parents of children from the surrounding community completed questionnaires on the day of their child's participation. A standardized protocol was used to explain all study instructions for each child and research assistants (RAs) read verbatim from the standardized script. Two research assistants then walked with the child to the Quiton Lab for the remainder of the study procedures.

Randomization. To control for possible experimental order effects children were stratified by sex and dispositional mindfulness and then randomized to receive either the 1-back or the control condition first. To perform randomization, envelopes were created that contained a number corresponding to the two orders. The randomization envelopes were placed in four larger envelopes: (1) boys with lower dispositional mindfulness (below a score of 23), (2) boys with higher dispositional mindfulness (i.e., at or above a score of 23), (3) girls with lower dispositional mindfulness (below a score of 23) and (4) girls with higher dispositional mindfulness (at or above a score of 23). An experimenter selected a randomization envelope according to the child's sex and level of dispositional mindfulness. The order was written on the participant packet.

Thermal stimulus calibration. To ensure that individualized temperatures that related to the child's personal pain threshold were used in the subsequent experimental trials, participants completed a series of thermal stimulus calibration steps. The following values were calibrated: warmth threshold, pain tolerance and pain threshold.

The experimenter directed the child to remain seated in a chair for the duration of the experiment, with their arm on top of a pillow placed on an armrest. The experimenter asked the child to keep their arm and palm facing upwards. Research assistants placed the thermode on the dorsal surface of the child's non-dominant arm halfway between their wrist and their elbow. The thermode was comfortably secured on their arm using a Velcro strap. The experimenter positioned the MEDOC response mouse to place under the child's dominant hand to provide indicated responses.

Warmth threshold. To determine warmth threshold, a set of three stimulus calibration trials were conducted. At the beginning of the first trial children were instructed to click any button on the mouse when they first noticed that the thermode changes from ‘room temperature’ to ‘warm.’ Before starting the trial, experimenters asked the child, “*So, when should you press the button?*” to ensure comprehension of the task. Experimenters reviewed the instructions if the child did not respond with an appropriate response (e.g., “*when it first starts to feel warm”*). After ensuring that the child understood the instructions, the experimenter initiated the three warmth threshold trials. During all stimulus calibration trials the thermode increased at a rate of 1 °C per second, returned to baseline (32 °C) at a rate of 8 °C per second following a response (clicking the mouse) and remained at baseline for 8 s prior to the onset of the subsequent trial. The average temperature of the second and third trials was calculated to determine the child’s ‘warmth threshold’. See Table 1 for warmth threshold descriptive statistics.

Pain tolerance. During the second set of three stimulus calibration trials, children were instructed to click any button of the mouse when they first noticed that the thermode became ‘too uncomfortable’ or ‘too painful’ to continue. Before starting the trial, experimenters asked the child, “*So, when should you press the button?*” to ensure comprehension of the task. Experimenters reviewed the instructions if the child did not respond with an appropriate response (e.g., “*when it hurts too much or is too uncomfortable”*). After ensuring that the child understood the instructions, the experimenter initiated the three pain tolerance trials. The mouse click triggered the thermode to return to baseline temperature. The following trials automatically began following an 8-second inter-stimulus interval. The average temperature of the second and third trials was calculated to determine the child’s ‘pain tolerance.’ See Table 1 for pain tolerance descriptive statistics.

Pain threshold. During the third and final set of three stimulus calibration trials, children were instructed to click any button on the mouse when they ‘first noticed’ the thermode change from ‘warm’ to ‘just painful’. Before starting the trial, experimenters asked the child, “*So, when should you press the button?*” to ensure comprehension of the task. Experimenters reviewed the instructions if the child did not respond with an appropriate response (e.g., “*when it first starts to hurt”*). After ensuring that the child understood the instructions, the experimenter initiated the three pain tolerance trials. The mouse click triggered the thermode to return to baseline temperature. The following trials automatically began following an 8-second inter-stimulus interval. The average temperature of the second and third trials was calculated to determine the child’s ‘pain threshold.’ See Table 1 for pain threshold descriptive statistics.

Reliability series. Following the stimulus calibration trials, the experimenter tested the reliability of the child’s subjective pain ratings. Two trials at each of the following three heat levels were presented in a standardized order: 1) 37 °C (not painful), which is a temperature considered to be below pain threshold, 2) at the child’s average pain threshold (‘slightly painful’) and, 3) 1 °C higher than pain threshold (‘moderately painful’). The heat trials during the reliability series were presented in this order for all children: ‘slightly painful’, ‘moderately painful’, ‘not painful’, ‘moderately painful’, ‘not painful’ and ‘slightly painful’. This order was designed to reduce expectancy, and prohibited children from receiving two of the same heat levels in a row, which could impact pain ratings. Following each reliability trial, the child provided a pain intensity and pain unpleasantness numerical rating. The experimenter adjusted the heat levels to obtain pain intensity ratings between 5 and 7 on an 11-point scale for the ‘moderately painful’ heat level. In order to select an appropriate heat level efficiently, experimenters used a standardized protocol for how to adjust the heat program based on pain intensity ratings. For example, if a participant rated the first moderately painful heat stimulus as a 4, the program was discontinued and the program selected delivered pain stimuli 0.5°C higher than the previous heat program, but if the participant rated the first moderately painful heat stimulus as a 9, the program was discontinued and the next program selected delivered both pain stimuli 1°C lower than the previous heat program (see Appendix E for sample reliability program adjustment chart.)

During reliability trials the thermode increased and decreased at a rate of between 1 °C per second and 3.2 °C per second, depending on the peak temperature in order to standardize the duration of pain stimulation to a total of 13 s. For example, for all children, the “not painful” temperature, which is set at a standard 37 °C increased and decreased at a rate of 1°C per second, and remained at ‘peak’ for 11 s and ramped down at rate of 1°C per second. For children with an average pain threshold of 46.5 °C the thermode ramped up and down at a rate of 2.9 °C per second. Ramp rates during experimental trials were pre-programmed to ensure that all heat stimuli are presented for 13 s from onset to return to baseline.

Because the reliability series determined the final temperatures for the experimental conditions, scores to reflect participant’s consistency between ratings on the pain scale within each heat level were calculated to examine the degree to which consistency in ratings may impact response to intervention. Individual rating consistency scores in the reliability trial series (which will be referred to here forth as Baseline Reliability) were calculated in two steps. The first step was to compute a variable that reflected the variance between the two pain rating scores within each heat level to evaluate how much they varied from one another. I then computed a square root of that variance score to obtain standard deviation scores that reflected the average standard deviation of their two scores from the mean of their two scores on both trials for each of the heat levels separately. As a hypothetical example, if a participant rated the two moderately painful heat stimuli as a 6 and a 7 in pain intensity, that heat temperature program was selected as their final heat and their reliability score was computed from those two scores. Baseline Reliability scores were computed for the final reliability program (i.e. the heat levels used for the experimental conditions) using the two pain intensity ratings at each heat level. Baseline Reliability scores ranged from 0, which indicates perfect agreement (i.e. no deviation from their mean rating) between pain intensity ratings within each heat level, and 3.54, which indicates low agreement between ratings. Therefore lower baseline reliability scores indicated greater reliability. See Table 5 for descriptive statistics of Baseline Reliability scores.

Experimental tasks. A modification of the experimental procedures used by Buhle & Wager (2010) was followed. Children completed two blocks of nine trials during which they experienced the three individually determined heat stimuli (not painful, slightly painful, moderately painful) in a standardized order: “not painful,” “moderately painful,” “slightly painful,” “moderately painful” “slightly painful” “not painful,” “moderately painful,” “not painful,” and “slightly painful” to obtain average pain ratings within each heat level, which are more stable than single trial. During one block they performed the control task and during the other block they performed the experimental task. Each trial lasted for approximately 50 s. All experimental stimuli were presented on a 36-inch computer monitor placed approximately 2 ft in front of the child. Experimental stimuli consisted of 120-pt font white letters and numbers presented on a black background.

Control condition. A control condition offered methodological value to the experimental design as it controlled for features of the experimental distraction condition (i.e., motor movement, simple visual attention to stimuli) that would otherwise be confounds to the study findings. Therefore, in the control condition, children viewed a series of numbers each presented for 840 ms. Each number was followed by a rapidly presented series of uppercase letters (serial letter mask), which were presented for 1000 ms. The serial letter mask is used in the experimental literature to disrupt the development of a visual trace and to keep participant's attention on the monitor to scan for subsequent targets. Children were instructed to press a key on a numerical keyboard with to indicate (*'yes, I see a number'*) every time a number appears. A total of random 20 numbers (integers 1 through 9) were presented in random order during each trial.

Reliability scores were calculated to reflect participant's consistency between ratings on the pain intensity scale within each heat level during the control condition to examine the degree to which pain ratings from the reliability series correlated with reliability in the control condition, and to examine any effects of reliability on distraction effectiveness. Individual rating consistency scores in the control condition (which will be referred to here forth as Control Condition Reliability) were calculated in two steps. The first step was to compute a variable that reflected the variance between the three pain rating scores within each heat level to evaluate how much they varied from one another. A a square root of that variance score was then computed to obtain standard deviation scores that reflected the average standard deviation of their three scores from the mean of their three scores on both trials for each of the heat levels separately. As a hypothetical example, if a participant rated the three not painful heat stimuli as a 0, 1 and 2 on pain intensity across the control trials, those three scores were used to compute the reliability score, which would have equaled one standard deviation from their own average pain intensity score. Control Condition Reliability scores were computed for the control condition using the three pain intensity ratings at each heat level and ranged from 0, which indicates perfect agreement between pain intensity ratings within each heat level, and 3.51, which indicates low agreement between ratings. Therefore lower scores indicated greater reliability. See Table 5 for descriptive statistics of Control Condition Reliability scores.

1-back (high load 'working memory') condition. During the block of nine experimental trials, participants saw a series of numbers and serial letter masks presented in the same manner as in the control condition. Participants were asked to report if the number presented is the same as the number immediately preceding it. Participants responded by pressing one of two buttons ('*yes*' or '*no*'). Task performance scores (i.e., d') were calculated by subtracting standardized (z) scores of incorrectly identified numbers (false alarms) from correctly identified numbers (hits) (see Table 3). Task performance (d') scores have an upper limit of 4.65, indicating perfect performance.

Experimental task training. Children were trained on the control and 1-back tasks to ensure that they understood the task demands prior to the start of the experimental trials. Following demonstration of their comprehension of the basic rules of the task, children completed a mock trial generated by the E-prime software of the same duration as the actual experimental trial length, but without heat stimuli, with the goal of reaching 80% accuracy. Children were told that they could earn up to five "coins" (i.e. pretend money) that they could trade in for prizes as the end of the study depending on their performance on the task. Children earned the five coins at the end of the mock trial in which they reached 80% accuracy. All children earned five coins regardless of whether or not they reached 80% accuracy on the last trial. The purpose of pairing coins with performance was to increase children's motivation to put effort into the task.

Three children required a second trial of the control task to achieve 80% or higher. Forty-five children required a second trial of the 1-back task to achieve 80% or higher. Twenty-three children required a third trial, and 19 of those children did not achieve the anticipated goal of 80% accuracy. Careful inspection of their experimental trial data showed that of the 19 who did not achieve 80% mastery during the practice trials, 11 achieved 80% or higher accuracy during one or more of the experimental trials, suggesting that with additional practice they showed adequate comprehension of the 1-back instructions and persistent effort. The remaining seven participants achieved accuracy ranging from 63.63% to 77.73%, and showed comprehension of the 1-back instructions and persistent effort on the task, and therefore their data were included in analyses.

Experimental trials. The children were notified at the start of each block whether the trial required performance of the 1-back task or the control task. In each experimental trial, the experimenter started the control or 1-back task; the trial started with a 4 s fixation cross to orient the child to the location on the screen where the experimental stimuli will appear. At 26 s a warning tone sounded and one of the three heat levels were delivered. At 39 s, the temperature reached baseline and the experimental task ended. Children immediately rated the pain intensity and pain unpleasantness on the scales presented on the screen (see Figure 5 for a visual diagram of a single trial). Children were told that they could earn up to five “coins” (i.e. pretend money) if they “did well” on the task. All children earned five coins at the end of each experimental block.

Children received \$10.00 and a small toy for their participation. Parents from the community (i.e., parents of children not attending the UMBC summer camp) were reimbursed \$10.00 to cover transportation and parking expenses incurred during the experimental session.

Data Analytic Plan

Preliminary analyses. Descriptive analyses were conducted to examine the normalcy of distributions to ensure that all variables met assumptions for analyses. Correlational analyses were conducted to examine the relations between child age, gender, pubertal status and past pain exposure with the pain outcome variables to identify potential covariates. Post-hoc *t*-tests were conducted to examine the mean differences in pain ratings for each of the three heat levels in the control condition to confirm that pain ratings increased from not painful stimuli to slightly painful stimuli to moderately painful stimuli. Correlational analyses were conducted to examine the relations between pain intensity reliability scores in the heat calibration reliability series, reliability scores in the control condition, and pain intensity change scores (from the control condition to the 1-back condition) for each level of heat separately.

Primary outcome and moderation analyses. Separate 2 x 3 (experimental condition by heat) analyses of variance (ANOVAs) were conducted to examine the effects of high load distraction and heat level on pain intensity and pain unpleasantness ratings. Post hoc *t*-tests were conducted to compare mean differences between experimental conditions at each of the heat levels.

Moderation analyses. Separate 2 x 3 x 2 (experimental condition by heat by mindfulness level) ANOVAs were conducted to examine the effect of dispositional mindfulness on the effects of high load distraction and heat level on pain intensity and pain unpleasantness ratings. Participants were dichotomized into 'high' and 'low' dispositional mindfulness based on whether they scored above (n = 32) or below (n = 24) the sample mean (M = 25.68). I chose to examine mindfulness by categorizing into two groups for purposes of retaining statistical power to detect effects.

Serial mediation analyses. The PROCESS macro for SPSS (Hayes, 2013) was used to examine the direct and indirect effects of 1) emotional control, 2) attentional control and 3) 1-back task performance on the relation between dispositional mindfulness and distraction effectiveness (defined as pain unpleasantness change from control to 1-back) for moderately painful heat. See Figure 6 for a visual model of the serial mediation model including the relations (i.e., direct and indirect) that were analyzed within the mediation model.

In a serial mediation model the effect of the independent variable (dispositional mindfulness) on the dependent variable (pain unpleasantness change score) is fully or partially explained through several intervening variables (emotional control, attention control and task performance). More specifically, it was hypothesized that dispositional mindfulness would be positively related to pain unpleasantness change (hypothesis 2a), and that the total effect would be partially explained by children's emotional control abilities as a function of their dispositional mindfulness which is thought to increase the skill of non-judgmental (i.e., non-emotional) attention to present experiences (hypothesis 2bi), which would in turn, be positively related to attentional control, as experiencing painful stimuli with low affective responding increases the ability to sustain attention toward distraction stimuli while inhibiting attention to interfering stimuli (i.e., noxious heat), leaving more cognitive resources available to process working memory distraction task demands, resulting in better performance (hypothesis 2diii). Finally, better performance on a demanding cognitive task was expected to result in greater effectiveness of the distractor during painful stimulation, resulting in greater unpleasantness pain change scores.

To test if the anticipated mediation was occurring in the proposed theoretical model, various statistical steps were taken. The first step was to test if an overall effect of dispositional mindfulness on distraction effectiveness was present (i.e., total effect '*c*'). Then the model systematical examined each direct effect of dispositional mindfulness on each mediator (all *a* paths), as well as the direct effects of each mediator on one another (all *d* paths) and on pain unpleasantness (all *b* paths) separately, while controlling for other effects in the model to examine each unique effect's contribution to the overall model.

Then the indirect effects of each simple mediation model within the larger serial mediation model were examined. Statistically, indirect effects are the product of two effects, which are both partial correlations (i.e., controlling for the other effects in the indirect effect.) Each indirect effect in a serial mediation model measures a mediation effect of the relation between dispositional mindfulness and pain unpleasantness, which is equal to the product of *a* and *b* paths for that/those mediator(s). For example, in the proposed mediation model the first indirect effect is composed on the effects of 1) dispositional mindfulness (X) and emotional control (M1) (a_1), and 2) emotional control (M1) and pain unpleasantness change score (Y)(b_1) on the relation between dispositional mindfulness (X) and pain unpleasantness change score (Y)(c'). Mediation is considered to occur when the total effect (c), which is the simple relation between dispositional mindfulness and pain unpleasantness change in this model, is statistically reduced in size when each of the mediators (e.g., emotional control) are added into the model. Therefore three within-model indirect effects were estimated, one for each of the three mediators. To calculate each of these anticipated indirect effects the *a* and *b* paths for each mediator were multiplied together to create a product of the two (*ab*). To determine power to detect each of the indirect effects, I multiplied the effects for the test of paths *a* and *b* (which are estimated from effect sizes found in the literature) which I used to obtain the power of the test of the indirect effect, as recommended by Kenny (2016).

Finally, an indirect effect for the full serial mediation model was estimated. In this model the test of each direct and within-model indirect effect was statistically controlled. In this case, the indirect effect is the product of the two effects that constitute the overall *a* path (a_1 and d_{21}) multiplied by the product of the two effects that constitute the overall *b* path (b_3 and d_{32}). With this estimate it is possible to estimate needed sample sizes from a power analysis. The test of the indirect effect for the full mediation model has low power due to a significant amount of variance in the model being statistically controlled in the analysis. To improve my ability to detect a mediation effect, I used the PROCESS macro for SPSS, as developed by Hayes to allow for bootstrapping, which increased the power of the analysis by creating a larger sampling distribution using my collected data points. This program also provided a bootstrapped confidence interval to determine if each effect was different from zero, and was therefore indicative of mediation. This is a commonly used statistical strategy due to the common issue of low power with small sample sizes (Kenny, 2016). To ascertain the effects of each indirect effect, I examined bootstrapped 95% confidence intervals, which provided an interval with two end-points that contain the true indirect effect, with a probability estimate that 95% of samples would contain the true population effect within the interval. As such, I expected to find confidence intervals that do not include zero.

Power Analyses

To determine the number of participants required to detect each expected effect I conducted *a priori* power analyses using *G*Power 3.1* (Faul, Erdfelder, Buchner, & Lang, 2009) and MedPower (Kenny, 2017). All power analyses were conducted using the assumptions of a one-tailed test with an alpha of .05. A table of interpretations of effect sizes is provided below:

	Effect Size Interpretation		
Effect Size Index	Small	Medium	Large
Cohen's f	.10	.25	.40
Pearson Correlation r	.10	.30	.50
F-test (f^2)	.02	.15	.35
Hedges' g and Cohen's d	.20	.50	.80
Partial eta Sq	.01	.09	.25

Hypothesis 1: Cognitive load and distraction effectiveness. Although some researchers have found that the level of cognitive load of distraction does not have an effect on behavioral pain outcomes (Seminowicz & Davis, 2007), various research groups have found that increased cognitive load does improve the effectiveness of distraction. Wiech and colleagues (2005) found that at high levels of painful stimulation (capsaicin with heat), participants rated pain as less intense when they were performing a high cognitive load task compared to a low load task (Cohen's d = 2.55), but that at low levels of painful stimulation there was no difference in pain intensity between the high and low cognitive load task (d = -.16). Bantick and colleagues (2002) found that a high cognitive load task had a large effect compared to a low load task on pain intensity using one level of heat stimulation (Cohen's d = 2.88). Buhle and Wager (2010) similarly a large effect of task demand on reduction in pain intensity at all levels of heat (Hedges' *g* = 1.79).

Power analyses indicated that to detect medium to large effects of Cohen's f coefficients from a 2 x 3 ANOVA, ranging from .35 to .40 between high cognitive load and low cognitive load conditions on pain intensity at both pain levels, at a power of .80, I needed a sample size of 15 to 19 children for this analysis. The table below indicates different sample sizes needed at each level of power.

Power	Cohen's f	
	.35	.40
.70	16	12
.80	19	15
.90	25	19

Hypotheses 2a-diii: Serial mediation of the effect of dispositional mindfulness on distraction effectiveness. I expected that a serial mediation model would show that emotional control, attentional control and distraction task performance mediated the relation between dispositional mindfulness and the effectiveness of distraction (i.e. pain unpleasantness ratings) in the high load 'working memory' distraction condition for moderately painful heat. Evidence exists to suggest that dispositional mindfulness may be related to key mechanisms of distraction and its effectiveness as an intervention for pain management. However, no known research to date has examined the potential mechanism of function between dispositional mindfulness and the effectiveness of distraction for pain.

However, various researchers have examined the relation between distraction and affective components of pain. Valet and colleagues (2004) found that a Stroop distraction task was effective for reducing pain unpleasantness ratings ($r = .60$) and to a lesser degree, pain intensity ($r = .56$) in adults. Bantick and colleagues (2003) similarly found a large effect of distraction on pain intensity ($d = 2.88$). Although the researchers in this study did not measure affective pain ratings, they found increased activity in areas of the brain associated with affective pain processing (i.e., the anterior cingulate cortex and orbitofrontal regions), as well as reduced activity in other parts of the brain considered to be relevant to the pain matrix. Further, an early adult study by Miron, Duncan and Bushnell (1989) found a large effect of a distraction on pain unpleasantness ($d = 3.78$). Given that dispositional mindfulness has been shown to predict, and causally affect variables associated with the function of distraction (i.e., emotional control, attentional control and task performance), I anticipated that dispositional mindfulness would have an overall effect on the effectiveness of distraction, as measured by pain unpleasantness ratings in a high load 'working memory' distraction condition, that can be partially explained by these mediating variables. Each effect within the serial mediation model required a unique power analysis, as presented below:

Hypothesis 2a: Dispositional mindfulness and pain unpleasantness (total effect 'c'). Little research to date has examined the direct relation between dispositional mindfulness and pain unpleasantness. The few studies that have measured these variables have found effects between dispositional mindfulness and pain unpleasantness ratings that range from non-significant (Pearson correlation coefficient r = .03) (Prins, Decuypere, & Van Damme, 2014) to small-to-medium effect sizes (r = -.16 to -.23) (Lu et al., 2007). Relatedly, in a mindfulness meditation intervention study, Perlman and colleagues (2010) found a reduction in unpleasantness ratings for long-term experienced meditators during an Open Monitoring mindfulness meditation practice trial compared to non-meditators with a large effect size of $\eta^2_p = .69$, indicating that 69% of the variance in the reduction in unpleasantness between meditators and non-meditators was attributable to the Open Monitoring meditation. I expected to find small to medium effect sizes (i.e., Pearson Correlation coefficients between -.25 and -.30) between dispositional mindfulness and baseline thermal pain unpleasantness in children during the high load 'working memory' distraction condition.

Hypotheses 2b: Emotional control.

Hypothesis 2bi: Dispositional mindfulness and emotional control. The adult and child literature both agree that mindfulness has powerful effects on emotion regulation abilities. Brown and colleagues (2013) showed that after controlling for attentional control, brain activity related to emotional reactivity (LPP amplitude) was significantly lower for more mindful individuals (r = -.52). Teper and Inzlicht (2013) similarly found that a group of meditators were significantly better at emotional acceptance (d = .86), and further that the higher the participants scored on emotional acceptance, the higher their average error-related negativity (ERN) amplitudes (r = .31, d = .65), which measures a neurophysiological response emitted by the ACC, which is known to process emotional information. For this effect (a_1) I expected to find medium to large effects of .45 and would therefore required a sample of 29 to 35 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2bii: Emotional control and pain unpleasantness. Research has found that the negative affectivity (NA) subscale of the Positive Affectivity Negative Affectivity Schedule (PANAS; Watson et al., 1988) which assesses negative affective arousal over the past week, is highly correlated with LPP amplitudes following highly arousing unpleasant stimuli (e.g., mutilations, corpses) (Pearson r = .45) and low arousal unpleasant images (e.g., homeless people, pollution) (Pearson r = .43) but not highly arousing pleasant images, or neutral images (Pearson rs of .10 to .28, respectively) (Brown, Goodman, & Inzlicht, 2013). Therefore the b_1 pathway of the proposed mediation model was expected to show a medium to large effect of .45 and therefore required a sample of 29 to 35 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2biii.Emotional control as a mediator. The indirect effect with emotional control as a mediator of the relation between dispositional mindfulness and pain unpleasantness (a_1b_1) was therefore expected to produce a small to medium effect size (beta = .20), and required a sample of 38 to 45 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2c: Attentional control.

Hypothesis 2ci. Dispositional mindfulness and attentional control. A substantial body of literature has examined the relation between dispositional mindfulness and executive functioning. In adults, various research groups have found strong relations between mindfulness and attentional control in particular. For example, Brown and colleagues (2013) found large effect sizes (r = .60 to .68) between dispositional mindfulness and attentional control (i.e., focusing and shifting), as measured by the Attentional Control Scale (ACS; Derryberry & Reed, 2002). In a sample of adults and adolescents with ADHD, researchers detected significant changes in neurocognitive performance following a mindfulness training program. Effects in this study ranged from small to large (Pearson Correlation coefficients from .04 to .69) with the most notable changes in Attentional Network Test conflict scores (r = .69), which measures an individual's ability to prioritize information among competing tasks (Zylowska et al., 2008). In the sample of adults and adolescents with ADHD, Zylowska and colleagues (2008) found large effects of the mindfulness intervention on the Stroop color-word task (r = .67) and Trails A task (r = .67), which measures attentional set-shifting and inhibition. However, smaller effects were found in changes in Digit Span performance from pre- to post-training (Pearson Correlation coefficients from .04 to .23)(Zylowska et al., 2008). For this effect (a_2) I expected to find medium to large effects of .45 and required a sample of 29 to 35 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2cii: Attentional control and pain unpleasantness. Perlman and colleagues found that long-term meditators, who are considered to have higher attentional control abilities than novices, rated pain stimuli as less unpleasant during an open monitoring (attentive, non-reactive awareness of stimuli in the present moment without focusing on any particular object) task than novices ($\eta^2_p = .31$). Therefore the b_2 pathway was expected to show a medium to large effect of .31 and required a sample of 66 to 83 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2ciii: Attentional control as a mediator. The indirect effect (a_2b_2) with attentional control as a mediator of the relation between dispositional mindfulness and pain unpleasantness was expected to produce a small effect size (beta = .14), and therefore required a sample of 68 to 84 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2di-2diii: Task performance.

Hypothesis 2di: Dispositional mindfulness and task performance. Moore and colleagues (2009) found large effects between dispositional mindfulness and various indicators of task performance on two experimental executive function tasks, namely the d2 test of attention and the Stroop, both of which measure participants' ability to suppress interfering information and to effortfully direct attention. Within these two tests the researchers found that dispositional mindfulness was related to the total number of correct items processed on the d2 (r = .67), the total number of errors on the d2 (r = -.53), as well as with the total number of Stroop items completed (r = .33) and the total number of errors on the Stroop (r = -.78). Lee and colleagues (2012) similarly found that adults who scored higher on the "acting with awareness" subscale of a dispositional mindfulness measure also had better response times on an experimental inhibition task ($r = .53$). Although less research has been done with children, one study by Oberle and colleagues (2012) found a small effect ($r = .20$) between dispositional mindfulness and performance on an inhibitory control task in a sample of 97 healthy children. Given the abundant evidence in adult and adolescent samples, as well as the fact that the only sample with children (Oberle et al., 2012) did not include any children screened to be high in mindfulness, for this effect (a_3) I expected to find medium to large effects of .45 and required a sample of 29 to 35 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2dii: Task performance and pain unpleasantness. No known research to date has reported the relation between working memory task performance and pain unpleasantness. Although several studies have measured both task performance (e.g., response time, d') and pain ratings no studies have specifically examined and reported the relation between task performance and pain ratings. However, Buhle and Wager (2010) found a large negative effect of task performance on pain intensity ($b = -2.16$, $p < .001$). Verhoeven and colleagues (2011) found no statistically significant relations between distraction task performance and pain intensity or pain unpleasantness ratings, however, the Pearson correlation between reaction time on the Random interval Repetition (RIR) task pain affect was -.19. Further, the researchers found a significant effect between self-reported attention to pain and pain affect of $r = .32$. The researchers measured pain affect as a composite of three items: 1) how unpleasant the experience was, 2) how anxious and 3) how tense they were during the cold pressor pain task. Therefore the b_3 pathway was expected to show a medium effect of .20 and would have required a sample of 168 to 212 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 2ciii: Task performance as a mediator. The indirect effect (a_3b_3) with task performance as a mediator of the relation between dispositional mindfulness and pain unpleasantness was expected to produce a small effect size (beta = .09), and therefore would have required a sample of 168 to 212 participants to detect an effect at a power of .70 or .80, respectively.

Additional effects estimated within the mediation model.

Emotional control and attentional control (direct effect d_{21}). Teper and Inzlicht (2013) found that during an executive function task (Stroop), experienced meditators more intensely noticed their own performance errors (error-related negativity measured by EEG) and performed better on the task than non-meditators, suggesting that meditators were able to notice their errors without emotional judgment and thus were able to return their attention to the task quickly. Therefore, it was expected that in the proposed study that participant's emotional control abilities and attentional control abilities would be positively related, and would evidence a medium effect size of .25. This direct effect required a sample of 39 to 47 participants to detect an effect at a power of .70 or .80, respectively.

Attentional control and task performance (direct effect d_{32}). Similarly, the model was expected to show a medium effect between attentional control and task performance, as Judah and colleagues (2014) showed that attentional control, as measured by the adult version of the ACS was moderately correlated with performance on the WAIS letter-number sequencing task ($r = .27$) which measures working memory abilities. Therefore, it was expected that in the proposed study that participant's emotional control abilities and attentional control abilities would be positively related, and would evidence a medium effect size of .25. This direct effect required a sample of 39 to 47 participants to detect an effect at a power of .70 or .80, respectively.

Emotional control and task performance (direct effect d_{31}). Little research to date has examined relations relevant to the effect between emotional control and executive task performance. However, Teper and Inzlicht (2013) found that emotional acceptance mediated the relation between meditation experience and task performance (Stroop task) 95% CI [-5.24, -0.03] suggesting that enhanced control over emotional states may be a key predictor of executive functioning abilities. However, as this effect is not directly related to the variables of interest in the proposed study, as well as the challenge of estimating effects without a standardized effect, such as a correlation coefficient, it is anticipated that in the proposed study that participant's emotional control abilities and attentional control abilities will be positively related, and will evidence a small effect size of approximately .10. This direct effect would require a sample of 93 to 114 participants to detect an effect at a power of .70 or .80, respectively.

Hypothesis 3: Dispositional mindfulness and pain unpleasantness. In line with the power analysis for hypothesis 2 in the serial mediation model, it was expected that children higher in dispositional mindfulness would also rate pain unpleasantness lower during the control (low load motor control) condition. Power analyses indicated that to detect a small to medium effect of Pearson Correlation coefficients equal to -.25 or -.30 between dispositional mindfulness and pain unpleasantness, at a power of .80, this effect would require a sample size of 67 to 97 children to be detectable. The table below indicates different sample sizes needed at each level of power.

Power	Pearson Correlation r	
	-.25	-.30
.60	58	40
.70	75	51
.80	97	67

Hypothesis 4: Dispositional mindfulness and pain intensity. Previous research has found effects between dispositional mindfulness and pain intensity that range from no effect to medium effects in size (Prins et al., 2014; Zeidan, Gordon, Merchant, & Goolkasian, 2010). In one study with healthy adults, Prins and colleagues (2014) found that dispositional mindfulness was not related to baseline thermal pain intensity ratings ($r = -.01$). In contrast, Schutze and colleagues (2010) found that in adults with chronic pain, self-reported typical pain intensity was negatively correlated with dispositional mindfulness ($r = -.22$). Additionally, Zeidan and colleagues (2010) found that dispositional mindfulness was associated with a reduction in thermal pain intensity ratings following a 3-day mindfulness meditation intervention ($r = .44$). In a sample composed of healthy adolescents, researchers found a small-to-medium negative correlation ($r = -.20$) between dispositional mindfulness and self-reported typical pain intensity of a frequently experienced pain in the last 3 months (Petter, Chambers, McGrath, et al., 2013). Given this large range of effects in the literature, in the present study I expected to find small effects (i.e., Pearson Correlation coefficients between -.15

and -.20) between dispositional mindfulness and baseline thermal pain intensity in children.

Power analyses indicated that to detect a small-to-medium effect of Pearson Correlation coefficients of -.15 to -.20 between dispositional mindfulness and pain intensity, at a power of .80, the correlational analysis would require a sample size of 152 to 272 children. The table below indicates different sample sizes needed at each level of power. Given that this analysis is expected to produce a smaller, and less novel effect, this study was expected to be underpowered to detect this effect.

Power	Pearson Correlation r	
	-.15	-.20
.60	159	89
.70	207	116
.80	272	152

Results

Participants

Sixty-seven children participated in the study. Ten were excluded from analyses for: computer malfunctions (2), lack of comprehension of experimental tasks (2), inconsistent baseline pain ratings (2) and missing data (4). The final sample included 57 children.

The sample was 51% male. Boys and girls were randomized into experimental order equally. Parent-reported racial identities of their children indicated that the sample was 63% white, 16% black, 14% biracial, 2% Asian or Pacific Islander, and 5% declined to report racial identity (see Table 2 for frequencies of demographic variables). The majority (81.5%) of boys were classified as pre-pubertal, whereas the majority (51.9%) of girls were classified at early pubertal (see Table 2). Only one participant was classified as having developed "*much earlier*" compared to her peers (See Table 2). Child age ranged from 9 to 13 years (M = 10.68, SD = 0.91) (see Table 3).

Preliminary Analyses

Descriptive analyses. Descriptive analyses were conducted for all of the predictor and dependent variables to determine the normalcy of their distributions (see Tables 3 and 4). Tests for skewness and kurtosis suggested that no transformations were necessary for analyses, per guidelines by Tabachnick and Fidell (2001).

Pain rating calibration reliability checks. Baseline Reliability and Control Condition Reliability scores in the three heat stimuli (not painful, slightly painful, moderately painful) were examined (see Table 5). Pearson correlations revealed that participants Baseline Reliability at moderately painful heat levels significantly predicted

Control Condition Reliability for moderately painful heat stimuli, suggesting consistency between the two estimates of reliability. For pain intensity change scores (i.e. distraction effectiveness), Baseline Reliability for moderately painful heat significantly predicted pain intensity change for both slightly painful and moderately painful heat. Additionally, Control Condition Reliability for not painful heat stimuli significantly predicted pain intensity change for not painful and moderately painful heat. See Table 6 for complete correlation matrix.

Heat stimulus ratings check. Pain intensity and pain unpleasantness ratings obtained in the three heat stimuli (not painful, slightly painful, moderately painful) were examined. A repeated measures ANOVA, with heat stimulus (not painful, slightly painful, moderately painful) as the within-subjects factor and pain intensity ratings as the dependent variable revealed a significant main effect of heat, $F(2,112) = 81.42$, $p < .001$. Post-hoc *t*-tests indicated that participants rated pain intensity of the three heat stimuli in the expected manner. Specifically, pain intensity ratings were significantly lower in the not painful heat trials compared to the slightly painful and moderately painful heat trials ($t(56) = -6.63$, $p < .001$, Cohen's d = 0.51, and $t(56) = -11.10$, $p < .001$, Cohen's d= 1.29, respectively). Additionally, pain intensity ratings were significantly lower in the slightly painful heat trials compared to the moderately painful heat trials, $t(56) = -7.69$, $p < .001$, Cohen's d = 0.81 (see Table 4.)

A repeated measures ANOVA, with heat stimulus (not painful, slightly painful, moderately painful) as the within-subjects factor and pain unpleasantness ratings as the dependent variable revealed a significant main effect of heat, $F(2,112) = 71.33$, $p < .001$. Post-hoc *t*-tests indicated that participants also rated pain unpleasantness of the three heat stimuli in the expected manner. Pain unpleasantness ratings were significantly lower in the not painful heat trials compared to the slightly painful and moderately painful heat trials ($t(56) = -6.56$, $p < .001$, Cohen's d = 0.65, and $t(56) = -10.29$, $p < .001$, Cohen's d = 1.24, respectively), and significantly lower in slightly painful heat trials compared to moderately painful heat trials, $t(56) = -6.59$, $p < .001$, Cohen's d = 0.56 (see Table 4.)

Covariates. Child age, gender, pubertal status and past pain experiences were considered as potential covariates. Pearson correlations revealed no significant relations between child age, gender, pubertal status and pain change scores (See Table 7). Past pain experience was significantly correlated with pain unpleasantness change in the moderately painful heat trials, and was trending toward significance with pain intensity and pain unpleasantness change for slightly painful stimuli. Given that past pain experience pain ratings were inconsistently related to pain ratings and due to power limitations to detect predicted effects, I chose to explore the effect of past pain experience in exploratory analyses rather than control for potentially meaningful error in main analyses.

Primary Hypotheses

Hypothesis 1: Cognitive load and distraction effectiveness. Separate repeated measures ANOVAs tested the effects of the high load working memory distraction condition (1-back) compared to the low load motor control condition (control) at each level of heat on pain intensity and pain unpleasantness.

Pain intensity. A repeated measures 2 x 3 (experimental condition by heat) ANOVA, with experimental condition (control vs 1-back) as one within-subjects factor, heat stimulus (not painful, slightly painful, moderately painful) as the second within-subjects factor, and pain intensity as the dependent variable revealed a significant condition by heat interaction, $F(2,55) = 10.12$, $p < .001$ (see Table 8 for full ANOVA table). Post-hoc *t*-tests showed that pain intensity ratings were significantly lower in the 1-back condition compared to the control condition in both slightly painful (t(56) = 2.14, $p = .036$, Cohen's d = .21) and moderately painful t(56) = 4.16 , $p < .001$, Cohen's d = .41) trials. Post hoc *t*-tests showed that experimental condition had no effect on pain intensity ratings in the not painful heat trials. To explicitly examine the magnitude of effects found at both pain levels, a post hoc repeated measures 2 x 2 (experimental condition (control vs 1-back) as one within subjects factor, heat stimulus (slightly painful vs moderately painful) as the second within subjects factor, and pain intensity as the dependent variable showed that pain intensity ratings were more significantly attenuated in the 1-back condition for moderately painful compared to slightly painful stimuli, $F(1,56) = 4.79$, $p = .033$, $\eta_p^2 = .08$. Figure 7 depicts mean pain intensity ratings for each heat stimulus in the control and 1-back conditions.

Pain unpleasantness. A repeated measures 2 x 3 (experimental condition by heat) ANOVA with experimental condition (control vs 1-back) as one within-subjects factor heat stimulus (not painful, slightly painful, moderately painful) as the second within-subjects factor, and pain unpleasantness as the dependent variable, also revealed a significant condition by heat interaction, $F(2,55) = 4.71$, $p = .011$ (see Table 9). Post-hoc *t*-tests showed that 1-back distraction significantly reduced pain unpleasantness ratings compared to the control condition in moderately painful trials t(56) = 2.64 , $p = .011$, Cohen's d = .23, but not in slightly painful trials t(56) = .52, p = .608, or in not painful trials t(55) = -25, $p = .807$. Figure 8 depicts mean pain unpleasantness ratings for each heat stimulus in the control and 1-back conditions.

Dispositional mindfulness and distraction effectiveness. Separate 2 x 3 x 2 (experimental condition by heat by mindfulness level) repeated measures ANOVAs were conducted to examine the effect of dispositional mindfulness on the effects of high load distraction and heat level on pain intensity and pain unpleasantness ratings (see Tables 10 and 11). Given the low power to detect a three way interaction effect, separate 2 x 2 ANOVAS, with experimental condition (1-back vs control) as the within-subjects factor and mindfulness group (high vs low) as the between subjects factor, were conducted on both dependent variables (pain intensity and pain unpleasantness) separately at each of the three heat levels (not painful, slightly painful, moderately painful).

Pain intensity. As can be seen in Table 12, the interaction between mindfulness and experimental condition was not significant at any of the heat levels. Thus, mindfulness did not appear to moderate the effects of experimental condition on pain intensity ratings.

Pain unpleasantness. As shown in Table 13 the interaction between mindfulness and experimental condition was not significant at any of the heat levels. Thus, mindfulness did not appear to moderate the effects of experimental condition on pain unpleasantness ratings.

Hypothesis 2: Serial mediation of the effect of dispositional mindfulness on change in pain unpleasantness. A serial mediation model was tested to examine the effect of dispositional mindfulness on distraction effectiveness (pain unpleasantness change from control to 1-back condition) in the moderately painful heat trials, through three predictors: emotional control, attentional control and 1-back task performance (d').

All indirect effects were tested using bootstrap confidence intervals with 5000 samples. See Table 14 for full mediation model effects, and Figure 9 for a visual depiction of the serial mediation model and pathways.

Dispositional mindfulness and pain unpleasantness (total effect 'c'). The serial mediational analysis revealed that dispositional mindfulness did not significantly predict distraction effectiveness after controlling for the other variables in the model, as evidenced by a non-significant total effect c = .02, $p = .401$.

Emotional control effects.

Direct effect of dispositional mindfulness on emotional control. Dispositional mindfulness directly predicted emotional control, $a_1 = -.17$, $p = .012$.

Direct effect of emotional control on distraction effectiveness. Emotional control did not significantly predict distraction effectiveness after controlling for all other predictors, $b_1 = .05$, $p = .396$.

Indirect effect of dispositional mindfulness on distraction effectiveness through emotional control. Emotional control did not significantly mediate the relation between dispositional mindfulness and distraction effectiveness, as evidenced by a bootstrap confidence interval that included zero, $a_1 b_1 = -.01$ CI [-.04, .01].

Attentional control effects.

Direct effect of dispositional mindfulness on attentional control. Dispositional mindfulness directly predicted attentional control, after controlling for emotional control, $a_2 = .45$, $p < .001$.

Direct effect of attentional control on distraction effectiveness. Attentional control did not significantly predict distraction effectiveness after controlling for all other predictors, $b_2 = .05$, $p = .314$.

Indirect effect of dispositional mindfulness on distraction effectiveness through attentional control. Attentional control did not significantly mediate the relation between dispositional mindfulness and distraction effectiveness, as evidenced by a bootstrap confidence interval that includes zero, $a_2\, b_2 = .00$, CI [-.01, .01].

1-back task performance effects.

Direct effect of dispositional mindfulness on task performance. Dispositional mindfulness did not significantly predict 1-back task performance after controlling for attentional control and emotional control, $a_3 = .03$, $p = .520$.

Direct effect of task performance on distraction effectiveness. 1-back task performance directly predicted distraction effectiveness, after controlling for all other predictors, $b_3 = -.27$, $p = .038$.

Indirect effect of dispositional mindfulness on distraction effectiveness through task performance. 1-back task performance did not significantly mediate the relation between dispositional mindfulness and pain unpleasantness ratings, as evidenced by a bootstrap confidence interval that includes zero, $a_3\, b_3 = .00$ CI [-.04, .01].

Additional direct effects.

Direct effect of emotional control on attentional control. Emotional control directly predicted attentional control, after controlling for dispositional mindfulness, $d_{21} = -.35$, $p = .027$.

Direct effect of attentional control on task performance. Attentional control did not significantly predict 1-back task performance, after controlling for dispositional mindfulness and emotional control, $d_{32} = .06$, $p = .338$.

Direct effect of emotional control on task performance. Emotional control did not significantly predict 1-back task performance, after controlling for dispositional mindfulness and attentional control, d_{31}' = -.01, p = .921.

Hypothesis 3: Dispositional mindfulness and pain unpleasantness. Pearson Product Moment Correlation Coefficients revealed that dispositional mindfulness and pain unpleasantness ratings were not significantly related during slightly painful or moderately painful trials during the control condition (r = .14, p = .296, r = .04, p = .766, respectively), or during the 1-back condition (r = -.02, p = .900, r = .12, p = .381, respectively). See Table 15 for full correlation table. Positive correlation coefficients would indicate that higher pain unpleasantness ratings were associated with higher dispositional mindfulness and negative correlation coefficients would indicate that higher pain unpleasantness ratings were associated with lower dispositional mindfulness.

Hypothesis 4: Dispositional mindfulness and pain intensity. Pearson Product Moment Correlation Coefficients revealed that dispositional mindfulness and pain intensity ratings were not significantly related during slightly painful or moderately painful trials during the control condition (r = .08, p = .576, r = .05, p = .699, respectively), or during the 1-back condition (r = -.01, p = .942, r = .07, p = .588, respectively). Positive correlation coefficients would indicate that higher pain intensity ratings were associated with higher dispositional mindfulness and negative correlation coefficients would indicate that higher pain intensity ratings were associated with lower dispositional mindfulness.

Exploratory Analyses

Participants in the present study scored within expected range for dispositional mindfulness (*M* = 25.68, SD 6.14) in comparison with two samples used for validation of the CAMM. Mean scores in the present study fell in between mean scores of participants in the American validation study (*M* = 23.27, SD = 7.28), and the mean scores of participants from the Netherlands validation study (*M* = 27.26, SD = 5.82).

Post-hoc *t*-tests showed that pain intensity ratings were consistently higher than pain unpleasantness ratings at all heat levels (not painful, slightly painful, moderately painful) in the control condition, t(56) = 3.78 , $p < .001$, t(56) = 3.66 , $p = .001$ and t(56) = 3.68 , $p = .001$, respectively). However, in the 1-back condition pain intensity ratings were higher than pain unpleasantness ratings at the not painful heat levels, t(55) = 3.61 , $p = .001$, and did not differ in the slightly painful and moderately painful trials, t(56) = 1.47 , $p = .148$, t(56) = 1.63 , $p = .109$ respectively.

Exploratory qualitative analyses revealed several patterns of pain intensity ratings for the not painful heat stimuli. Twelve participants rated between two and three of the not painful heat stimuli (i.e. 37 °C stimulus that is below nociceptive threshold) as a numerical rating of ‘4’ (on an 11-point scale) or higher during one of the three control trials, suggesting that they experienced an objectively ‘non-painful’ stimulus as painful. During calibration trials, 3 out of those 12 participants exhibited average pain thresholds of 37 °C; the remaining 9 participants indicated pain thresholds at or above 39 °C, suggesting that the majority of the participants who rated not painful heat stimuli as painful during control trials exhibited baseline pain thresholds within expected the temperature range.

Discussion

The primary purpose of the present study was to examine the effect of cognitive load on distraction effectiveness for acute pain management in a sample of healthy children. Based on the adult literature it was predicted that a high load distraction condition would reduce pain ratings compared to a low load motor control condition. The present study also examined dispositional mindfulness as a potential moderator and mediator of distraction effectiveness. It was expected that dispositional mindfulness would predict benefit from high load distraction, and that the effect would be partially explained by several factors: attentional control, emotional control and better performance on the high load distraction task. Finally, it was expected that dispositional mindfulness would predict pain unpleasantness ratings to a greater degree than pain intensity.

Cognitive load and distraction effectiveness

This is the first known study to examine the effect of cognitive load on distraction effectiveness in children. The methodology closely replicated the experimental paradigm developed by Buhle & Wager (2009) to isolate cognitive load as the only manipulated factor between experimental conditions. As expected, the results were consistent with their findings such that the high load 'working memory' (1-back) distraction intervention was more effective for reducing pain intensity than the low load 'motor' control condition at both levels of painful heat (slightly painful and moderately painful).

A similar pattern was detected with regard to pain unpleasantness ratings. Specifically, high load distraction was more effective for reducing pain unpleasantness ratings at moderately painful heat levels than the low load control condition. Interestingly, the effects were smaller than the effects for pain intensity, suggesting that distraction may reduce the sensory aspects of pain processing to a greater degree than the more affective components of pain that are thought to be better captured by pain unpleasantness ratings.

The current study corroborates evidence that suggests that pain competes with other inputs of information for limited cognitive resources. Legrain and colleagues (2013) suggest that working memory intervention may function as an effective distractor by suppressing early cortical responses to nociceptive stimuli, by way of blocking ascending signals from nerve endings in the body from reaching parts of the brain that are known to process pain information. Brain imaging research provides further evidence to suggest that pain and distraction compete for limited cognitive resources (Frankenstein et al., 2001) such that regions of the brain that are activated by pain stimuli are also reliably activated by cognitive performance tasks in the absence of pain, suggesting that both types of information use the same pathways. However, these results are in contrast with those found in adults by Seminowicz and Davis (2007), which showed that increasing task difficulty did not affect pain intensity or unpleasantness ratings, and further, that pain stimuli did not affect performance on several high load tasks. The authors concluded that pain and cognitive processes do not entirely prohibit the other, and that they can be concurrent without significant impact on the other process. The authors suggest that it is possible that the shift from cognitive task to pain stimuli may occur quickly and therefore cognitive resources may indeed be shared but less substantially than has been found in behavioral pain reporting studies that have shown powerful effects of cognitive load on pain reduction.

In the current study the low load motor control condition was designed to control for task factors including visual stimuli, motor responses to manipulate cognitive load most effectively. As such, the control task required less executive cognitive resources to compete with pain stimuli. The results provide support to Eccleston’s (1995) theory that lower cognitive load tasks that include repetitive or boring tasks become automatic over time likely require fewer cognitive resources making them less effective at competing for attentional resources than more effortful distraction interventions. Seminowicz and Davis (2007) found that some prefrontal cortical areas (i.e. DLPF) were only activated during high load tasks, suggesting that lower difficulty tasks can be performed without activation of cognitive processes in this higher level prefrontal area. Taken together with Eccleston (1995), the findings in the present study with children suggest that the low load task was not effortful enough to activate areas of the prefrontal cortex that could interfere more effectively with pain processing.

Another important contribution to the literature is the finding that the benefit of cognitive load increased as pain level increased, as evidenced by a larger effect size for moderately painful heat stimuli (.41) than it for slightly painful heat stimuli (.21) in pain intensity ratings. This finding is consistent with results from Wiech and colleagues' (2005) study with an adult sample that found a large effect of cognitive load at higher levels of pain stimulation, and no differences between high load and low load distraction at low levels of pain stimulation.

It has been suggested, but not explicitly examined, that the type of pain stimulus may moderate the effect of cognitive load on distraction effectiveness (Terrighena, Shao, & Lee, 2017). Our research team conducted a pilot study of the current examination using cold pressor pain, and found that cognitive load did not increase pain tolerance.

One potential reason for the different results between the two studies may be that heat stimuli elicit a more immediate and rapid pain localization and affective process, whereas cold pressor pain elicits a more diffuse, extended pain response that requires increased cognitive effort, and therefore interrupts attention to distraction more, resulting in cognitive load producing less robust effects. Future research should examine if different modalities of pain (e.g. heat, cold, mechanical) elicit different effects of cognitive load. Due to the fact that our pilot study and the present study used tasks that varied on degree of cognitive load, this hypothesis is not testable with currently collected data.

Finally, it is worth noting that the findings revealed no differences between the experimental conditions at the not painful heat levels, as was anticipated.

Dispositional mindfulness as a moderator of distraction effectiveness

It was hypothesized that dispositional mindfulness would significantly moderate distraction effectiveness, particularly for pain unpleasantness ratings, in part because distraction is known to vary in its effectiveness for individuals, and also because mindfulness has been shown to positively impact pain outcomes and response to distraction intervention. However, contrary to prediction, dispositional mindfulness did not moderate the effectiveness of distraction at any of the heat levels.

There are several potential reasons to explain the lack of anticipated findings with regard to dispositional mindfulness. First, dispositional mindfulness may reflect an ability that develops with age, similar to executive functions, such as emotional control. It is possible that given the young age of the children in the sample, mindfulness abilities were early in development, or, that children were not able to transfer their mindfulness abilities to the context. The mindfulness measure used in the present study is not worded to capture pain-related mindfulness skills, and therefore it may not be sensitive to pain contexts. A dispositional mindfulness measure that includes pain-related non-judgmental attention may show a more robust prediction of pain outcomes. Future research should examine these hypotheses directly by longitudinally examining the development and reliability of dispositional mindfulness over time and context in addition to other factors that may moderate the effects of dispositional mindfulness on pain outcomes.

Another possible reason for the non-significant moderating effect of mindfulness also relates to the construct of dispositional mindfulness as it relates to pain specifically. Although I hypothesized that mindfulness and distraction would produce additive effects, there is some preceding literature that found that adults who were higher on dispositional mindfulness did not benefit more from a math distraction task (Zeidan et al., 2010). It is possible that the two strategies may not provide added benefit, or may work in opposite, and non-additive ways. For example, children who naturally attend to pain more non-judgmentally may be more likely to benefit from attending to pain stimuli to reduce its unpleasantness rather than effortfully attempting to distract from the pain. If that is the mechanism by which mindfulness functions distraction may not utilize their strengths of processing pain differently because it forces them to use a different strategy altogether. By introducing a distractor, we may have reduced natural coping strategies that facilitate more effective processing of pain stimuli, which may in turn function to allow more nociceptive signals through the dorsal horn and to pain systems in the brain. The present study offers preliminary support for this possibility in that the focus subscale of attentional control was significantly related to dispositional mindfulness, and that shifting abilities from the attentional control measure was not significantly related to dispositional mindfulness, suggesting that dispositional mindfulness may not offer added benefit to switching between distraction and pain stimuli as anticipated. Future studies may address this question by asking participants directly about their level of attention toward pain stimuli compared to the distractor.

It is also possible that the CAMM did not adequately capture in the moment use of mindfulness skills during the experimental trials. It is likely that children were effortfully choosing to attend to the distractor and not engage in mindful attention toward pain stimuli. As such, it would be valuable to measure qualitative experiences of children during pain stimulation to examine the explicit attentional and regulatory processes that children use during pain trials. No known studies to date have examined state measures of use of mindfulness skills during acute pain. Future research may address this question by asking participants directly about their experience of the pain stimuli with particular attention to non-judgmental attention to sensations compared to threat- and fear-based attention to sensations.

Finally, it is possible that low statistical power reduced the ability to detect a small, but clinically important effect. To increase power to detect predicted effects a mean split at the sample mean of dispositional mindfulness was used in analyses to examine the moderating effect of dispositional mindfulness on the effect of cognitive load on pain ratings. However, this statistical approach is not ideal as it eliminates valuable variance in dispositional mindfulness as a continuous measure. As such participants who were in the middle of the normal distribution were potentially arbitrarily sorted into a category (high or low) that may not reflect their true score. For future studies a preferable approach to examine the moderating effect of dispositional mindfulness would be to examine dispositional mindfulness as a continuous variable to retain important variability in the measure. Post-hoc power analyses revealed that I would have required a sample of 160 children to detect a small effect of dispositional mindfulness as a continuous variable at power of .80, which was prohibitive for the current examination.

The mediated effect of dispositional mindfulness on distraction effectiveness.

In contrast with hypotheses, the serial mediation model revealed that dispositional mindfulness did not significantly predict distraction effectiveness (change in pain unpleasantness ratings) in moderately painful heat trials through the three predictors: emotional control, attentional control and task performance. However, several direct effects that were statistically significant within the serial mediation model may contribute to the literature with regard to how dispositional mindfulness correlates with factors thought to be associated with pain.

Emotional control. As expected, dispositional mindfulness was significantly related to emotional control in the expected direction, such that parents of children who were higher on dispositional mindfulness reported that their children had fewer emotional control problems than parents of children who were lower on dispositional mindfulness. Research with adults has suggested that mindfulness likely improves emotion-regulation abilities by way of reducing the interference of emotional stimuli or reducing the duration of time in which individuals attend to emotion stimuli (Brown et al., 2013; Teper & Inzlicht, 2013). With regard to pain processing, Chiesa, Serretti and Jakobsen (2013) suggested that for short-term practitioners of mindfulness dispositional mindfulness likely reduces the emotional valence of emotional stimuli because of improved ability to quickly evaluate pain stimuli to be less emotionally threatening. In the present study I did not find that dispositional mindfulness predicted greater benefit from distraction in the same way. For children, the ability to modulate emotional responses is developing rapidly, but is clearly not fully developed. As such, it is possible that mindfulness skills are related to greater emotional control, but that these skills have not generalized to the modulation of pain. As noted by Crombez, Van Damme and Eccleston (2005), pain is evolutionary predisposed to capture attention, and it may also be that early in development pain systems are highly attuned to potential threats in the environment for safety and survival, and may be less flexible regardless of executive functioning skills. To examine how dispositional mindfulness modulates emotional control abilities in children in the context of acute pain, research could replicate the methodology of Brown and colleagues (2013) by measuring the relation between dispositional mindfulness and immediate neural responses (LPP) as measured by EEG during presentation of pain stimuli to examine developmental trends of pain experience using either a longitudinal or cross-sectional design.

Attentional control. Dispositional mindfulness also significantly predicted attentional control in the expected direction, as evidenced by a medium to large effect. This finding is in line with previous research that has shown large effect sizes between measures of attentional control and dispositional mindfulness in adult samples (Brown et al., 2013). Further, in a sample of adolescents and adults with ADHD, Zylowska and colleagues (2008) found that an 8-week mindfulness training program improved performance on multiple cognitive tasks that measure attentional control. The present study is the first to evaluate the relation between dispositonal mindfulness and attentional control in a sample of children. Therefore the results contribute new data that can inform future research with the aim of disentangling the direction of effects between dispositional mindfulness and attentional control, as well as potential clinical uses of both measures.

As with emotional control, the hypothesized mediating role of attentional control was not shown in the present study, suggesting that the increases in attentional control did not improve distraction effectiveness as expected. Verhoeven, Van Damme, and colleagues (2011) also hypothesized that distraction would be more effective for college students with better switching abilities compared to participants with poorer switching abilities, however they found no evidence to support that premise. It is possible that both studies failed to measure critical moderators that might explain why some individuals with better executive functioning may not benefit more from distraction in the context of acute pain stimulation. For example, neither study measured pain catastrophizing, which may function such that individuals who catastrophize about pain may be less able to utilize switching during pain stimulation.

1-back task performance. Task performance in the 1-back condition significantly predicted distraction effectiveness, as expected. The effect size of the relation was surprisingly larger than those found in adult studies. This may indicate that pain naturally captures attention more easily for children than for adults, and therefore performance of a distraction task is able to capture more attentional resources that would otherwise be allocated to process pain stimuli. In line with that developmental explanation for larger effects in children, Quiton and colleagues (2007) found that older adults show significantly smaller neural responses in areas of the brain associated with pain sensation when compared to young adults. Contrary to prediction, 1-back task performance was not directly predicted by dispositional mindfulness as hypothesized. Previous studies have found small to large effects for the relation between mindfulness and cognitive task performance with adults and adolescents. The data from the current study revealed that task performance was overall low, suggesting that children made a significant number of errors. As such, it is plausible that the distribution of d' scores was restricted in the current sample, reducing the size of the true effect, and making the current study underpowered to detect the effect. Finally, pain has been shown to interfere with cognitive performance in adults (Buhle & Wager, 2010). No known studies to date have examined the interruptive effects of pain on task performance in children. Future examination of task performance and the impact on subjective pain ratings is indicated in samples of children.

Dispositional mindfulness and pain ratings

In contrast to prediction, dispositional mindfulness was not significantly related to pain unpleasantness ratings in either experimental condition at any of the heat levels. However, visual examination of the effects suggests that dispositional mindfulness was more highly correlated with pain unpleasantness ratings in the control condition at the slightly painful heat levels than other with other pain ratings in the control condition,. In the 1-back condition, a similar pattern emerged at the moderately painful heat level for pain unpleasantness, such that children higher on mindfulness rated pain unpleasantness lower than children lower on mindfulness. Although the effects are not interpretable given that they did not reach statistical significance.

Unique Contributions to the Literature

Several other research groups have conducted thermal pain testing with children. However, few studies have explicitly examined methodological issues in thermal pain testing with children. A recent paper that examined the use of various methods of experimental pain research in children noted the critical need for examinations of thermal pain procedures to develop guidelines (Birnie et al., 2014). As such, this study offers valuable insight into challenges and benefits of thermal pain as a modality to study acute pain in children.

This study also examined pain intensity and pain unpleasantness ratings separately to capture valuable information about sensory and affective processing of pain in children. Results are consistent with previous research that has found higher pain intensity ratings compared to pain unpleasantness ratings (Lu et al., 2007). However it is worth noting that in the present study study and the study by Lu (2007) and colleagues pain unpleasantness was rated following pain intensity for all trials. So, it is possible that the relatively lower unpleasantness ratings are an artifact of the order in which the ratings were obtained.

Limitations and Future Directions

In addition to those noted above, there are several limitations to the current study. As is common in experimental pain studies overall, within-participant consistency in pain ratings varied between participants. The method of delivering a series of threshold and tolerance stimulation trials to calibrate heat temperatures was informed by widely used procedures in both adult and child studies (Birnie et al., 2014; Buhle & Wager, 2010; Myers et al., 2006). Reliability was low for some children, and reliability scores correlated with magnitude of improvement from the control condition to the 1-back condition, but not in the direction expected and not in a consistent manner across heat levels. Although it is unlikely that any methodological changes would affect within-subject consistency substantially, it is important to note some potential additions to the calibration procedure and how they may function to examine children's pain ratings over consecutive measurements. Perceptual sensitization is a method of delivering heat stimuli at the child's identified pain threshold for 30 s and at the end of the stimulation asking children to readjust the temperature to their pain threshold level,(Birnie et al., 2014). The perceptual sensitization method assumes that children believe that the temperature is changing even though it is remaining constant. The addition of the perceptual sensitization procedure could increase pain threshold accuracy by relying less on the ability of children to quickly identify changes in sensations. With a potentially more stable pain threshold estimate experimenters may be better able to select heat programs that more accurately reach the desired pain intensity ratings between 5 and 7 on a 0-10 scale. Yet another option that is used less frequently is that of temporal summation, which delivers a series of 10 pain stimuli of the same temperature and asks the child to report on the pain intensity level after each stimulation (Birnie et al., 2014). Integration of either of those methodologies may improve reliability of pain ratings in future studies, however this has not been systematically examined to date. Additionally, some studies conduct pain calibration trials on a different day before experimental trials (Quiton, Keaser, Zhuo, Gullapalli, & Greenspan, 2014), which could reduce potential effects of the calibration procedure on the experiment.

However, regardless of thermal pain methodology, it is commonly reported in research across methods that children provide unreliable pain ratings, suggesting that it is a difficult task that likely is affected by many factors not easily controlled for research purposes.

For ethical reasons (to avoid undue coercion), The consent and experimental scripts used during the experiment emphasized the participant's ability to discontinue at any time, in addition to stating that all heat levels delivered would be safe and would not cause actual damage to skin. It is very likely that adding such a high level of perceived control and reducing the perceived threat of pain reduced the overall noxious and threatening aspects of pain. Correspondingly, it is likely the affective component of pain was uniquely attenuated because humans are hardwired to naturally want to escape pain for survival, and with that threat removed the remaining effects were too small to detect other factors that predict pain affect (e.g. dispositional mindfulness). Future research may examine the impact of perceived control on pain affect by manipulating the instructions read to participants prior to pain trials. For example the script could vary by the including or excluding instructions about the ability to discontinue, either in a between-subjects design or in a counter-balanced within-subjects design that would provide added statistical control to detect true differences beyond the effect of individual differences. Another method for examining the potential influence of the threat of pain on pain unpleasantness could be to provide instructions for one set of trials that increase the threat of pain by noting that the pain could not be discontinued (i.e. escaped).

With regard to capturing dispositional mindfulness accurately, the present study may have benefitted from gathering addition information about children's actual mindfulness practice. Most adult studies, and several studies with children, examine previous mindfulness practice for the purpose of describing level of experience of participants (Lyvers et al., 2014; Perlman et al., 2010). Therefore the lack of data on actual practice may be a limitation because actual practice may more accurately predict use of mindfulness skills. Future examinations should also examine the effect of variables including time per day practicing mindfulness, and children's exposure to different types of mindful practice when examining dispositional mindfulness.

Although this study offers valuable information about unique effects for pain intensity and pain unpleasantness, the method of gathering the ratings is worth noting as a potential limitation. Specifically, pain intensity ratings were presented first to children following the discontinuation of the experimental trial and the pain stimulus presentation. Pain unpleasantness ratings were recorded after pain intensity ratings. As such, it is possible that pain unpleasantness ratings were affected by rating pain intensity first. Future research should systematically examine the effects of order of presentation on subjective pain intensity and unpleasantness ratings.

Finally, the sample was underpowered to detect the full serial mediation effect as well as indirect mediation effects within the model. Future research should continue to explore each of the mechanisms considered in the present study to provide additional information regarding the potential mechanisms of function in the effectiveness of distraction. Post-hoc power analyses revealed that I would have required a sample of 168 to 220 children to detect small indirect effects power of .80, which was prohibitive for the current examination.

Clinical Implications

This study offers several notable clinical implications to the literature. First, the use of thermal pain is a strength of the study as it has been speculated that it may approximate the experience of needle procedures or other acute pain experiences more than other pain stimuli (i.e. cold pressor or water load symptom provocation) (Birnie et al., 2014).

This study also suggests that distraction tasks used in clinical settings for medical procedures (e.g. immunizations) will likely be more effective in reducing the general noxious aspects of pain for children if they are determined to have higher cognitive load. Additionally, the current study offers evidence that increasing cognitive load of a distractor may be more beneficial for medical procedures that are associated with moderate levels of pain than for slightly painful procedures. This finding suggests that cognitive load should be examined with various painful procedures to determine what constitutes slightly painful compared to moderately painful to better inform intervention in clinical settings.

Research in pediatric settings should evaluate the cognitive load of available distractors before use with children to determine the relative clinical usefulness of the intervention. By selecting the most effective distractors, it is anticipated that distraction will produce greater effects for children undergoing painful medical procedures. Improved pain care in clinical settings is also correlated with a wealth of important factors including increased health care use in adulthood, better parent and family coping over time and lower provider and healthcare costs (Cohen et al., 1997; Kazak et al., 1995; Luthy et al., 2009; Pate et al., 1996)

Table 1

Descriptive Statistics for Heat Stimulus Calibration

	n	*M*	*SD*	Min.	Max.	Skewness	*SE*	*Kurtosis*	*SE*
Warmth Threshold	57	37.26	3.12	33.20	47.60	1.24	0.32	1.22	0.62
Pain Threshold	57	41.84	3.69	34.10	49.25	-0.09	0.32	-0.99	0.62
Pain Tolerance	57	44.46	3.15	37.20	49.95	-0.42	0.32	-0.52	0.62

Note: Acceptable skewness and kurtosis values for z-scores (i.e., $z < \pm 1.64$) indicating skewness/kurtosis values are not significantly different from zero (Tabachnick & Fidell, 2001).

Table 2

Number of Participants by Sex, Race and Pubertal Status

	Race					Pubertal Status			
	Caucasian	African American	Asian/Pacific Islander	Biracial	Decline to answer	Pre-pubertal	Early Pubertal	Pubertal	Decline to answer
Male	20	7	1	1	0	22	5	0	2
Female	16	2	0	7	3	8	14	5	1
Total N	36	9	1	8	3	30	19	5	3

Table 3

Descriptive Statistics of Demographic and Predictor Variables and Pain Rating Change Scores by Heat Level

Variable	*n*	*M*	*SD*	Min.	Max.	Skewness	*SE*	*Kurtosis*	*SE*
Dispositional Mindfulness[a]	57	25.68	6.14	11	38	0.17	0.31	-0.56	0.62
Emotional Control[b]	57	10.98	3.16	8	22	1.14	0.32	1.33	0.62
Attentional Control (Focus)[c]	57	25.05	4.67	14	34	0.16	0.32	-0.56	0.63
Attentional Control (Shift)[c]	56	14.68	2.24	9	20	-0.12	0.32	-0.24	0.62
Child age	57	10.68	0.91	9	13	0.09	0.32	-0.25	0.62
Past pain experience	52	2.62	1.05	1	4.60	0.05	0.33	-0.97	0.65
Task performance (d') in 1-back trials									
Not painful	56	-0.07	1.47	-4.39	1.91	-1.19	0.32	1.16	0.62
Slightly painful	57	-0.06	1.46	-4.12	1.84	-0.68	0.32	-0.03	0.62
Moderately painful	57	-0.02	1.44	-3.89	2.04	-0.97	0.32	0.19	0.63
Pain Rating Change Scores									
Pain Intensity									
Not painful	56	0.01	1.23	-3.33	3.67	0.27	0.32	1.92	0.63
Slightly painful	57	-0.37	1.30	-3.67	2.67	-0.07	0.32	0.31	0.62
Moderately painful	57	-0.74	1.34	-3.67	2.67	0.05	0.32	0.20	0.62
Pain Unpleasantness									
Not painful	56	0.03	0.91	-3.00	1.67	-0.44	0.32	1.15	0.63
Slightly painful	57	-0.09	1.37	-3.33	3.33	-0.30	0.32	0.78	0.62
Moderately painful	57	-0.46	1.30	-3.33	2.67	-0.02	0.32	0.02	0.62

Note: Acceptable skewness and kurtosis values for z-scores (i.e., $z < \pm 1.64$) indicating skewness/kurtosis values are not significantly different from zero (Tabachnick & Fidell, 2001).
[a]The Child and Adolescent Mindfulness Questionnaire (CAMM).
[b]The Behavior Rating Inventory of Executive Function- Second Edition (BRIEF-II).
[c]The Attentional Control Scale for Children (ACS-C) comprises the subscles: Focus and Shift.

Table 4

Descriptive Statistics for Pain Intensity and Pain Unpleasantness Ratings by Heat Level

Condition	Heat	*n*	*M*	*SD*	Min.	Max.	Skewness	*SE*	*Kurtosis*	*SE*
					Pain Intensity					
Control	Not painful	57	2.61_a	1.55	1	7.00	1.25	0.32	0.91	0.62
	Slightly painful	57	3.79_b	1.75	1	8.00	0.59	0.32	-0.48	0.62
	Moderately painful	57	4.92_c	2.00	1	8.00	0.01	0.32	-1.13	0.62
1-back	Not painful	56	2.61	1.40	1	6.00	0.76	0.32	-0.26	0.62
	Slightly painful	57	3.42	1.71	1	8.33	0.94	0.32	0.38	0.62
	Moderately painful	57	4.18	1.55	1	7.33	0.34	0.32	-0.54	0.62
					Pain Unpleasantness					
Control	Not painful	57	2.25_a	1.41	1	6.67	1.48	0.32	1.68	0.62
	Slightly painful	57	3.33_b	1.87	1	7.67	0.62	0.32	-0.86	0.62
	Moderately painful	57	4.43_c	2.03	1	8.33	0.19	0.32	-1.25	0.62
1-back	Not painful	56	2.28	1.35	1	5.67	1.05	0.32	0.09	0.62
	Slightly painful	57	3.24	1.88	1	8.67	1.13	0.32	0.67	0.62
	Moderately painful	57	3.98	1.91	1	8.00	0.56	0.32	-0.56	0.62

Note: Acceptable skewness and kurtosis values for z-scores (i.e., $z < \pm 1.64$) indicating skewness/kurtosis values are not significantly different from zero (Tabachnick & Fidell, 2001).
Means with differing subscripts within pain rating are statistically significantly different at the $p < .01$ level.

Table 5

Descriptive Statistics of Baseline Reliability and Control Condition Reliability Scores by Heat Level

Heat	*n*	*M*	*SD*	Min.	Max.	Skewness	*SE*	*Kurtosis*	*SE*
				Baseline Reliability					
Not painful	57	0.79	0.89	0	4.95	2.05	0.32	7.11	0.62
Slightly painful	57	0.88	0.93	0	4.95	1.68	0.32	5.06	0.62
Moderately painful	57	0.86	0.89	0	3.54	1.31	0.32	1.64	0.62
				Control Condition Reliability					
Not painful	57	0.95	0.85	0	3.00	0.96	0.32	0.27	0.62
Slightly painful	57	0.91	0.64	0	3.06	0.96	0.32	1.83	0.62
Moderately painful	57	1.13	0.83	0	3.51	0.85	0.32	0.69	0.62

Note. Consistency between pain ratings is defined as the standard deviation of each participant's averaged pain intensity ratings within each heat level

Table 6

Correlation Matrix of Baseline Reliability, Control Condition Reliability and Pain Intensity Change by Heat Level

Heat	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
				Baseline Reliability					
1. Not painful	1.00								
2. Slightly Painful	.13	1.00							
3. Moderately Painful	.06	-.01	1.00						
				Control Condition Reliability					
4. Not painful	.15	.17	.17	1.00					
5. Slightly Painful	.16	.17	.08	.11	1.00				
6. Moderately Painful	.07	.16	.30*	.17	.34**	1.00			
				Pain Intensity Change					
7. Not painful	.03	-.18	-.16	-.32*	-.18	-.12	1.00		
8. Slightly Painful	.02	-.02	-.42**	-.26	-.21	-.17	.50**	1.00	
9. Moderately Painful	-.09	-.09	-.29*	-.51**	-.12	-.05	.60**	.54**	1.00

Note. Pearson Correlation Coefficients reveal negative associations that indicate that high reliability was associated with less pain intensity change between the control condition and the 1-back condition.

*p < .05

**p < .01

Table 7

Summary of 2 x 3 (Experimental Condition x Heat) ANOVA on Pain Intensity Ratings

Source	*SS*	*Df*	*MS*	*F*	*p*	η_p^2
Condition	11.07	1	11.07	6.30	.015	.10
Heat	220.71	2	110.35	81.41	<.001	.60
Condition x Heat	7.75	2	3.88	10.12	<.001	.16
Error (Condition)	96.65	55	1.76			
Error (Heat)	149.11	110	1.36			
Error (Condition x Heat)	42.24	110	0.38			

Table 8

Summary of 2 x 3 (Experimental Condition x Heat) ANOVA on Pain Unpleasantness Ratings

Source	*SS*	*Df*	*MS*	*F*	*p*	$\eta_p{}^2$
Condition	2.17	1	2.17	1.42	.239	.03
Heat	216.87	2	108.43	69.07	<.001**	.56
Condition x Heat	3.19	2	1.60	4.71	.011*	.08
Error (Condition)	84.11	55	1.53			
Error (Heat)	172.69	110	1.57			
Error (Condition x Heat)	37.25	110	0.34			

Table 9

Correlation Matrix of Pain Rating Change Scores, Demographic Variables and Dispositional Mindfulness

Variable	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. Pain intensity change (not painful)	1.00										
2. Pain intensity change (slightly painful)	.50**	1.00									
3. Pain intensity change (moderately painful)	.60**	.54**	1.00								
4. Pain unpleasantness change (not painful)	.71**	.53**	.44**	1.00							
5. Pain unpleasantness change (slightly painful)	.48**	.80**	.31**	.62**	1.00						
6. Pain unpleasantness change (moderately painful)	.49**	.42**	.69**	.55**	.54**	1.00					
7. Gender	-.10	-.16	-.05	.02	-.17	-.01	1.00				
8. Age	-.06	.08	-.01	-.08	-.10	-.16	.25	1.00			
9. Pubertal status	.04	-.03	.09	.05	-.11	.09	.54**	.45**	1.00		
10. Past pain experience	.07	-.23	-.08	-.07	-.25	-.27*	.12	-.21	.14	1.00	
11. Dispositional Mindfulness	-.07	-.12	.01	-.07	-.17	.11	.12	-.18	-.06	.04	1.00

Table 10

Summary of 2 x 3 x 2 (Experimental Condition x Heat x Dispositional Mindfulness) ANOVA on Pain Intensity Ratings

Source	*SS*	*Df*	*MS*	*F*	*p*	$\eta_p{}^2$
Condition	11.47	1	11.47	6.43	.014*	.11
Heat	223.68	2	111.84	82.76	<.001**	.61
Mindfulness	22.17	1	22.17	1.94	.169	.04
Condition x Heat	7.50	2	3.75	9.62	<.001**	.15
Condition x Mindfulness	0.42	1	0.42	0.23	.631	.00
Heat x Mindfulness	3.16	2	1.58	1.17	.314	.02
Condition x Heat x Mindfulness	0.03	2	0.01	0.03	.967	.00
Error (Condition)	96.23	54	1.78			
Error (Heat)	145.94	108	1.35			
Error (Mindfulness)	616.17	54	11.41			
Error (Condition x Heat)	42.11	108	0.39			

Table 11

Summary of 2 x 3 x 2 (Experimental Condition x Heat x Dispositional Mindfulness) ANOVA on Pain Unpleasantness Ratings

Source	*SS*	*Df*	*MS*	*F*	*p*	η_p^2
Condition	2.30	1	2.30	1.48	.229	.03
Heat	222.81	2	111.40	72.93	<.001**	.58
Mindfulness	45.93	1	45.93	3.56	.064	.06
Condition x Heat	2.78	2	1.39	4.09	.019*	.07
Condition x Mindfulness	0.17	1	0.17	0.11	.741	.00
Heat x Mindfulness	7.71	2	3.86	2.52	.085	.05
Condition x Heat x Mindfulness	0.56	2	0.28	0.83	.439	.02
Error (Condition)	83.94	54	1.55			
Error (Heat)	164.98	108	1.53			
Error (Mindfulness)	696.02	54	12.89			
Error (Condition x Heat)	36.69	108	0.34			

Table 12

Summary of Post Hoc 2 x 2 (Experimental Condition x Dispositional Mindfulness) ANOVAs Examining the Effect of Dispositional Mindfulness on Pain Intensity Ratings

Source	*SS*	*Df*	*MS*	*F*	*p*	η_p^2	Observed power
			Not painful				
Condition	8.27	1	8.27	0.00	.992	.00	.05
Mindfulness	1.86	1	1.86	0.51	.478	.01	.11
Condition x Mindfulness	0.25	1	0.25	0.33	.570	.01	.09
Error (Condition)	41.30	54	.77				
Error (Mindfulness)	199.50	54	3.69				
			Slightly painful				
Condition	3.94	1	3.94	4.16	.036*	.08	.56
Mindfulness	7.39	1	7.39	1.45	.234	.03	.22
Condition x Mindfulness	0.08	1	0.08	0.09	.767	.00	.06
Error (Condition)	47.00	55	0.86				
Error (Mindfulness)	280.46	55	5.10				
			Moderately Painful				
Condition	15.59	1	15.59	17.13	.000	.24	.98
Mindfulness	11.40	1	11.40	2.11	.152	.04	.30
Condition x Mindfulness	0.13	1	0.13	0.14	.707	.00	.07
Error (Condition)	50.06	55	0.91				
Error (Mindfulness)	296.64	55	5.39				

Table 13

Summary of Post Hoc 2 x 2 (Experimental Condition x Dispositional Mindfulness) ANOVAs Examining the Effect of Dispositional Mindfulness on Pain Unpleasantness Ratings Split by Heat

Source	*SS*	*Df*	*MS*	*F*	*p*	$\eta_p{}^2$	Observed power
			Not painful				
Condition	0.01	1	0.01	0.02	.899	.00	.05
Mindfulness	2.71	1	2.71	0.78	.381	.01	.14
Condition x Mindfulness	0.27	1	0.27	0.65	.424	.01	.12
Error (Condition)	22.32	54	0.41				
Error (Mindfulness)	187.38	54	3.47				
			Slightly painful				
Condition	0.33	1	0.33	0.35	.559	.01	.09
Mindfulness	24.09	1	24.09	4.16	.046	.07	.52
Condition x Mindfulness	0.39	1	0.39	0.42	.522	.01	.10
Error (Condition)	52.13	55	0.95				
Error (Mindfulness)	318.21	55	5.79				
			Moderately Painful				
Condition	5.71	1	5.72	6.61	.013	.11	.71
Mindfulness	21.85	1	21.85	0.08	.075	.06	.43
Condition x Mindfulness	0.04	1	0.04	0.05	.829	.00	.06
Error (Condition)	47.59	55	0.86				
Error (Mindfulness)	365.37	55	6.64				

Table 14

Serial Mediation Model Coefficients, Indirect Effects and Confidence Intervals Predicting Pain Unpleasantness Change Scores

Effect	Path	Effect	SE	t	p	BootLLCI	BootULCI
Dispositional Mindfulness (X) and Pain Unpleasantness Change (Y)	c (total)	.02	.03	0.85	.401	-.03	.08
Dispositional Mindfulness (X) to Emotional Control (M1)	a_1	-.17	.07	-2.61	.012	-.30	-.04
Emotional Control (M1) to Pain Unpleasantness Change (Y)	b_1	.05	.06	0.86	.396	-.07	.17
	a_1b_1(indirect 1)	-.01				-.04	.01
Dispositional Mindfulness (X) to Attentional Control (M2)	a_2	.45	.08	5.70	< .001	.29	.60
Attentional Control (M2) to Pain Unpleasantness Change (Y)	b_2	.05	.05	1.02	.314	-.05	.16
	a_2b_2 (indirect 2)	.00				-.00	.01
Dispositional Mindfulness (X) to Task Performance (M3)	a_3	.03	.04	0.65	.520	-.06	.11
Task Performance (M3) to Pain Unpleasantness Change (Y)	b_3	-.27	.13	-2.14	.038	-.52	-.02
	a_3b_3 (indirect 3)	.00				-.01	.01
Emotional Control (M1) to Attentional Control (M2)	d_{21}	-.35	.15	-2.27	.027	-.65	-.04

Attentional Control (M2) to Task Performance (M3)	d_{32}	.06	.06	0.97	.338	-.06	.17
Emotional Control (M1) to Task Performance (M3)	d_{31}	-.01	.07	-.010	.921	-.14	.13
Direct: Dispositional Mindfulness (X) and Pain Unpleasantness Change (Y) controlling for M1, M2 and M3	c' (direct)	.02	.04	0.56	.577	-.06	.10
Dispositional Mindfulness (X) and Pain Unpleasantness Change (Y) through M1, M2 and M3	Full model (indirect) $(a_1 * d_{21}) * (d_{32} * b_3)$	.00				-.05	.07

Table 15

Correlation Matrix of Pain Ratings and Dispositional Mindfulness for Experimental Conditions by Heat

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
Control													
1. Pain intensity (not painful)	1.00												
2. Pain intensity (slightly painful)	.75**	1.00											
3. Pain intensity (moderately painful)	.63**	.76**	1.00										
4. Pain unpleasantness (not painful)	.89**	.73**	.56**	1.00									
5. Pain unpleasantness (slightly painful)	.64**	.87**	.68**	.75**	1.00								
6. Pain unpleasantness (moderately painful)	.55**	.69**	.88**	.62**	.79**	1.00							
1-back													
7. Pain intensity (not painful)	.66**	.50**	.27*	.72**	.46**	.27*	1.00						
8. Pain intensity (slightly painful)	.69**	.72**	.62**	.76**	.74**	.64**	.76**	1.00					
9. Pain intensity (moderately painful)	.53**	.59**	.74**	.52**	.58**	.74**	.49**	.75**	1.00				
10. Pain unpleasantness (not painful)	.67**	.48**	.34**	.79**	.56**	.41**	.88**	.77**	.49**	1.00			
11. Pain unpleasantness (slightly painful)	.49**	.56**	.59**	.65**	.73**	.71**	.60**	.87**	.67**	.76**	1.00		
12 Pain unpleasantness (moderately painful)	.45**	.52**	.67**	.52**	.62**	.78**	.44**	.68**	.86**	.54**	.79**	1.00	
13. Dispositional Mindfulness	.03	.08	.05	.00	.14	.04	-.03	-.01	.07	-.05	.02	.12	1.00

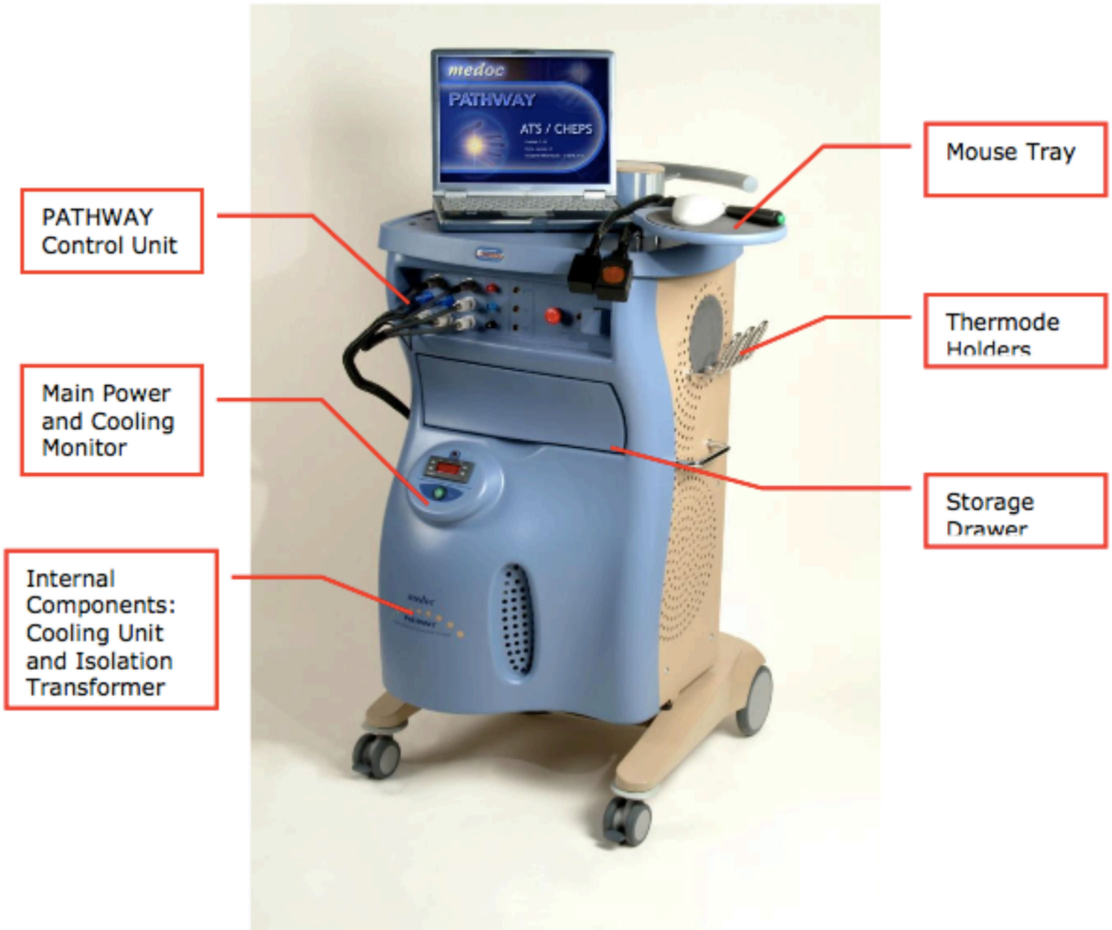

Figure 1. MEDOC Pathways system and components

Figure 2. Advanced Thermal Stimulator (ATS) thermode

Figure 3. MEDOC response mouse

Figure 4. Experimental room arrangement

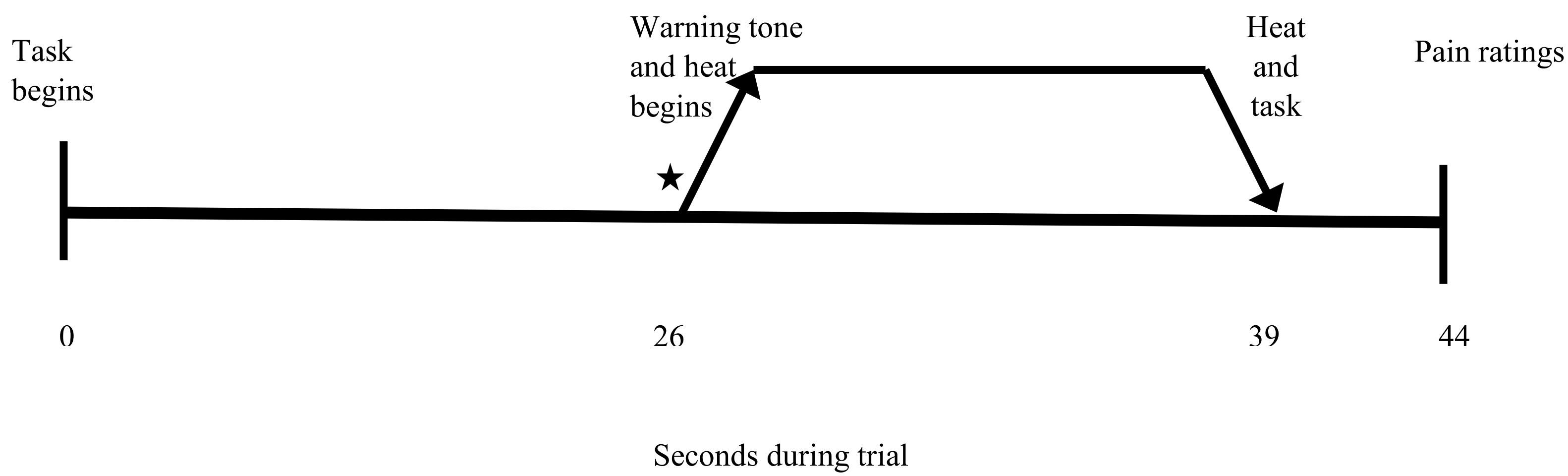

Figure 5. Visual diagram of a single experimental trial

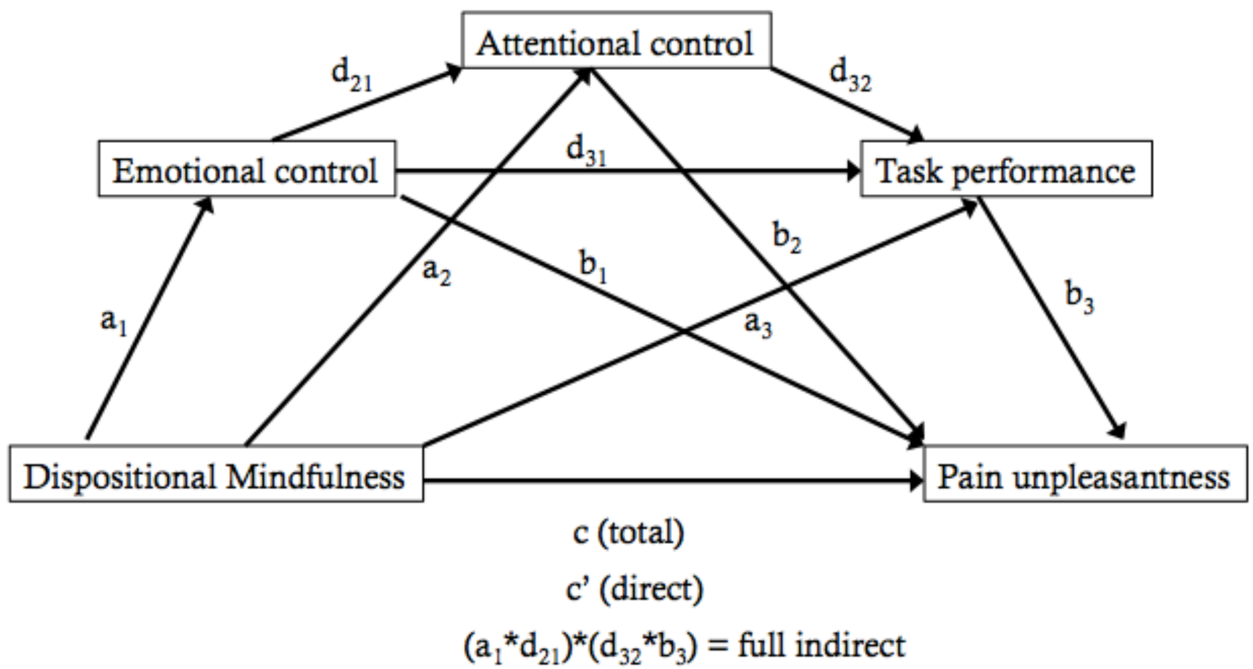

Figure 6. Serial Mediation Model

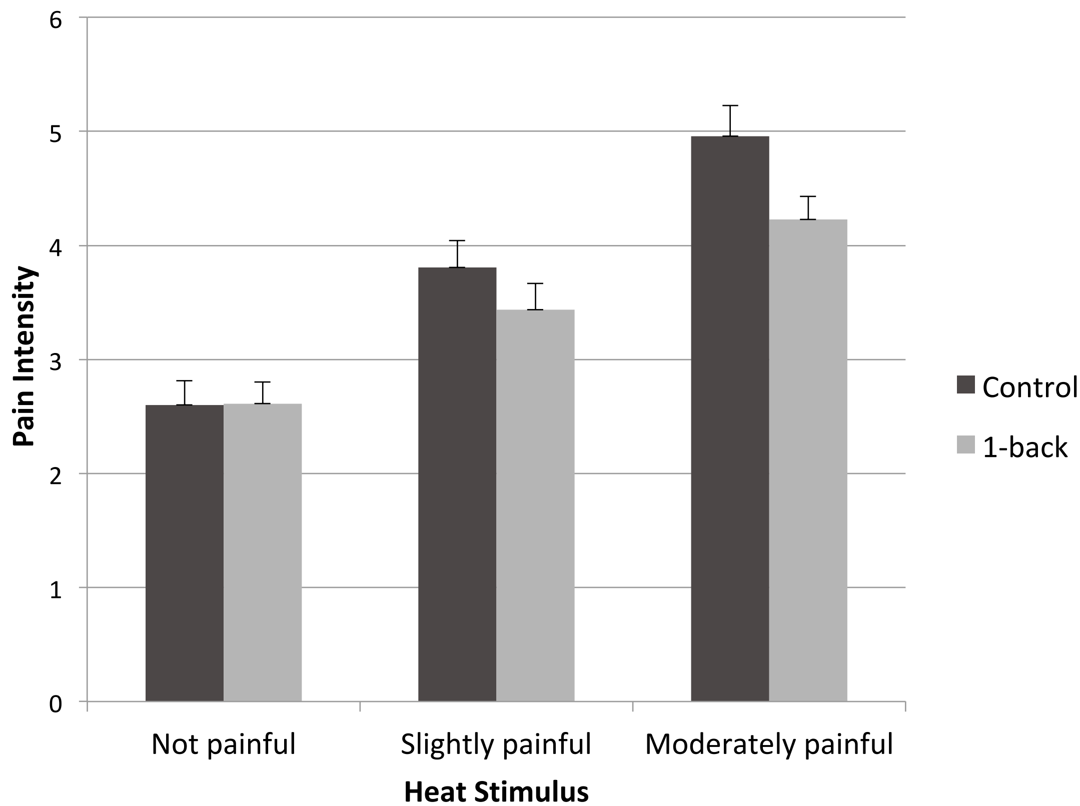

Figure 7. Pain Intensity Ratings Across Heat Stimulus Levels for Control and 1-back Cond

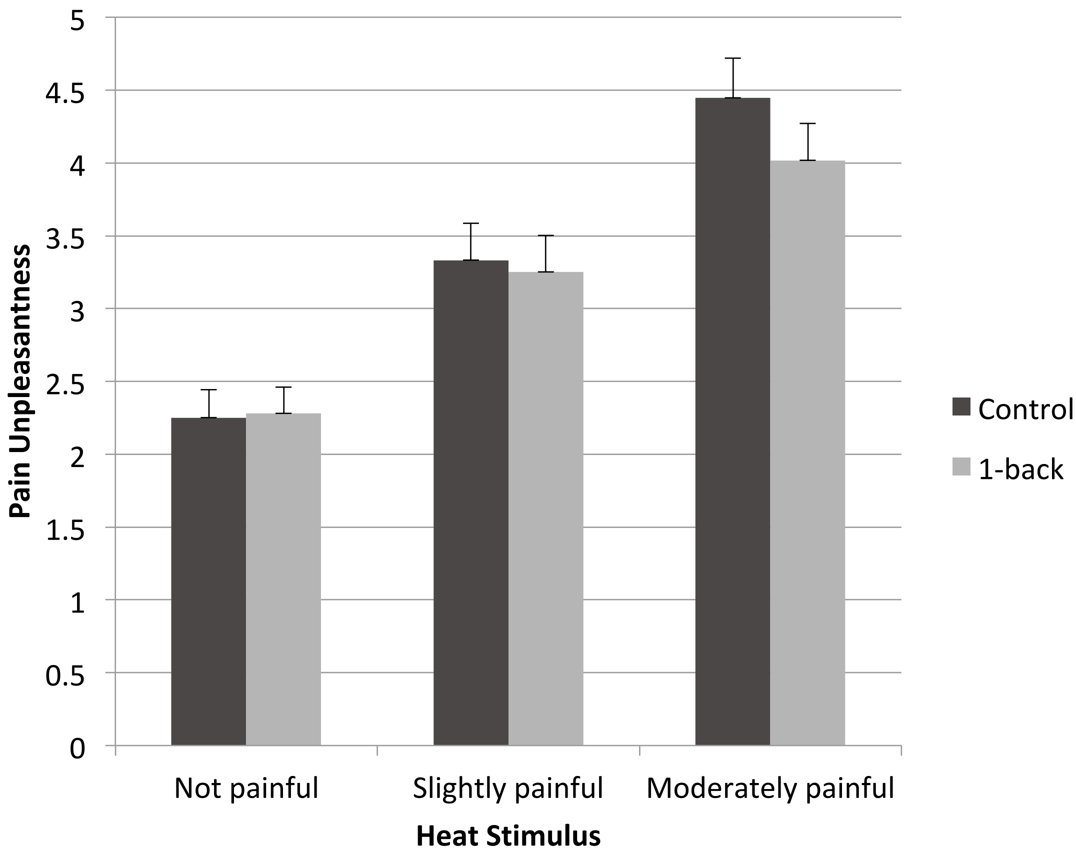

Figure 8. Pain Unpleasantness Ratings Across Heat Stimulus Levels for Control and 1-back Conditions

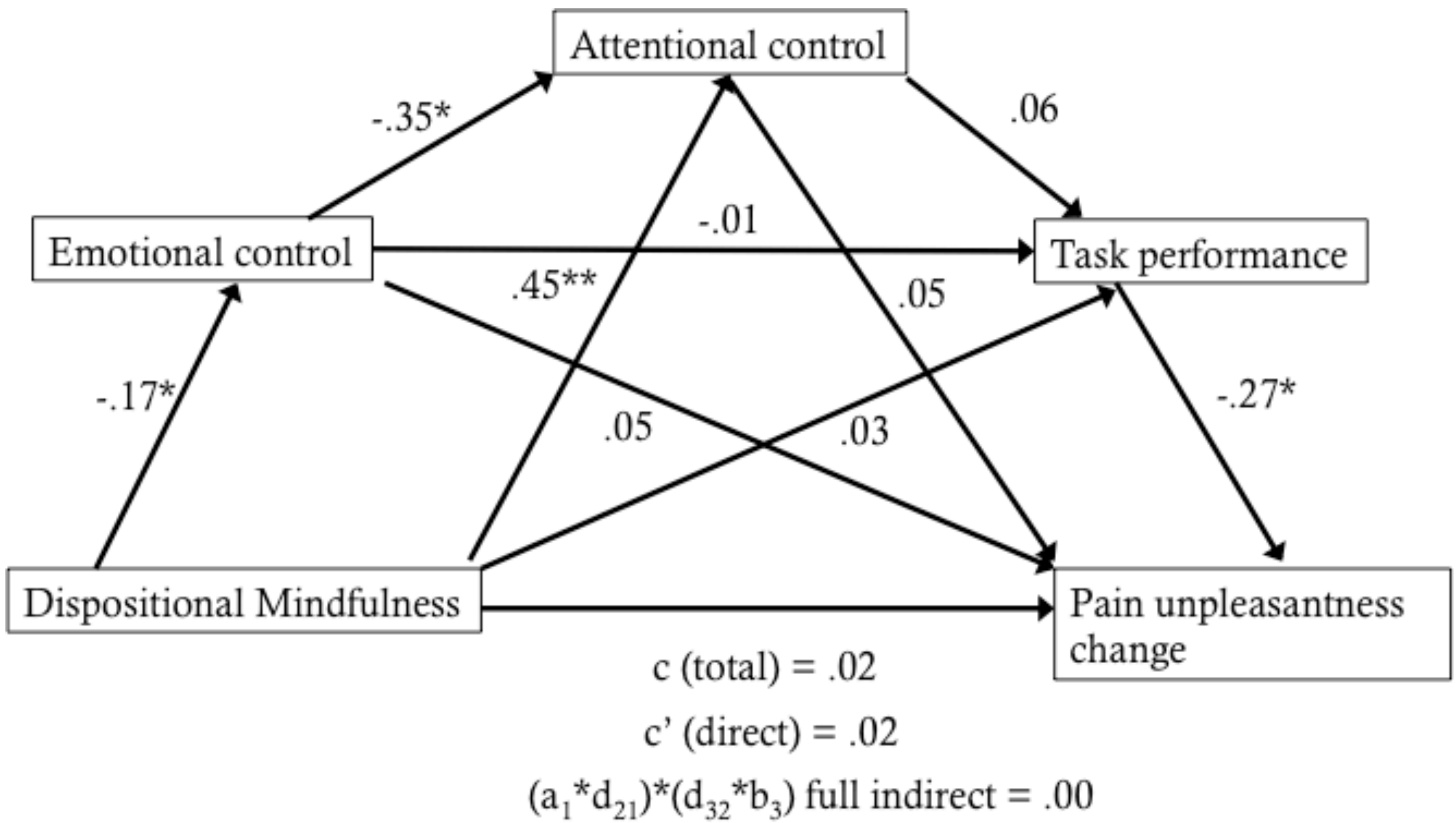

Figure 9. Serial Mediation Effects

Appendix A- Demographic Questionnaire

DEMOGRAPHIC QUESTIONNAIRE

Date _____________

Child's date of birth (Month/ date/ year) ________________

Child's age ______ Grade in school (if summer, grade child will enter in fall) _____

Child's race/ethnicity _____________ Child's sex (circle): boy girl

Parent/female caregiver's occupation* ____

Highest year of school completed* _________________________

Parent/male caregiver's occupation* ____

Highest year of school completed* _________________________

Additional parent/caregiver's occupation* _______________________________________

Highest year of school completed* _________________________

(*If not applicable, please write NA)

Does your child have any of the following health conditions? If yes, please describe.

Health condition	**Yes**	**No**	**If yes, please describe**
Hearing problems			
Vision problems			
Car/motion sickness			
Seizures			
Circulation problems, (e.g., sickle cell anemia, Raynauds disorder, etc)			
Coordination problem			
Sleep problems			
ADHD If yes, does your child take ADHD medications?			
Other condition that might affect your child's response to games or sensory testing (describe)			

DEMOGRAPHIC QUESTIONNAIRE CONT.

Parent Ratings of Past Medical Experiences

For each medical experience listed below, please indicate if your child has ever had this experience (yes/no). **If yes, please indicate approximately how many times and rate your child's reaction.**	**Circle Yes or No**	**If yes, about how many times?**	**Please rate your child's reaction to each experience on a scale of 1 to 7, 1 = very positive and 7 = very negative** [Circle one]								
Admitted to the hospital	Yes No		very positive	1	2	3	4	5	6	7	very negative
Emergency Room visit	Yes No		very positive	1	2	3	4	5	6	7	very negative
Doctor's Visit	Yes No		very positive	1	2	3	4	5	6	7	very negative
Finger stick	Yes No		very positive	1	2	3	4	5	6	7	very negative
Venipuncture for a blood test (blood drawn from vein)	Yes No		very positive	1	2	3	4	5	6	7	very negative
I.V. Placement	Yes No		very positive	1	2	3	4	5	6	7	very negative
Surgery	Yes No		very positive	1	2	3	4	5	6	7	very negative
Immunizations	Yes No		very positive	1	2	3	4	5	6	7	very negative
Dental Visit	Yes No		very positive	1	2	3	4	5	6	7	very negative
Other	Yes No		very positive	1	2	3	4	5	6	7	very negative

DEMOGRAPHIC QUESTIONNAIRE CONT.

Instructions for Parents: Because the onset of puberty can impact how children respond t different sensations, we are asking that you complete the questions below.
Please complete the following questions about your child's pubertal development:

	Please Circle one response:			
Would you say your child's:	**Has not started yet**	**Has barely started**	**Has definitely started**	**Seen comp**
Growth in height	0	1	2	3
Body hair growth	0	1	2	3
Skin changes (especially pimples)	0	1	2	3
FOR GIRLS: Breast growth	0	1	2	3
FOR BOYS: Voice deepening	0	1	2	3
FOR BOYS: Facial hair growth	0	1	2	3

Does your child's physical development seem to be earlier or later than most of the oth boys/girls his/her age? Please circle one option:

(1) Much earlier (2) Somewhat earlier (3) About the same (4) Somewhat later (5) Much later

Appendix B- Brief®2

BRIEF®2

Behavior Rating Inventory of Executive Function® Second Edition

PARENT FORM

Gerard A. Gioia, PhD, Peter K. Isquith, PhD,
Steven C. Guy, PhD, and Lauren Kenworthy, PhD

Instructions

On the following pages is a list of statements that describe children. We would like to know if your child has had problems with these behaviors over the past 6 months. Please answer all the items the best that you can. Please DO NOT SKIP ANY ITEMS. Think about your child as you read each statement and circle:

N if the behavior is **Never** a problem

S if the behavior is **Sometimes** a problem

O if the behavior is **Often** a problem

For example, if your child **never** has trouble completing homework on time, you would circle **N** for this item:

Has trouble completing homework on time (N) S O

If you make a mistake or want to change your answer, DO NOT ERASE. Draw an "X" through the answer you want to change and then circle the correct answer:

Has trouble completing homework on time ⊗ (S) O

Before you begin answering the items, please fill in your child's name, gender, age, grade, your relationship to the child, today's date, and child's date of birth in the spaces provided at the top of the next page.

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BRIEF®2 PARENT FORM

Child's name_______________ Gender_______ Age_____ Grade_____

Relationship to child_______________ Today's date_______________ Date of birth_______________

	N = Never S = Sometimes O = Often			
1.	Is fidgety	N	S	O
2.	Resists or has trouble accepting a different way to solve a problem with schoolwork, friends, tasks, etc.	N	S	O
3.	When given three things to do, remembers only the first or last	N	S	O
4.	Is unaware of how his/her behavior affects or bothers others	N	S	O
5.	Work is sloppy	N	S	O
6.	Has explosive, angry outbursts	N	S	O
7.	Does not plan ahead for school assignments	N	S	O
8.	Cannot find things in room or school desk	N	S	O
9.	Is not a self-starter	N	S	O
10.	Does not think before doing (is impulsive)	N	S	O
11.	Has trouble getting used to new situations (classes, groups, friends, etc.)	N	S	O
12.	Has a short attention span	N	S	O
13.	Has poor understanding of own strengths and weaknesses	N	S	O
14.	Has outbursts for little reason	N	S	O
15.	Gets caught up in details and misses the big picture	N	S	O
16.	Gets out of control more than friends	N	S	O
17.	Gets stuck on one topic or activity	N	S	O
18.	Forgets his/her name	N	S	O
19.	Has trouble with chores or tasks that have more than one step	N	S	O
20.	Does not realize that certain actions bother others	N	S	O
21.	Written work is poorly organized	N	S	O
22.	Small events trigger big reactions	N	S	O
23.	Has good ideas but does not get job done (lacks follow-through)	N	S	O
24.	Talks at the wrong time	N	S	O
25.	Has trouble finishing tasks (chores, homework, etc.)	N	S	O
26.	Does not notice when his/her behavior causes negative reactions	N	S	O
27.	Reacts more strongly to situations than other children	N	S	O
28.	Has trouble remembering things, even for a few minutes	N	S	O
29.	Makes careless errors	N	S	O
30.	Gets out of seat at the wrong times	N	S	O
31.	Becomes upset with new situations	N	S	O
32.	Has trouble concentrating on tasks, schoolwork, etc.	N	S	O

	N = Never S = Sometimes O = Often			
33.	Has poor handwriting	N	S	O
34.	Mood changes frequently	N	S	O
35.	Has good ideas but cannot get them on paper	N	S	O
36.	Has trouble counting to three	N	S	O
37.	Leaves messes that others have to clean up	N	S	O
38.	Needs to be told to begin a task even when willing	N	S	O
39.	Acts too wild or "out of control"	N	S	O
40.	Thinks too much about the same topic	N	S	O
41.	Forgets what he/she was doing	N	S	O
42.	Does not check work for mistakes	N	S	O
43.	Angry or tearful outbursts are intense but end suddenly	N	S	O
44.	Becomes overwhelmed by large assignments	N	S	O
45.	Loses lunch box, lunch money, permission slips, homework, etc.	N	S	O
46.	Needs help from an adult to stay on task	N	S	O
47.	Forgets to hand in homework, even when completed	N	S	O
48.	Has trouble putting the brakes on his/her actions	N	S	O
49.	Resists change of routine, foods, places, etc.	N	S	O
50.	Has trouble getting started on homework or tasks	N	S	O
51.	Mood is easily influenced by the situation	N	S	O
52.	Underestimates time needed to finish tasks	N	S	O
53.	Does not bring home homework, assignment sheets, materials, etc.	N	S	O
54.	Cannot find the front door of home	N	S	O
55.	Does not take initiative	N	S	O
56.	Becomes upset too easily	N	S	O
57.	Starts assignments or tasks at the last minute	N	S	O
58.	Has trouble moving from one activity to another	N	S	O
59.	Has trouble carrying out the actions needed to reach goals (saving money for special item, studying to get a good grade, etc.)	N	S	O
60.	Is disturbed by change of teacher or class	N	S	O
61.	Has trouble organizing activities with friends	N	S	O
62.	Becomes too silly	N	S	O
63.	Leaves a trail of belongings wherever he/she goes	N	S	O

Appendix C- ACS-C

Attentional Control Scale –Child version

	Almost never	Sometimes	Often	Always
1. It's very hard for me to concentrate on a difficult lesson if there is a lot of noise in the class.	1	2	3	4
2. If I have to concentrate and solve a difficult math problem, I have trouble focusing my attention.	1	2	3	4
3. When I am working hard on something, I still get distracted by things going on around me.	1	2	3	4
4. My concentration is good, even when somebody turns the music on.	1	2	3	4
5. When I concentrate myself, I do not notice what is happening in the room around me.	1	2	3	4
6. When I am reading in the classroom, I am easily disturbed by other children talking to each other.	1	2	3	4
7. When I try to concentrate myself, I find it difficult not to think about other things.	1	2	3	4
8. I find it difficult to concentrate myself when I am excited about something.	1	2	3	4
9. When I am concentrated, I do not notice that I am hungry or thirsty.	1	2	3	4
10. When I am doing something, I can easily stop and switch to some other task.	1	2	3	4
11. When I have to start a new task, it takes me a while to get really involved in it.	1	2	3	4
12. When the teacher explains something, I find it difficult to understand and write it down at the same time.	1	2	3	4
13. When it is necessary, I can become interested in a new topic very quickly.	1	2	3	4
14. It is easy for me to read or write while I am also talking to someone on the telephone.	1	2	3	4
15. I have trouble having two conversations at the same time.	1	2	3	4
16. I find it difficult to come up with new ideas quickly.	1	2	3	4
17. After being interrupted or distracted, I can easily shift my attention back to what I was doing before.	1	2	3	4
18. When I am daydreaming or having distracted thoughts, it is easy for me to switch back to the work I have to do.	1	2	3	4
19. It is easy for me to switch back and forth between two different tasks.	1	2	3	4
20. I find it difficult to let go on my own way of thinking about something, and to look at it in a different way.	1	2	3	4

Appendix D- CAMM

Child and Adolescent Mindfulness Measure (CAMM)

We want to know more about what you think, how you feel, and what you do. **Read** each sentence. Then, circle the number that tells **how often each sentence is true for you.**

	Never True	Rarely True	Some-times True	Often True	Always True
1. I get upset with myself for having feelings that don't make sense.	0	1	2	3	4
2. At school, I walk from class to class without noticing what I'm doing.	0	1	2	3	4
3. I keep myself busy so I don't notice my thoughts or feelings.	0	1	2	3	4
4. I tell myself that I shouldn't feel the way I'm feeling.	0	1	2	3	4
5. I push away thoughts that I don't like.	0	1	2	3	4
6. It's hard for me to pay attention to only one thing at a time.	0	1	2	3	4
7. I get upset with myself for having certain thoughts.	0	1	2	3	4
8. I think about things that have happened in the past instead of thinking about things that are happening right now.	0	1	2	3	4
9. I think that some of my feelings are bad and that I shouldn't have them.	0	1	2	3	4
10. I stop myself from having feelings that I don't like.	0	1	2	3	4

Appendix E- Reliability Chart

Reliability Program Adjustment Chart

Intensity Rating	0	1	2	3	4	5	6	7	8	9	10
High 1	+2	+1.5	+1.5	+1	+.5	Stay	Stay	Stay	Stay	-1	-1.5
High 2	+2	+1.5	+1.5	+1	+.5	Stay	Stay	Stay	-.5	-1	-1.5

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