2022

Effects of acute pain and chronic low back pain on temporal perception

https://hdl.handle.net/2144/45574

BOSTON UNIVERSITY

SCHOOL OF MEDICINE

Thesis

EFFECTS OF ACUTE PAIN AND CHRONIC LOW BACK PAIN ON TEMPORAL PERCEPTION

by

JASMINE HYEJIN JEON

B.S., Boston College, 2020

Submitted in partial fulfillment of the
requirements for the degree of
Master of Science

2022

Approved by

First Reader
Vickery Trinkaus-Randall, Ph.D.
Professor of Biochemistry

Second Reader
Samantha Meints, Ph.D.
Instructor of Anesthesiology
Brigham and Women's Hospital

ACKNOWLEDGMENTS

I would like to thank everyone from the Meints Lab for the support and guidance throughout the completion of this thesis. Thank you to Drs. Samantha Meints, Bethany Pester, and Jenna Wilson for their feedback and communication. Thank you Marise Cornelius and Jihee Yoon for the moral support and advice.

I would like to thank my MAMS Advisor and thesis reader, Dr. Trinkaus-Randall for helping me throughout my graduate school journey.

I would also like to especially thank Song and Jiyun Jeon for their love and encouragement. I wouldn’t be who I am today without you.

EFFECTS OF ACUTE PAIN AND CHRONIC LOW BACK PAIN ON TEMPORAL PERCEPTION

JASMINE JEON

ABSTRACT

Chronic low back pain (CLBP) is a critical public health issue and affects a significant number of people physically, emotionally, and financially. There is evidence that pain may affect one's perception of time, but more work is needed to understand how different types of pain (acute, chronic) impact temporal perception. This study aimed to examine how acute experimental pain and CLBP, together and separately, impact the perception of time. A sample of 77 participants, 10 with CLBP and 67 healthy pain-free controls, completed two temporal perception tasks (Bisection and Threshold) twice, once with induced acute pressure pain and once without pain. The effects of acute pain and CLBP on temporal perception were examined using repeated measures ANOVAs. Results showed that the presence of either acute or chronic pain was related to overestimating time during shorter stimuli presentations and underestimating time during longer stimuli presentations. Further, subjects with chronic pain generally required a longer time difference to accurately distinguish between stimuli of differing lengths. This study demonstrates that both acute and chronic pain affect temporal perception, though the combination of acute and chronic pain does not confer additive adverse effects. The results of this study broaden our understanding of the impact of different types of pain on a person's perception of time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACP	American College of Physicians
ANOVA	Analysis of Variance
BMI	Body Mass Index
CBT	Cognitive Behavioral Therapy
CLBP	Chronic Low Back Pain
CPA	Cuff Pressure Algometry
fMRI	Functional Magnetic Resonance Imaging
HC	Healthy Control
IASP	International Association for the Study of Pain
IRB	Institutional Review Board
LBP	Low Back Pain
NRS	Numeric Pain Rating
PAG	Periaqueductal Gray
RMANOVA	Repeated Measures Analysis of Variance
SET	Scalar Expectancy Theory
STM	Scalar Timing Model
QST	Quantitative Sensory Testing
US	United States

INTRODUCTION

Pain:

Pain is a widespread problem. Whether acute (lasting less than 6 weeks) or chronic (lasting longer than 3 months) (Dahlhamer, 2018; Deyo et al., 2014), pain is one of the leading reasons that people seek healthcare, take medications, and go on work disability (Cherry et al., 2003; Hardt et al., 2008). The prevalence of chronic pain is growing, with more than 70 million American adults suffering from chronic pain and 20 million reporting high-impact chronic pain (Dahlhamer, 2018). The economic costs of pain on affected individuals, their families, employers, and the nation are immense. Each year, an estimated $560 billion dollars are associated with pain including direct medical costs, lost productivity, and disability programs (Institute of Medicine (US) Committee on Advancing Pain Research, Care, and Education, 2011). With so many Americans dealing with and having to pay for the financial consequences of pain, it is indeed a public health concern in the United States.

Pain is also incredibly complex. Although pain is universal, it is experienced and perceived differently by everyone. The International Association for the Study of Pain (IASP) defines it as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (“Pain Terms,” 1979a). From an evolutionary standpoint, pain is a warning sign and defense mechanism. Pain signals that something is wrong and initiates action. Whether the stimulus is a hot stove, broken arm, or food poisoning, pain notifies the brain to avoid further tissue damage or harm to the body (Yam et al., 2018). Without the perception of pain, an individual would be in great danger of being hurt even further. In fact, children born with rare genetic diseases that impair their ability to feel pain often have a shortened lifespan as they are unable to recognize and flee from harmful stimuli (Daneshjou et al., 2012; Narayanan, 1996; Rasmussen, 1996). However, pain that persists after an injury has healed, when the body is no longer in danger, such as chronic pain, can be detrimental to an individual as it no longer serves a necessary and biological purpose (Chou et al., 2015). Thus, the experience of pain is complicated as acute pain is often necessary and beneficial whereas chronic pain can cause unneeded suffering and functional impairments.

Indeed, modern science has demonstrated that pain is more complicated than just an evolutionary adaptation. Throughout early scientific history, a biomedical approach to pain was favored. The biomedical explanation of pain posits that pain is strictly a biological occurrence as a result of tissue damage (Hylands-White et al., 2017). Under this view, pain conditions were viewed as primarily medical issues with clear pathophysiological bases and were treated with surgery and medication (Jensen & Turk, 2014). However, we now know that this does not fully capture the pain experience, as pain is more than a translation of neurotransmitters with action potentials to be blocked or modulated (Webster & Harden, 2013). Although pain is often an indicator of bodily harm, researchers acknowledge that it cannot be defined by a strict biomedical approach as pain is often not restricted to a particular injury site and does not always immediately end after healing occurs (Kuner, 2010). Even when tissue damage is not discernible, pain can be present (Jensen & Gebhart, 2008; Wilson et al., 2008). The inadequacy of the biomedical approach is further supported by the fact that imaging methods are not efficient or exact at identifying pain in patients. Neuroimaging studies have revealed that simple biomedical tools such as functional neuroimaging machines (fMRI) are largely unspecific for pain (Mouraux & Iannetti, 2018). For instance, the same fMRI responses seen in painful scenarios can be elicited by non-painful stimuli (Colpitts et al., 1981; Downar et al., 2003; Mouraux et al., 2011; Mouraux & Iannetti, 2009). More recently, it has even been shown that patients with congenital insensitivity to pain can have an identical pain imaging response as normal controls experiencing a painful stimulus (Salomons et al., 2016). Thus, in place of the biomedical approach, the biopsychosocial model of pain has become widely accepted in present-day research. This model suggests that pain is caused and maintained by a combination of dynamic biological, psychological, and social factors (Gatchel et al., 2007). The subjective experience of pain and its effects vary based on a person's demographic characteristics (e.g., age, sex), coexisting medical conditions, mood and psychological state, and culture, among other factors (Fillingim, 2017; Miaskowski et al., 2020).

In addition to the evolutionarily adaptive reasons for pain such as an injury or disease, there are other biological aspects to pain. An individual's age, sex, and medical comorbidities may also impact the pain experience. Many studies have shown that female sex, increased chronological age (often >65 years of age), and a greater number of comorbid conditions are commonly linked to more cases of chronic pain (Butchart et al., 2009; Cho & Chu, 2015; Jacobs et al., 2006; Mansfield et al., 2016; Sibille et al., 2016;

van Hecke et al., 2013; Wong et al., 2017). A high body mass index (BMI) may also affect one's pain levels (Dong et al., 2018; Li et al., 2018; Marttinen et al., 2019). Studies have shown that an increase in BMI is associated with a higher prevalence of back pain (Sidiq et al., 2021). To further support the biological basis of pain, many brain structures such as the anterior cingulate cortex, prefrontal cortex, insular cortex, primary somatosensory cortex, secondary somatosensory cortex, thalamus, amygdala, cerebellum, and periaqueductal gray (PAG) have been associated with pain perception (Apkarian et al., 2005; Navratilova et al., 2016). These and other biological factors are important to consider in the development, perception, and effects of pain on an individual.

In addition, there is a large body of literature on the bi-directional relationship between pain perception and mood/psychological state. Negative affect (or feelings of distress such as anxiety, depression, fear, anger, guilt, and shame) has been shown to impact pain perception and quality of life (Elman & Borsook, 2016; Watson et al., 1988). Countless studies have shown that a negative affective state co-occurs with higher incidences of pain, and recent reviews highlight that patients in chronic pain, compared to pain-free controls, show greater levels of self-reported negative affect (Burke et al., 2015; Howe et al., 2015). Specifically, there appears to be a strong co-occurrence of depression and chronic pain (Blay et al., 2007; Eggermont et al., 2012; Parmelee et al., 2013). Similarly, anxiety and pain appear to have a synergistic relationship (Asmundson & Katz, 2009). Negative affective states such as depression, anxiety, and distress have been identified as robust predictors of the development of chronic pain (Edwards et al., 2011; Linton et al., 2011; Nicholas et al., 2011). A study found that individuals with back or neck pain were two to three times more likely to have an anxiety-related disorder (panic disorder, agoraphobia, social anxiety disorder) and/or a generalized anxiety disorder or post-traumatic stress disorder (Demyttenaere et al., 2007). Additional psychological factors such as sleep and fatigue have also been studied in relation to pain. Fatigue is a common symptom in adults with pain. In a cross-sectional study review, there was a prevalence rate of 56.8% of fatigue in older adults with chronic pain (Jakobsson, 2006). Patients with co-occurring fatigue and pain report higher levels of anxiety and depression (Creavin et al., 2010), further supporting the dynamic interplay between pain and psychological factors.

In addition to general negative affect, there are pain-specific psychological factors that impact the pain experience such as pain catastrophizing, pain coping mechanisms, and fear avoidance. Pain catastrophizing is the tendency to exaggerate and magnify one's pain, ruminate, and feel helpless about doing something about the pain (Miaskowski et al., 2020). People who are prone to pain catastrophizing often amplify their current suffering and are at increased risk of developing chronic pain (Alschuler et al., 2013; Campbell et al., 2010; Dunn et al., 2018; Wright et al., 2017). A recent study on chronic back pain found that pain catastrophizing mediated the relationship between pain and disability and pain and fear (Marshall et al., 2017). There are a multitude of studies on psychological interventions for pain showing that change in catastrophizing is related to better pain outcomes (Wood et al., 2016).

Pain coping is another pain-specific psychological factor, which relates to how a person adjusts to their pain (Keefe et al., 2004). Making use of different coping strategies is a common practice among patients suffering from pain. Studies show that among musculoskeletal pain populations, the following coping responses were frequently used: Guarding (limiting bodily movement), Relaxation (relaxing activity such as listening to music), Task Persistence (continuing activities despite pain), and Coping Self-Statements (thinking positive thoughts), among various others (Ferreira-Valente et al., 2020). Research suggests that patients' beliefs about their pain, as well as the coping strategies they use, contribute to inter-individual variability in pain and disability (Ramond et al., 2011). Specifically, differences in pain coping methods are associated with differences in pain intensity, psychological functioning, and physical functioning (Jensen et al., 1991, 2003; Jensen & Karoly, 1991, 2011; Tan et al., 2005). Active coping strategies that involve a person functioning effectively despite the presence of pain are shown to correlate with positive affect and better psychological well-being (Kraaimaat & Evers, 2003; Snow-Turek et al., 1996). Conversely, passive coping strategies where a person depends on others to control their pain are linked to poorer outcomes such as higher levels of pain and depression (Brown et al., 1989; Covic et al., 2000; Holmes & Stevenson, 1990; Snow-Turek et al., 1996; Stewart & Yuen, 2011).

Fear avoidance is another pain-specific psychological construct that both contributes to and is impacted by pain. Fear avoidance typically involves fear of movement because of pain and can lead to adverse outcomes such as higher pain levels, increased rates of disability, and less than ideal treatment outcomes (Corbett et al., 2019; Cruz-Almeida et al., 2017). Among low back pain patients, avoidance of movement is associated with the maintenance of chronic back pain (Asmundson et al., 1999; Leeuw et al., 2007). The fear-avoidance model suggests that negative beliefs about a pain-related problem leads to a cycle of catastrophizing, hypervigilance, and fear of movement, which in turn leads to diminished activity and, subsequently, increased pain, disability, and distress. The cycle continues until the person engages in activity or movement despite pain, and ultimately, experiences less distress, pain, and disability (Leeuw et al., 2007).

In addition to biological and psychological factors, social influences shape the pain experience including cultural/racial/ethnic group, socioeconomic status, and social support. Recent evidence has emerged of potential cultural influences on pain. In a recent study on osteoarthritis, Asian participants, compared to non-Hispanic Whites, reported greater levels of experimental pain sensitivity and intensity (Ahn et al., 2017). A person's race, ethnicity, and culture may impact personal and societal ideologies regarding pain and coping strategies. Socioeconomic status has also been identified as an important predictor of pain. In a 12-year longitudinal retirement study, older adults with less education or income reported more pain. On average, participants with no high school degree had pain scores twice as high as those with graduate degrees. Moreover, the least wealthy participants had an average of 78% more pain than the wealthiest respondents (Grol-Prokopczyk, 2017). Finally, social support and relationships are important influences on pain perception. Social isolation and loneliness have been linked to greater rates of chronic pain and higher pain intensity ratings (Emerson et al., 2018; Jaremka et al., 2014; Marttinen et al., 2019; Richmond et al., 2018; Smith et al., 2019).

While various biopsychosocial factors influence the development and perception of pain, pain can also impact a person's physical, psychological, and social functioning.

Chronic pain often adversely impacts a person’s life, interfering with physical activity, activities of daily living, occupational functioning, sleep, mood, cognition, and overall quality of life (Miaskowski et al., 2020; Morlion, 2013). A strong correlation between pain and reduced physical activity has been demonstrated (Azevedo et al., 2012; Lerman et al., 2015). Being in any amount of pain often immobilizes that region of the body, and this is exaggerated in patients with severe and/or chronic pain. Pain can, therefore, result in various physical limitations, including inability to perform intense physical exercise, walk, perform domestic chores, and/or participate in social activities (Breivik et al., 2006). In some cases, people can struggle with basic movements such as getting up and sitting down (Amris et al., 2011; Boonen et al., 2005; McBeth et al., 2010).

In addition to the physical effects of pain, psychological well-being is often negatively affected including increased depression, anxiety, stress, and substance abuse. While negative affect such as depression and anxiety can contribute to pain onset and pain intensity, the reciprocal is also frequently observed as pain contributes to increased negative affect. For instance, in a recent longitudinal study in older adults with osteoarthritis, subjects with more severe and constant joint pain had higher levels of anxiety and depression compared to individuals with fluctuating pain (Liu et al., 2019). Depression in particular is strongly associated with chronic pain. Some authors have proposed depression as a risk factor (Brox et al., 2008) while others consider it a consequence of chronic pain (Roelofs et al., 2002). Regardless, it is well-known that pain and depression are intertwined and may co-exacerbate each other (IsHak et al., 2018). Related to negative affect, higher stress levels are also shown to correlate with chronic pain. As shown in a study of older adults, higher levels of stress were associated with higher levels of pain intensity and interference (White et al., 2014).

Several studies suggest that sleep disturbance is a common consequence of pain (Tüzün, 2007). Approximately 40% of older adults had reported sleep problems related to their chronic medical conditions and the presence of pain (Onen & Onen, 2018). Moreover, a community study revealed that as pain severity increased so did the occurrence of sleep disturbance (Chen et al., 2011). Sleep disorders may further increase stress levels and impair cognitive ability (Tüzün, 2007). Thus, disruption of sleep is another unwanted effect of pain.

Research also indicates that pain may exacerbate the development of other disorders and substance/opioid abuse. Pain, especially with the presence of negative affect, often leads to anxiety and stress-induced disorders and opioid overdoses (Elman & Borsook, 2016). With the current opioid crisis in the United States, the link between chronic pain and prescription opioid abuse has gained increased attention. Patients with chronic pain and mental health disorders are at a higher risk of misusing prescription opioids (Dowell et al., 2016). In addition, several studies have shown that those who report more subjective pain and multiple pain complaints are more likely to be at high-risk for opioid misuse. The consequences of opioid misuse can be life-threatening (Jamison et al., 2009; Liebschutz et al., 2010; Sullivan et al., 2010), and therefore, there is a critical need for more research on pain-related problems.

Pain may also affect the workplace and lead to the decline of productivity. Pain has a consequential impact in the workplace. It is common to see individuals with pain have to change their occupational duties, lose their job, or display a reduction in efficiency and productivity (Langley et al., 2011; Stewart et al., 2003). In fact, chronic low back pain (CLBP) is the leading cause for premature retirement of employees (Chenot et al., 2017; Maher et al., 2017). With decreases in work productivity and increases in the financial burdens of pain, pain yields negative effects on individuals.

Along with this, pain not only affects the individual suffering from the onset of pain, but it also affects those around them such as family and friends (Closs et al., 2009; Ojeda et al., 2014). Whether due to the financial costs of pain, the likelihood of being absent from social gatherings due to pain intensity, or the inability to cope and make plans for the future due to the common fluctuating nature of pain, pain has a significant impact on daily functioning in the family context and workplace (Corbett et al., 2007; Crowe et al., 2010; Raak & Wahren, 2006; Snelgrove & Liossi, 2009; Young et al., 2011). For instance, marital strain is common among people with pain and spouse (Strunin & Boden, 2004; Walker et al., 2006; White & Siebold, 2008). Furthermore, stigma is another problem that people with pain sometimes deal with. Qualitative studies suggest that patients believe society views people with chronic pain as burdensome individuals who imbalance social order (Holloway et al., 2007; Smith & Osborn, 2007).

In addition to the physical, emotional, and relational toll of pain, cognitive functioning is also shown to be adversely impacted and will be a focus of this paper. Cognition is the brain's acquisition, processing, storage, and retrieval of information (Lawlor, 2002). It is considered an umbrella term to describe a collection of neuropsychological processes including mental imaging, problem solving, and the experience of emotion (Moriarty et al., 2011). Through research, it has been demonstrated that pain and cognition share an inherent overlap. As pain has a crucial cognitive-evaluative component on a person's thoughts and feelings and requires learning, recall of past experiences, and active decision making (Moriarty et al., 2011), a person's cognitive function is often impaired as a result of pain. The presence of pain is an inherently attention-demanding sensory process (Moriarty et al., 2011), and chronic pain patients frequently self-report difficulties with paying attention to tasks (Dufton, 1989; Jamison et al., 1988; Kewman et al., 1991; McCracken & Iverson, 2001; Muñoz & Esteve, 2005). On top of that, empirical studies have also revealed attentional deficits in chronic pain patients (Alanoğlu et al., 2005; Bosma & Kessels, 2002; Oosterman et al., 2011; Veldhuijzen et al., 2006), possibly because pain competes with other stimuli for limited cognitive resources (Eccleston & Crombez, 1999). Research demonstrates that pain leads to loss of function in cognitive domains such as attention, learning and memory, speed of information processing, psychomotor ability, and executive function which is likely to impact an individual's execution of daily tasks (Moriarty et al., 2011). Compared to controls, pain patients perform poorly on memory tasks (Luerding et al., 2008; Oosterman et al., 2011; Park et al., 2001), display slower reaction times in standardized cognitive tests (Harman & Ruyak, 2005; Sjøgren et al., 2005), and perform worse in executive functioning tasks (Karp et al., 2006; Weiner et al., 2006). Pain is important to continue studying as we can predict the immense impact that pain and cognitive impairments could have on our patients in their personal lives, school, and work.

Chronic back pain:

Within the large umbrella of pain, low back pain is one of the most common types of pain. Low back pain (LBP) is defined as pain localized below the costal margin and above the inferior gluteal folds, with or without leg pain (van Tulder et al., 2006). LBP is the leading cause of disability (Hoy et al., 2014) and the most common cause of all non-communicable diseases (Vos et al., 2012). In fact, LBP leads to a greater number of people leaving the labor force than diabetes, hypertension, neoplasm, asthma, and heart and respiratory disease combined (Schofield, 2008). The adjusted lifetime prevalence of LBP is reported to be around 31% with a peak in prevalence between the ages of 40 and 69 years of age (Hoy et al., 2012).

Back pain is also a considerable public health concern as it has a high tendency for recurrence. In fact, large-scale epidemiological studies indicate that one of the main characteristics of LBP is recurrence (Costa et al., 2009). Available evidence suggests that around 33% of people with LBP will have a recurrence within one year of recovering from a previous episode (da Silva et al., 2017). Back pain poses significant issues as it tends to not improve over time and consumes the most resources (Krismer & Tulder, 2007). As the symptoms and timing of back pain vary widely, LBP is sectioned into acute (<6 weeks), subacute (6-12 weeks), and chronic (>12 weeks) low back pain categories (Atlas & Deyo, 2001; Heuch & Foss, 2013). Acute back pain is defined as pain with a sudden onset and often stems from some form of illness process or tissue injury. An episode of acute low back pain is usually a self-limited condition, and most patients do not require any active medical treatment (Carey et al., 1996). These patients often are able to return to work and normal activities within a month as their pain and disability improves rapidly (Pengel et al., 2003). However, chronic low back pain (CLBP) is often associated with a less favorable prognosis than acute back pain (Koes et al., 2006; Pengel et al., 2003) and will be the focus of this paper.

About 1 in 3 patients report persistent and chronic back pain of moderate intensity after 1 year of an acute episode with substantial limitations in activity (Patrick et al., 2014). About one fourth of American adults report CLBP (Deyo et al., 2006) which is responsible for high treatment costs, sick leave, and individual suffering (Liao et al., 2009; Loisel et al., 2002; Melloh et al., 2008). Just as pain in general costs a lot of money, chronic back pain also comes with considerable financial implications. CLBP places a great economic burden on society with an estimated \$81.24 billion to even \$200 billion spent in total society cost in the U.S. when considering health care expenses and pain management (Casiano et al., 2022; Hartvigsen et al., 2018; Luo et al., 2004; Rizzo et al., 1998). This is partly attributed to the need for long-term treatment in chronic back pain patients. It is costly for individuals suffering from chronic back pain to continue seeing healthcare providers and to obtain prescription medications for long periods of time. Further, the medical diagnostic tests that are performed are also expensive (Balagué et al., 2012; Dreisinger, 2014).

Despite these costly efforts, CLBP is a tough condition to treat; many patients do not respond to medications and treatments, and the best treatment approach remains unclear (Deyo et al., 2009; Haldeman & Dagenais, 2008). Even according to the IASP, chronic musculoskeletal pain is typically managed but not cured (“Pain Terms,” 1979b).

Given its long-term nature, CLBP can have significant negative effects on quality of life and functioning. Even amongst individuals reporting low pain intensity and disability, low back pain reduces one’s quality of life. One study found that women, regardless of low or high intensity of pain and disability, experienced reduced well-being (Urquhart et al., 2009). Chronic back pain is associated with considerable emotional distress, increased risk of developing psychiatric disorders, impaired social/educational/occupational functioning, and increased use of medical services (Asmundson & Katz, 2009; Dick et al., 2008; Fichtel & Larsson, 2002; Forgeron et al., 2010; Gureje et al., 1998; Kashikar-Zuck et al., 2001). Although there is a sizable population of people with back pain who do not seek medical care with no changes in quality of life (Côté et al., 2001), CLBP is often associated with high unemployment rates, functional limitations, depression, opioid analgesic use, more doctor visits, and poor self-rated health (Baykara et al., 2013). Many studies show an association between psychological factors and low back pain such as anxiety, depression, somatization symptoms, job dissatisfaction, mental stress at work, and negative body image (Andrew et al., 2014; Moriarty et al., 2011). All these factors contribute to the diminished quality of life associated with chronic back pain as well as deficits in social, educational, and occupational functioning. For example, one study found that low back pain was the leading contributor to the loss of work days and disability (Hoy et al., 2012). Along with affecting daily activities and emotional well-being, there is accumulating evidence to support that pain impairs cognition. For instance, patients with fibromyalgia have more difficulties in their abilities to retain new information (Dick et al., 2008; Leavitt & Katz, 2006). Individuals suffering from back pain are shown to have deficits in decision-making when tested with the Iowa gambling task (Apkarian et al., 2004). In another study with an older population with chronic pain, pain severity was associated with poorer selective and sustained attention (van der Leeuw et al., 2018). In addition, a 2016 study of 765 participants concluded that subjects with more severe pain performed worse on executive functioning and memory tests. All of these studies suggest the serious impact that chronic pain may have on patients as pain competes with the ability to perform cognitive tasks (van der Leeuw et al., 2016).

Pain & Attention:

One cognitive domain that seems particularly effected by pain is attention, and there is a bidirectional relationship between pain and attention. Similar to the pain experience, attention differs person to person and is defined as an individual's information processing capacity (Mirsky et al., 1991; Shumway-Cook & Woollacott, 2000). Literature may explain the link between pain and attention in an evolutionary and biological way. In terms of evolutionary adaptation, researchers have explained how acute pain can be considered beneficial and protective to signal one's bodily harm (Yam et al., 2018). Pain is proposed to demand attentional resources to avoid further damage by interrupting an individual's current activities and focusing one's full attention on the painful and noxious stimuli (Eccleston, 1994). Researchers have sought to find the biological basis behind attention-demand and pain. It is hypothesized that an opiate-sensitive descending pathway may be involved in the attentional modulation of pain. This pathway follows from the frontal cortex to the amygdala, periaqueductal gray (PAG), rostral ventral medulla, and spinal cord dorsal horn (Fields, 2000). Using functional imaging techniques, it was found that when a subject's attention was distracted by pain, the PAG was significantly more activated. The level of PAG activity was predictive of the reduction in pain intensity due to the distraction task (Tracey et al., 2002). Although further research is needed to fully understand the pain and attention relationship, there is support of this connection.

Given evidence that cognitive functioning is implicated in the pain experience, studies have sought to uncover how attention and distraction may reduce pain perception. At any given moment, a human only has a certain capacity for attention. Due to this limited attention ability at a given time, a patient's perception of a painful stimulus can be dampened if attention is focused on another stimuli (McCaul & Malott, 1984). Many report that pain is perceived as less intense when an individual is distracted from the pain. In these studies, distraction is oftentimes achieved by forcing the subject to attend to a different sensory modality (Rode et al., 2001). For example, one study found that while administering painful thermal stimuli to a subject's forearm, those who completed a more distracting working memory task reported significantly less pain intensity compared to participants who completed less demanding tasks (Rischer et al., 2020). Therefore, because pain is distracting, attention modification is a common method to control pain during medical procedures. There is robust evidence in clinical research that attention can be used as a technique to manage pain (Buhle & Wager, 2010; Legrain et al., 2009). Attention management has been increasingly employed especially to treat and manage chronic pain (Mortensen et al., 2015; Subnis et al., 2016). Other methods such as virtual reality have even been used as a distraction intervention to relieve pain and distress in patients (Indovina et al., 2018).

There is also growing evidence that pain may impact attention and cognition. Pain impairs attention and hinders an individual's ability to conduct daily tasks. Because pain is innately attention-grabbing, the presence of pain may dominate a patient's life as they fight to control the pain and even achieve pain relief (Crombez et al., 2013). These individuals may not be able to focus on important tasks and hobbies as pain interferes and disrupts the daily activities of people's lives (Dow et al., 2012). This has also been demonstrated experimentally in the lab. When a person is asked to divide their attention between pain and another sensory modality, more often the attention to pain dominates (Lee & Tracey, 2013; Miron et al., 1989; Ojala et al., 2014). Studies show that people with pain have inaccuracies and impairments in attention and cognition. It was found that in healthy controls, acute pain caused a decrease in accuracy on attentional switching tasks (Attridge et al., 2016). In patients with fibromyalgia (a widespread chronic pain condition), there was an impairment in performance on a divided attention task (Moore et al., 2019).

Temporal Perception:

Temporal perception, or the perception of the passage of time, is closely related to attention. Subjective time is an internal experience of how much time has passed since the occurrence of a certain event (Wittmann et al., 2010a). Although time can be measured and precisely reported using a clock, it is a well-known idea that an internal sense of time differs from person to person. Time often seems to fly by during pleasant moments but drag on during unpleasant situations (Wittmann et al., 2006). The subjective nature of temporal perception is such that, despite the actual duration of an event, perception of time can vary between individuals based on a number of factors. Some of these factors may include emotion, anxiety, attention, and pain (Droit-Volet, 2013; Droit-Volet & Meck, 2007; Koestler & Myers, 2002; Tse et al., 2004). For instance, when an individual becomes depressed, they may experience a slowing down of time, sometimes to the point where a day may feel like it lasts for a year (Ratcliffe, 2012). Researchers have begun investigating how the presence of pain may similarly alter one's perception of time and how this may affect that individual's life and functioning.

There are a number of internal time models to conceptualize how humans make sense of time. Unlike other senses, such as the visual and auditory senses, there is no special receptor that has been found to be responsible for the processing and perception of time (Zhang et al., 2012). Therefore, several different models of time perception have been proposed such as the processing integration model, the storage size model, and the scalar timing model (STM) (Gibbon, 1977; Ornstein, 1969; Thomas & Weaver, 1975). Of these models, the STM is used most often in literature. The STM was proposed by

Gibbon in 1977 and describes an internal clock model based on the scalar expectancy theory (SET). The internal clock is made up of a pacemaker, switch, and accumulator. The switch connects the pacemaker to the accumulator and is controlled by attention. Thus, when our attention is focused on time, the switch closes to allow pulses from the pacemaker to flow into the accumulator. Once the stimulus is removed, the switch reopens and the pulses cease accumulating. The scalar timing model proposes that we estimate time based on these pulse accumulations. The more pulses that have accumulated, the longer the duration of time that we perceive (Droit-Volet, 2013; Gibbon, 1977). Although further research is needed, there are studies that regard the dopaminergic system and basal ganglia to function as the pacemaker and accumulator from the STM (Meck et al., 2008). Within this model, it is suggested that time is influenced by a variety of cognitive functions such as perception, attention, and memory (Lui et al., 2011).

It is a common finding in temporal perception literature that emotion influences time. For example, it's often found that negative, fear-inducing stimuli are perceived as lasting for a longer period of time than neutral stimuli (Droit-Volet & Meck, 2007). Among all of the primary emotions (fear, anger, happiness, disgust, sadness, and surprise) (Ekman, 1992), fear is most studied with regard to time judgment in humans (Droit-Volet, 2013). The existence of the emotion of fear in humans is an adaptive function for defense and survival. Innately, an angry face triggers defense mechanisms in many animals and humans (Juth et al., 2005). Most of these studies on fear and temporal perception have used visual and auditory stimuli. Findings using somatosensory stimuli such as pain are not as common and, thus, warrants further research (Ogden et al., 2015b).

If time perception models such as the internal clock theory propose that cognitive functions like attention affect temporal perception, it is likely that the attention-grabbing nature of pain could also affect a person's perception of time (Gibbon et al., 1984). There is growing evidence around the biological basis of this suggestion as well. As the actual experience of and anticipation of pain produces feelings of fear, anxiety, and anger (Rhudy & Meagher, 2000), the amygdala is activated (Bornhövd et al., 2002). This may be the physiological and neural mechanism for pain to modulate temporal perception as the amygdala is a part of a neural circuitry for enhanced attention to one's emotions (Ogden et al., 2015b; Vuilleumier, 2005).

There has been some work on the effect of pain on temporal perception. In 2014, Ogden sought to examine how the experience as well as the anticipation of a noxious painful stimulus could affect temporal perception. Using an acutely painful thermal stimulus, this study found that the duration estimates by subjects in trials with received or anticipated pain were significantly longer than control trials without any pain with a 14% and 35% increase in perceived duration, respectively (Ogden et al., 2015b). Another recent study also used an acutely noxious stimulus of cold water hand immersions to investigate the impact of pain on temporal perception. Using varying durations of visual stimuli with a temporal bisection task during the administration of the painful water stimuli, Rey found that pain significantly lengthened the subjects' perception of time.

Further, increases in painful stimuli led to more significant time-estimate distortions (Rey et al., 2017). Notably, these prior studies examined acute experimental pain only.

There has been one study to date examining the effect of a chronic pain condition on temporal perception. Zhang and colleagues examined temporal perception in individuals with migraines. They found similar results to those in the acute pain studies with migraineurs, in comparison to healthy adults, displaying an overestimation of time during the task (Zhang et al., 2012). Although migraines can be chronic conditions, these patients were tested interictally and none had a migraine attack within 48 hours of the experiment. Thus, it is important to examine the effect of concurrent chronic pain on temporal perception. The current study builds upon prior research by examining the effects of both acute and chronic pain on temporal perception.

SPECIFIC AIMS

The purpose of this study was to examine the impact of acute and chronic low back pain on the accuracy and variability of temporal perception. We hypothesized that: (1) acute and chronic pain would decrease accuracy and increase variability of temporal perception such that time would be perceived as longer when pain is present and (2) there would be an additive effect of acute and chronic pain on the accuracy and variability of temporal perception.

METHODS

Design:

This study was part of a larger study that examined the impact of acute stress on pain perception. The current cohort study focused on how the presence of acute pain and CLBP affect a person's perception of time. All research was completed at Brigham and Women's Hospital between May 2018 through February 2020 under the supervision of Drs. Samantha Meints and Robert Edwards. This study was approved by the Brigham and Women's Hospital IRB.

Participants:

The current cohort study had 77 participants, 67 healthy pain-free controls and 10 with CLBP. Potential participants were recruited from the Partner's Healthcare Clinical Trials website as well as via word of mouth and flyers posted in Brigham & Women's Hospital clinics. Potential participants then provided their names and contact information via a secure network and were contacted and screened via telephone by study staff. Participants with CLBP were included if they: (1) had at least three months of self-reported CLBP with an average pain severity of 4 on a 0-10 scale; (2) were able to speak sufficient English to complete questionnaire measures (given the lack of demonstrated validity of these measures in other languages); and (3) were between the ages of 18-35. Healthy pain-free controls (HC) were included in this study if they: (1) were able to speak sufficient English to complete questionnaire measures and (2) were between the ages of 18-35. Potential participants were excluded if they: (1) were unable to speak sufficient English to complete the questionnaires; (2) had severe cognitive impairment by history (e.g., intellectual disability, severe head injury); and (3) had comorbid medical and/or pain conditions, which would potentially confound the data (e.g., cancer, sickle-cell disease, arthritis, fibromyalgia, pregnancy).

Eligible participants were scheduled for an in-person visit at the Brigham and Women's Pain Lab. Upon arrival, they were consented and completed study tasks for the larger parent study (i.e., a battery of self-report questionnaires and quantitative sensory testing). For the current sub-study, each participant completed temporal perception tasks, with and without an accompanying acute pain stimulus.

Acute Pain Induction:

To induce acute pain, participants had a standard blood pressure cuff applied comfortably around the left gastrocnemius (calf) muscle. The cuff was inflated using a Hokanson rapid cuff inflator to 60mmHg. Participants were asked to provide a numeric pain rating (NRS) from 0-100. The cuff pressure was then increased at intervals of 20mmHg. After each increase, participants provided an NRS until a pain rating of 50/100 was reached at which time the cuff was deflated. The pressure required to produce a 50/100 pain (P50) was documented and used during acute pain tasks.

Temporal Perception Tasks:

Each study participant was asked to complete the temporal perception tasks (Bisection and Threshold) twice, once with and once without the acute pain cuff task. The order (with vs. without acute pain) was counterbalanced between participants to prevent order effects. Both temporal perception tasks used E-Prime 2.0 software for programming and data acquisition and required participants to sit in a chair in front of a computer with their legs propped up on a footrest.

During the *Temporal Bisection Task* (Gil & Droit-Volet, 2011) participants first completed the training phase, during which they were presented with visual stimuli (black squares) that lasted for short (400ms) and long (1000ms) periods of time. During this phase, participants were told whether the stimulus was short or long. They saw each stimulus duration three times. Afterwards, participants were asked to categorize a series of black square stimuli as closer to the standard short or long stimuli presented during the training phase. There were seven durations (400ms, 500ms, 600ms, 700ms, 800ms, 900ms, and 1000ms) that were each presented five times in random order. Participant responses were measured and then calculated by the number of times out of 9 trials in which the subject responded that the test stimulus was perceived to be closer in duration to the longer of the standard durations ("long" response). Thus, the outcome of interest was the mean proportion of "long" responses.

During the *Temporal Threshold Task* (Jones et al., 2009) participants were presented with two visual stimuli (black squares) of varying durations. Participants were asked to press '1' or '2' on a keyboard corresponding to the stimulus they perceived to be longer in duration. The first set of stimuli were 1000ms and 700ms. If the participant responded correctly, the difference in duration between the two stimuli was reduced on the next trial. If the participant responded incorrectly, the difference in duration between the two stimuli was increased on the next trial. The step size between trials began at 15ms and fell to 10ms after 30 trials. A total of 50 trials were completed. To determine the threshold for which participants accurately identified differences in duration, the outcome of interest was the average duration in milliseconds necessary to detect a difference.

Figure 1. Temporal Bisection Task Diagram. Each participant completed the temporal bisection task twice, once with induced acute pain and once without acute pain.

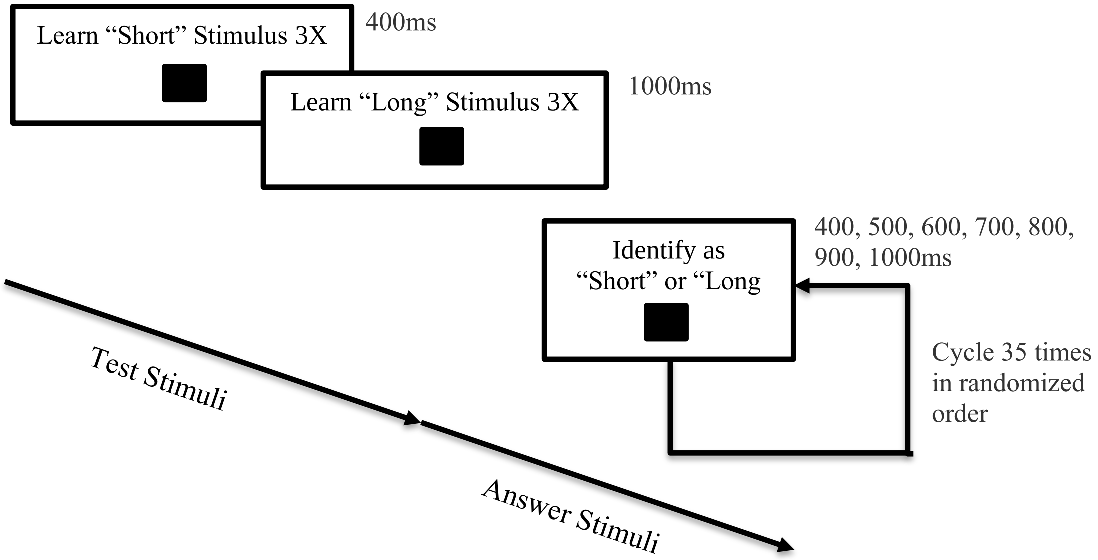
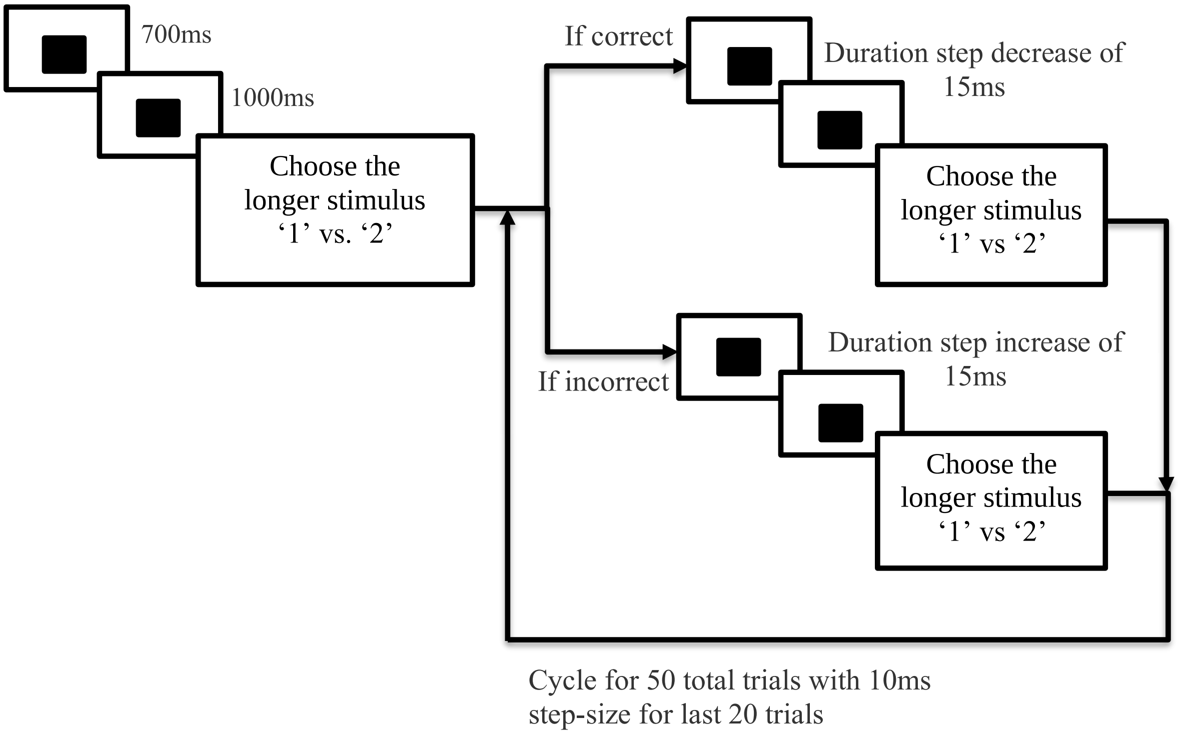


Figure 2. Temporal Threshold Task Diagram. Each participant completed the temporal threshold task twice, once with induced acute and once without acute pain.



Data Analysis:

The data analysis for this study was performed using IBM SPSS Statistics 27 (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp). Basic descriptive statistics were conducted to report demographics of the sample (e.g., age, sex, ethnicity, race).

In the temporal bisection tasks, the primary outcome of interest was the proportion of times participants identified a given stimulus length as “long” (as opposed to short). A 2 (presence vs. absence of acute pain) X 2 (CLBP vs. healthy control) X 7 (stimulus duration in ms) repeated measures analysis of variance (RMANOVA) was conducted to examine the main effects of acute pain, chronic pain, and time duration, as well as all two-way interactions. Proportions were plotted as a sigmoid bisection function for each actual duration of the stimulus to illustrate shifts of the function in order to compare those with and without CLBP. The sigmoid bisection model is used to illustrate the point of inflection which represents the bisection point. At the bisection point, it is equally likely for subjects to identify a stimulus as short or long.

For the temporal threshold tasks, the outcome of interest was the threshold time in milliseconds needed to accurately differentiate between a short and long stimulus. A 2 (presence vs. absence of acute pain) X 2 (CLBP vs. healthy control) RMANOVA was conducted to examine main effects of acute and chronic pain, as well as potential interaction effects. For all analyses, significance was defined as $p < 0.05$.

RESULTS

Participant characteristics:

This study included a total of 77 participants who met the eligibility criteria. Participants ranged in age from 18-65 years with an average age of 27. The sample was mostly White (57%), non-Hispanic (83%), and female (71%).

Table 1: Participant Demographic Characteristics.

Demographic		N (%) / Mean (SD)		
		Total Sample	Healthy Controls	CLBP
Subjects		77	67	10
Age		27 (10)	25 (4)	47 (16)
Sex	Female	55 (71%)	48 (72%)	7 (70%)
	Male	22 (29%)	19 (28%)	3 (30%)
Ethnicity	Hispanic or Latino	9 (12%)	9 (13%)	-
	Not Hispanic or Latino	64 (83%)	55 (81%)	9 (90%)
	Prefer not to answer	1 (1%)	-	1 (10%)
	Missing	3 (4%)	3 (6%)	-
Race	Black	7 (9%)	5 (7%)	2 (20%)
	White	44 (57%)	37 (54%)	7 (70%)
	Asian	14 (18%)	14 (21%)	-

	Native Hawaiian/Pacific Islander	1 (1%)	1 (2%)	-
	Other	5 (7%)	5 (7%)	-
	Prefer not to answer	3 (4%)	2 (3%)	1 (10%)
	Missing	3 (4%)	3 (6%)	-
Marital Status	Married	7 (9%)	5 (7%)	2 (20%)
	Never married	58 (75%)	55 (81%)	3 (30%)
	Divorced/Separated	2 (3%)	-	2 (20%)
	Living with partner	6 (8%)	4 (6%)	2 (20%)
	Widowed	1 (1%)	--	1 (10%)
	Missing	3 (4%)	3 (6%)	-
Living Situation	Alone	6 (8%)	2 (3%)	4 (40%)
	Spouse	6 (8%)	4 (6%)	2 (20%)
	Young children	1 (1%)	1 (2%)	-
	Adult children	1 (1%)	1 (2%)	-
	Parents	8 (11%)	8 (12%)	-
	Significant Other	11 (14%)	9 (13%)	2 (20%)

	Roommate	41 (53%)	39 (57%)	2 (20%)
	Missing	3 (4%)	3 (5%)	-
Household Income	Less than $22,500	18 (23%)	16 (24%)	2 (20%)
	$22,500-$45,000	22 (28%)	18 (27%)	4 (40%)
	$45,000-$100,000	19 (25%)	15 (22%)	4 (40%)
	More than $100,000	6 (8%)	6 (9%)	-
	Prefer not to answer	9 (12%)	9 (13%)	-
	Missing	3 (4%)	3 (5%)	-
Education	Some high school	1 (1%)	1 (2%)	-
	High School/GED	4 (5%)	1 (2%)	3 (30%)
	Some college	15 (20%)	12 (18%)	3 (30%)
	College graduate	33 (43%)	31 (46%)	2 (20%)
	Master’s degree	14 (18%)	12 (18%)	2 (20%)
	Doctoral degree	6 (8%)	6 (9%)	-
	Prefer not to answer	1 (1%)	1 (2%)	-
	Missing	3 (4%)	3 (3%)	-

Currently employed	Yes	48 (62%)	42 (62%)	6 (60%)
	No	26 (34%)	22 (32%)	4 (40%)
	Missing	3 (4%)	3 (6%)	-
Back pain	No	67 (87%)	67 (100%)	-
	Yes	10 (13%)	-	10(100%)

Table 2: RMANOVA Results for Temporal Bisection Task.

Variable	**F**	***p***	**η2**
Time	98.241	**<0.001**	0.898
Acute Pain	1.509	0.223	0.021
CLBP	0.492	0.485	0.007
Acute Pain X Time	2.975	**0.012**	0.210
Acute Pain X CLBP	0.093	0.762	0.001
Time X CLBP	2.500	**0.030**	0.183

Table 3: RMANOVA Results for Temporal Threshold Task.

Variable	**F**	***p***	**η2**
Acute Pain	5.244	**0.025**	0.070
CLBP	6.780	**0.011**	0.088
Acute Pain X CLBP	0.355	0.553	0.005

Temporal Bisection Task:

Results of a 2 (presence vs. absence of acute pain) X 2 (CLBP vs. healthy control) X 7 (stimulus duration in ms) RMANOVA revealed a significant main effect of time such that when the stimulus duration was short, the proportion of “long” responses was low, whereas when the stimulus duration was long, the proportion of “long” responses was large (*p*<0.001; see Table 2). There were no significant main effects of acute or chronic pain (*p*>0.050; see Table 2 and Figures 3 & 4). There was a significant CLBP X time interaction such that at shorter durations, people with CLBP pain perceived the stimuli to be significantly longer than healthy controls (*p*=0.030; see Table 2 and Figure 5). At longer durations, people with CLBP pain perceived the stimuli to be significantly shorter than healthy controls. There was also a significant acute pain X time interaction such that acute pain resulted in overestimations of time for short duration stimuli and underestimations for long duration stimuli (*p*=0.012; see Table 2 and Figure 6). However, there was not an acute pain X CLBP interaction (*p*=0.762; see Table 2). Thus, acute and chronic pain did not have additive effects on temporal perception.

Figure 3: Sigmoid Bisection Curve Without Acute Pain Condition. Mean proportion of “long” responses plotted against stimulus duration from the testing phase of the experiment without induced acute pain.

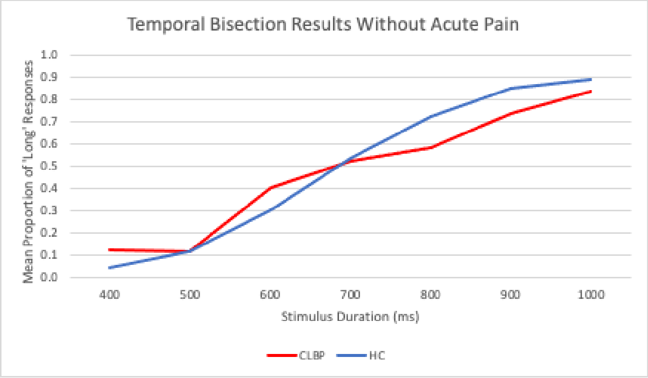


Figure 4: Sigmoid Bisection Curve With Acute Pain Condition. Mean proportion of "long" responses plotted against stimulus duration from the testing phase of the experiment with induced acute pain.

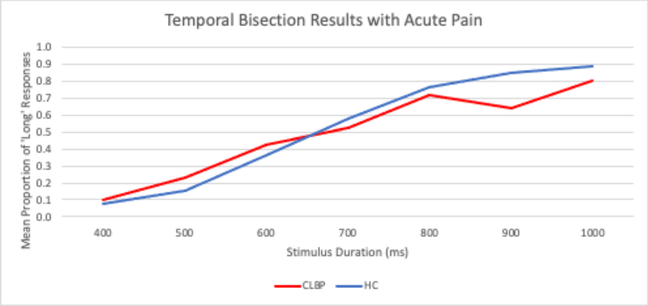


Figure 5: Sigmoid Bisection Curve Showing CLBP X Time Interaction. Mean proportion of "long" responses plotted against stimulus duration from the testing phase of the experiment when considering the interaction of CLBP and time.

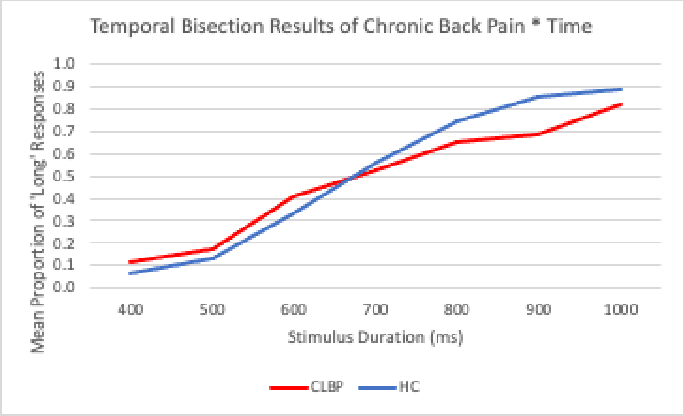
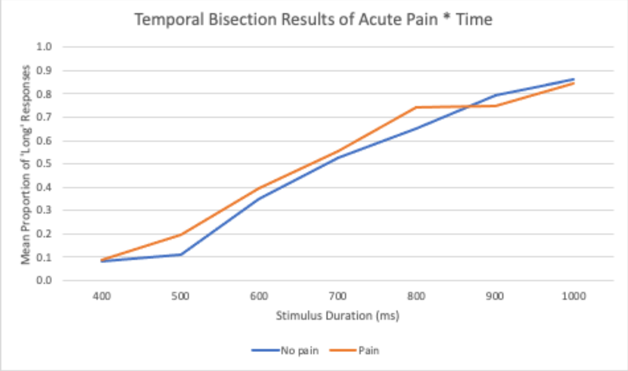


Figure 6: Sigmoid Bisection Curve Showing Acute Pain X Time Interaction. Mean proportion of “long” responses plotted against stimulus duration from the testing phase of the experiment when considering the interaction of acute pain and time.



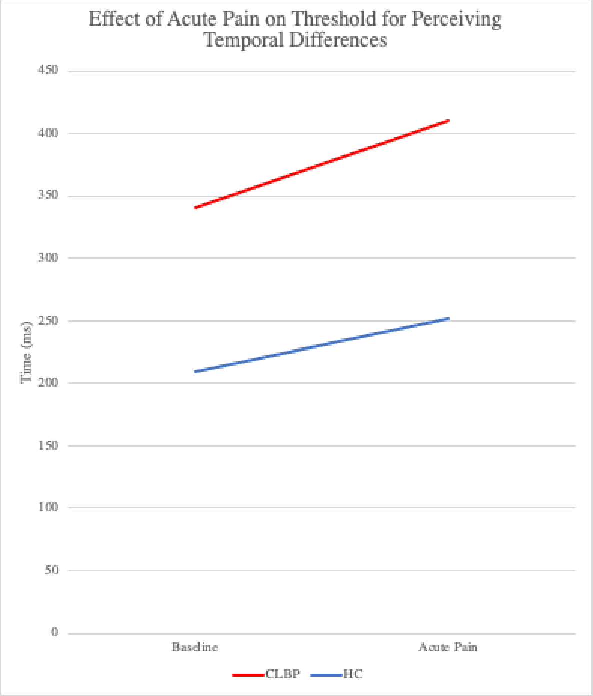
Temporal Threshold Task:

A 2 (CLBP vs. HC) X 2 (acute vs. no acute pain) RMANOVA revealed a significant main effect of acute pain (*p*=0.025; see Table 3 and Figure 7) such that participants required a longer time difference and had a higher threshold between stimuli to accurately distinguish between stimuli of differing lengths. People in acute pain needed an extra 60ms to perceive temporal differences compared to the condition without acute pain.

There was also a significant main effect of chronic pain such that those with CLBP demonstrated a longer threshold than the healthy controls (*p*=0.011; see Table 3 and Figure 7). Participants with CLBP needed an extra 145ms to accurately distinguish between the short and long stimuli presentations.

However, there was not a significant acute pain X CLBP interaction (*p*=0.553; see Table 3 and Figure 7). When a participant was performing the threshold tasks with the presence of both acute pain and CLBP, there was not an additive effect on performance.

Figure 7: Temporal Threshold Task Results. Average time in milliseconds for participants to accurately distinguish between "short" and "long" stimuli presentations at baseline and with induced acute pain.



DISCUSSION

Using temporal bisection and threshold tasks, we examined the effects of acute and chronic pain on temporal perception. The results of the temporal bisection task revealed that acute and chronic pain similarly affected subjects' perception of time such that acute pain and CLBP were both associated with longer perception of short time intervals and shorter perception of long time intervals. Similarly, for the temporal threshold tasks, people with CLBP and acute pain required a greater amount of time to accurately distinguish between visual stimuli of varying durations. However, contrary to our hypothesis, acute and chronic pain did not have an additive effect for either task.

These findings are consistent with previous studies showing that painful stimuli lengthen patients' perception of time. In a study of experimental pain and temporal perception, Ogden assessed temporal perception using a verbal estimation task while applying a painful thermal stimulus. This study revealed that acute pain resulted in an increase in perceived duration of time (Ogden et al., 2015a). Rey produced a similar study using temporal bisection with a painful thermal stimulus which further demonstrated how pain significantly lengthened one's perception of time (Rey et al., 2017). Extending this work, we used an alternative noxious stimulus (i.e., deep muscle pain produced by a cuff algometry task), suggesting that various modalities of acute pain may lengthen the time experience of patients.

In addition, we addressed a gap in the literature by examining the effect of chronic pain on temporal perception. To date, most extant studies on pain and temporal perception have focused on the effects of acute pain. Although one study concluded that participants with migraines, a clinical condition, overestimated time during the tasks, these participants were tested interictally. None of the participants were experiencing migraines during the experiment (Zhang et al., 2012). By including participants with constant and persistent CLBP, we were able to assess the effects of chronic pain on temporal perception as well as test for additive effects of acute and chronic pain. The results of our study revealed that, similar to the effects of acute pain and chronic migraine, CLBP affected one's temporal perception. In both the temporal bisection and threshold tasks, results showed that subjects suffering from CLBP pain were less accurate in perceiving events depending on the duration of the stimulus. When presented with "short" durations, participants with CLBP demonstrated a lengthened perception of time and had a higher proportion of "long" responses than healthy controls. On the other hand, when presented with "long" durations, participants with CLBP demonstrated a shortened perception of time and had a lower proportion of "long" responses than healthy controls. Overall, this indicates that people with CLBP have a less accurate perception of time.

Temporal perception is being studied as it is vital to a person's everyday life. How a person perceives time is the foundation for processing information, motor behavior, and making predictions (Wittmann et al., 2010b; Yang et al., 2007). People are constantly using their internal clocks to make sense of situations and act accordingly; however, if temporal perception is impaired, this could potentially create challenges and issues in many real-life scenarios.

In the context of people with chronic pain, inaccurate perception of time may result in difficulty managing medications. CLBP is a condition that requires complex medication regiments that are time sensitive (Malanga & Wolff, 2008; Patrick et al., 2014). In order to treat back pain, a guideline by the American College of Physicians (ACP) recommends the prescription of nonsteroidal anti-inflammatory drugs as first-line therapy or tramadol or duloxetine as second-line therapy if pharmacologic treatment is desired (Qaseem et al., 2017). However, a false sense of time may interfere with patients' ability to follow medication instructions as complex labels require patients to use cognitive resources to infer when to take a medicine (Davis et al., 2009). If a patient is unable to accurately time their schedule and fail to take their medication at the proper time, they could experience adverse side effects (Brown et al., 2016; Davis et al., 2009). Moreover, when considering the fact that most patients dealing with CLBP are older individuals, it is important to recognize that older populations often have problems adhering to medication schedules (Shade et al., 2021). With the combination of older age and the negative effects of pain on temporal perception, patients with CLBP may have an even harder time adhering to treatment schedules and have worse pain outcomes or side effects.

Notably, opioid therapy, which is often reserved for patients with moderate to severe pain that is unresponsive to other medical and pharmacological treatments, requires setting timely goals and medication schedules (Nafziger & Barkin, 2018). Increases in dosage and frequency are administered carefully, and adherence monitoring is done for therapeutic outcomes, misuse, abuse, and development of opioid use disorder

(Nafziger & Barkin, 2018). However, problems with opioid misuse and abuse may arise if patients have altered perceptions of time. For example, a patient with chronic pain may incorrectly perceive that a long period of time has passed and take their next dosage of medication too soon. This cycle may continue and bring about a dangerous habit of medication and/or opioid nonadherence.

Another method of chronic pain management that may be affected by temporal perception is activity pacing. Activity pacing is a strategy taught in cognitive behavioral therapy (CBT) (Beissner et al., 2009; Torrance et al., 2011; Wallman et al., 2004) to help people with chronic pain regulate activity (Goudsmit et al., 2012; Torrance et al., 2011). This strategy aims to reduce overactivity-underactivity cycling to improve function and symptom exacerbation (Birkholtz et al., 2004; Jamieson-Lega et al., 2013). As patients with chronic pain often avoid certain activities, activity pacing provides a method for patients to re-engage with activities for more regular and balanced functioning (Antcliff et al., 2021; Birkholtz et al., 2004; Jamieson-Lega et al., 2013). The activity pacing framework is based on setting goals according to time, distance, and activity (Antcliff et al., 2021). However, if a patient with chronic pain has a distorted temporal perception, this strategy could be difficult to implement. Without a good sense of time, an individual would be unable to correctly switch off between cycles of over- and underactivity and fail to successfully make use of activity pacing as a method for pain management.

In the clinical setting where both pain and emotions are involved, it is vital to recognize how a patient in pain may have an altered sense of temporal perception compared to individuals who are pain-free. This altered temporal perception among patients in pain may pose problems when waiting to be seen by medical providers. Although chronic pain is a condition that requires prompt access to care and treatment, clinic and hospital wait times often exceed benchmark recommendations and may impact patient health outcomes. One study, for example, found that wait times for chronic pain care, even those triaged as urgent cases, exceeded what patients considered ideal, often lasting more than three months from scheduling their appointment (Liddy et al., 2017). In the U.S., median Emergency Room wait times are as high as 141 minutes (Routhier, 2020). Inaccurate temporal perception may adversely impact these waiting periods, with people perceiving already long waits as even longer which may lead to patient dissatisfaction and frustration (Davenport et al., 2017). It has also been suggested that the diagnostic procedures and wait times experienced during a typical Emergency Department visit all contribute to the anxiety and overall pain perception of a patient (Kapoor et al., 2016). It is imperative that access to treatment and healthcare be improved as unacceptably long wait times to see a healthcare provider have been shown to result in physical and psychological deterioration (Burke et al., 2020; Hogg et al., 2021). Our findings further support the relationship between pain and temporal perception and call for more research, intervention, and advocacy to improve well-being of patients in pain.

Notably, the effects of pain and temporal perception may be cyclic and lead to greater intensities of pain and time inaccuracies. People with chronic pain often have greater tendencies toward pain catastrophizing (Marshall et al., 2017). Pain catastrophizing may lead to greater pain severity (Alschuler et al., 2013; Campbell et al., 2010; Dunn et al., 2018; Wright et al., 2017) and result in patients perceiving their pain as lasting for longer periods of time. This has been supported in literature as experimental conditions have revealed that the presence of pain, along with the emotions that come with pain, led to subjects judging a previous painful situation as being longer than it actually was (Gan et al., 2009; Hellström & Carlsson, 1997). Studies have revealed how the attentional biases elicited by attention-grabbing stimuli such as pain or strong emotions decrease the resources required for accurate time processing (Gan et al., 2009).

Strengths, Limitations, and Future Directions:

Our results should be interpreted in the context of several limitations including our small sample size of patients with CLBP. In this study, there were 77 total participants but only 10 had CLBP. This work should be replicated with a larger sample of CLBP subjects. Moreover, as our focus was on patients with CLBP, these findings may not be generalizable to other chronic pain conditions. Our study may also not generalize to other forms of acute clinical pain.

The lack of demographic diversity in our sample is another limitation. Although women report more chronic pain than men in the overall population (Berkley, 1997; Mogil & Bailey, 2010), future studies should include more diversity in gender identity as well as race, ethnicity, socioeconomic status, and education. Our cohort largely comprised non-Hispanic, White subjects, many of whom were students and younger in age. To ensure our results are generalizable, future studies should use samples that are more consistent with the overall population demographics.

Despite these limitations, this study also had several strengths and added to the extant literature on temporal perception and pain. In particular, our study examined the effects of both chronic pain and experimental acute pain on temporal perception. Given that most prior studies have focused on a singular source of experimental acute pain, the results of this study broaden our understanding of the impact of different types of pain on a person’s perception of time.

Conclusion:

There has been increased interest on the effects of pain on attention, including temporal perception. Pain is shown to compete for cognitive resources and affect how one processes and perceives time (Moriarty et al., 2011; Rey et al., 2017). This study builds upon prior work by showing that both acute experimental pain and CLBP lead to changes in time perception, though these effects are not additive. Although the effects of pain on temporal perception vary based on type of pain and the specific duration of time, our findings show that people in pain do in fact process time differently from those who are pain-free.

REFERENCES

Ahn, H., Weaver, M., Lyon, D., Kim, J., Choi, E., Staud, R., & Fillingim, R. B. (2017). Differences in Clinical Pain and Experimental Pain Sensitivity between Asian Americans and Whites with Knee Osteoarthritis. *The Clinical Journal of Pain*, *33*(2), 174–180. https://doi.org/10.1097/AJP.0000000000000378

Alanoğlu, E., Ulaş, U. H., Ozdağ, F., Odabaşi, Z., Cakçi, A., & Vural, O. (2005). Auditory event-related brain potentials in fibromyalgia syndrome. *Rheumatology International*, *25*(5), 345–349. https://doi.org/10.1007/s00296-004-0443-3

Alschuler, K. N., Molton, I. R., Jensen, M. P., & Riddle, D. L. (2013). Prognostic value of coping strategies in a community-based sample of persons with chronic symptomatic knee osteoarthritis. *Pain*, *154*(12), 2775–2781. https://doi.org/10.1016/j.pain.2013.08.012

Amris, K., Wæhrens, E. E., Jespersen, A., Bliddal, H., & Danneskiold-Samsøe, B. (2011). Observation-based assessment of functional ability in patients with chronic widespread pain: A cross-sectional study. *Pain*, *152*(11), 2470–2476. https://doi.org/10.1016/j.pain.2011.05.027

Andrew, R., Derry, S., Taylor, R. S., Straube, S., & Phillips, C. J. (2014). The Costs and Consequences of Adequately Managed Chronic Non-Cancer Pain and Chronic Neuropathic Pain. *Pain Practice*, *14*(1), 79–94. https://doi.org/10.1111/papr.12050

Antcliff, D., Keenan, A.-M., Keeley, P., Woby, S., & McGowan, L. (2021). Testing a newly developed activity pacing framework for chronic pain/fatigue: A feasibility study. *BMJ Open*, *11*(12), e045398. https://doi.org/10.1136/bmjopen-2020-045398

Apkarian, A. V., Bushnell, M. C., Treede, R.-D., & Zubieta, J.-K. (2005). Human brain mechanisms of pain perception and regulation in health and disease. *European Journal of Pain (London, England)*, *9*(4), 463–484. https://doi.org/10.1016/j.ejpain.2004.11.001

Apkarian, A. V., Sosa, Y., Krauss, B. R., Thomas, P. S., Fredrickson, B. E., Levy, R. E., Harden, R. N., & Chialvo, D. R. (2004). Chronic pain patients are impaired on an emotional decision-making task. *Pain*, *108*(1–2), 129–136. https://doi.org/10.1016/j.pain.2003.12.015

Asmundson, G. J. G., & Katz, J. (2009). Understanding the co-occurrence of anxiety disorders and chronic pain: State-of-the-art. *Depression and Anxiety*, *26*(10), 888–901. https://doi.org/10.1002/da.20600

Asmundson, G. J., Norton, P. J., & Norton, G. R. (1999). Beyond pain: The role of fear and avoidance in chronicity. *Clinical Psychology Review*, *19*(1), 97–119. https://doi.org/10.1016/s0272-7358(98)00034-8

Atlas, S. J., & Deyo, R. A. (2001). Evaluating and managing acute low back pain in the primary care setting. *Journal of General Internal Medicine*, *16*(2), 120–131. https://doi.org/10.1111/j.1525-1497.2001.91141.x

Attridge, N., Keogh, E., & Eccleston, C. (2016). The effect of pain on task switching: Pain reduces accuracy and increases reaction times across multiple switching paradigms. *Pain*, *157*(10), 2179–2193. https://doi.org/10.1097/j.pain.0000000000000627

Azevedo, L. F., Costa-Pereira, A., Mendonça, L., Dias, C. C., & Castro-Lopes, J. M. (2012). Epidemiology of chronic pain: A population-based nationwide study on its prevalence, characteristics and associated disability in Portugal. *The Journal of Pain*, *13*(8), 773–783. https://doi.org/10.1016/j.jpain.2012.05.012

Balagué, F., Mannion, A. F., Pellisé, F., & Cedraschi, C. (2012). Non-specific low back pain. *Lancet (London, England), 379*(9814), 482–491. https://doi.org/10.1016/S0140-6736(11)60610-7

Baykara, R. A., Bozgeyik, Z., Akgul, O., & Ozgocmen, S. (2013). Low back pain in patients with rheumatoid arthritis: Clinical characteristics and impact of low back pain on functional ability and health related quality of life. *Journal of Back and Musculoskeletal Rehabilitation*, *26*(4), 367–374. https://doi.org/10.3233/BMR-130393

Beissner, K., Henderson, C. R., Papaleontiou, M., Olkhovskaya, Y., Wigglesworth, J., & Reid, M. C. (2009). Physical therapists’ use of cognitive-behavioral therapy for older adults with chronic pain: A nationwide survey. *Physical Therapy*, *89*(5), 456–469. https://doi.org/10.2522/ptj.20080163

Berkley, K. J. (1997). Sex differences in pain. *Behavioral and Brain Sciences*, *20*(3), 371–380. https://doi.org/10.1017/S0140525X97221485

Birkholtz, M., Aylwin, L., & Harman, R. M. (2004). Activity Pacing in Chronic Pain Management: One Aim, but Which Method? Part One: Introduction and

Literature Review. *British Journal of Occupational Therapy*, *67*(10), 447–452. https://doi.org/10.1177/030802260406701005

Blay, S. L., Andreoli, S. B., Dewey, M. E., & Gastal, F. L. (2007). Co-occurrence of chronic physical pain and psychiatric morbidity in a community sample of older people. *International Journal of Geriatric Psychiatry*, *22*(9), 902–908. https://doi.org/10.1002/gps.1761

Boonen, A., van den Heuvel, R., van Tubergen, A., Goossens, M., Severens, J., van der Heijde, D., & van der Linden, S. (2005). Large differences in cost of illness and wellbeing between patients with fibromyalgia, chronic low back pain, or ankylosing spondylitis. *Annals of the Rheumatic Diseases*, *64*(3), 396–402. https://doi.org/10.1136/ard.2003.019711

Bornhövd, K., Quante, M., Glauche, V., Bromm, B., Weiller, C., & Büchel, C. (2002). Painful stimuli evoke different stimulus-response functions in the amygdala, prefrontal, insula and somatosensory cortex: A single-trial fMRI study. *Brain: A Journal of Neurology*, *125*(Pt 6), 1326–1336. https://doi.org/10.1093/brain/awf137

Bosma, F. K., & Kessels, R. P. C. (2002). Cognitive impairments, psychological dysfunction, and coping styles in patients with chronic whiplash syndrome. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, *15*(1), 56–65.

Breivik, H., Collett, B., Ventafridda, V., Cohen, R., & Gallacher, D. (2006). Survey of chronic pain in Europe: Prevalence, impact on daily life, and treatment. *European Journal of Pain*, *10*(4), 287–287. https://doi.org/10.1016/j.ejpain.2005.06.009

Brown, G. K., Nicassio, P. M., & Wallston, K. A. (1989). Pain coping strategies and depression in rheumatoid arthritis. *Journal of Consulting and Clinical Psychology*, *57*(5), 652–657. https://doi.org/10.1037//0022-006x.57.5.652

Brown, M. T., Bussell, J., Dutta, S., Davis, K., Strong, S., & Mathew, S. (2016). Medication Adherence: Truth and Consequences. *The American Journal of the Medical Sciences*, *351*(4), 387–399. https://doi.org/10.1016/j.amjms.2016.01.010

Brox, J. I., Storheim, K., Grotle, M., Tveito, T. H., Indahl, A., & Eriksen, H. R. (2008). Systematic review of back schools, brief education, and fear-avoidance training for chronic low back pain. *The Spine Journal: Official Journal of the North American Spine Society*, *8*(6), 948–958. https://doi.org/10.1016/j.spinee.2007.07.389

Buhle, J., & Wager, T. D. (2010). Performance-dependent inhibition of pain by an executive working memory task. *Pain*, *149*(1), 19–26. https://doi.org/10.1016/j.pain.2009.10.027

Burke, A. L. J., Mathias, J. L., & Denson, L. A. (2015). Psychological functioning of people living with chronic pain: A meta-analytic review. *The British Journal of Clinical Psychology*, *54*(3), 345–360. https://doi.org/10.1111/bjc.12078

Burke, A. L., Mathias, J. L., & Denson, L. A. (2020). Waiting for multidisciplinary chronic pain services: A prospective study over 2.5 years. *Journal of Health Psychology*, *25*(9), 1198–1212. https://doi.org/10.1177/1359105317752828

Butchart, A., Kerr, E. A., Heisler, M., Piette, J. D., & Krein, S. L. (2009). EXPERIENCE AND MANAGEMENT OF CHRONIC PAIN AMONG PATIENTS WITH

OTHER COMPLEX CHRONIC CONDITIONS. *The Clinical Journal of Pain*, *25*(4), 293–298. https://doi.org/10.1097/AJP.0b013e31818bf574

Campbell, C. M., Kronfli, T., Buenaver, L. F., Smith, M. T., Berna, C., Haythornthwaite, J. A., & Edwards, R. R. (2010). Situational versus dispositional measurement of catastrophizing: Associations with pain responses in multiple samples. *The Journal of Pain*, *11*(5), 443-453.e2. https://doi.org/10.1016/j.jpain.2009.08.009

Carey, T. S., Evans, A. T., Hadler, N. M., Lieberman, G., Kalsbeek, W. D., Jackman, A. M., Fryer, J. G., & McNutt, R. A. (1996). Acute severe low back pain. A population-based study of prevalence and care-seeking. *Spine*, *21*(3), 339–344. https://doi.org/10.1097/00007632-199602010-00018

Casiano, V. E., Sarwan, G., Dydyk, A. M., & Varacallo, M. (2022). Back Pain. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK538173/

Chen, Q., Hayman, L. L., Shmerling, R. H., Bean, J. F., & Leveille, S. G. (2011). Characteristics of chronic pain associated with sleep difficulty in older adults: The Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly (MOBILIZE) Boston study. *Journal of the American Geriatrics Society*, *59*(8), 1385–1392. https://doi.org/10.1111/j.1532-5415.2011.03544.x

Chenot, J.-F., Greitemann, B., Kladny, B., Petzke, F., Pfingsten, M., & Schorr, S. G. (2017). Non-Specific Low Back Pain. *Deutsches Arzteblatt International*, *114*(51–52), 883–890. https://doi.org/10.3238/arztebl.2017.0883

Cherry, D. K., Burt, C. W., & Woodwell, D. A. (2003). National Ambulatory Medical Care Survey: 2001 summary. *Advance Data*, *337*, 1–44.

Cho, S.-J., & Chu, M. K. (2015). Risk factors of chronic daily headache or chronic migraine. *Current Pain and Headache Reports*, *19*(1), 465. https://doi.org/10.1007/s11916-014-0465-9

Chou, R., Turner, J. A., Devine, E. B., Hansen, R. N., Sullivan, S. D., Blazina, I., Dana, T., Bougatsos, C., & Deyo, R. A. (2015). The Effectiveness and Risks of Long-Term Opioid Therapy for Chronic Pain: A Systematic Review for a National Institutes of Health Pathways to Prevention Workshop. *Annals of Internal Medicine*, *162*(4), 276–286. https://doi.org/10.7326/M14-2559

Closs, S. J., Staples, V., Reid, I., Bennett, M. I., & Briggs, M. (2009). The impact of neuropathic pain on relationships. *Journal of Advanced Nursing*, *65*(2), 402–411. https://doi.org/10.1111/j.1365-2648.2008.04892.x

Colpitts, Y. H., Mayeno, J. K., & Gagliardi, G. J. (1981). Rate of stimulus repetition changes evoked potential amplitude: Dental and auditory modalities compared. *Experimental Brain Research*, *43*(3), 246–252. https://doi.org/10.1007/BF00238365

Corbett, D. B., Simon, C. B., Manini, T. M., George, S. Z., Riley, J. L., & Fillingim, R. B. (2019). Movement-evoked pain: Transforming the way we understand and measure pain. *Pain*, *160*(4), 757–761. https://doi.org/10.1097/j.pain.0000000000001431

Corbett, M., Foster, N. E., & Ong, B. N. (2007). Living with low back pain-Stories of hope and despair. *Social Science & Medicine (1982)*, *65*(8), 1584–1594. https://doi.org/10.1016/j.socscimed.2007.06.008

Costa, L. da C. M., Maher, C. G., McAuley, J. H., Hancock, M. J., Herbert, R. D., Refshauge, K. M., & Henschke, N. (2009). Prognosis for patients with chronic low back pain: Inception cohort study. *BMJ (Clinical Research Ed.)*, *339*, b3829. https://doi.org/10.1136/bmj.b3829

Côté, P., Cassidy, J. D., & Carroll, L. (2001). The treatment of neck and low back pain: Who seeks care? who goes where? *Medical Care*, *39*(9), 956–967. https://doi.org/10.1097/00005650-200109000-00006

Covic, T., Adamson, B., & Hough, M. (2000). The impact of passive coping on rheumatoid arthritis pain. *Rheumatology (Oxford, England)*, *39*(9), 1027–1030. https://doi.org/10.1093/rheumatology/39.9.1027

Creavin, S. T., Dunn, K. M., Mallen, C. D., Nijrolder, I., & van der Windt, D. A. W. M. (2010). Co-occurrence and associations of pain and fatigue in a community sample of Dutch adults. *European Journal of Pain (London, England)*, *14*(3), 327–334. https://doi.org/10.1016/j.ejpain.2009.05.010

Crombez, G., Viane, I., Eccleston, C., Devulder, J., & Goubert, L. (2013). Attention to pain and fear of pain in patients with chronic pain. *Journal of Behavioral Medicine*, *36*(4), 371–378. https://doi.org/10.1007/s10865-012-9433-1

Crowe, M., Whitehead, L., Gagan, M. J., Baxter, G. D., Pankhurst, A., & Valledor, V. (2010). Listening to the body and talking to myself - the impact of chronic lower back pain: A qualitative study. *International Journal of Nursing Studies*, *47*(5), 586–592. https://doi.org/10.1016/j.ijnurstu.2009.09.012

Cruz-Almeida, Y., Cardoso, J., Riley, J. L., Goodin, B., King, C. D., Petrov, M., Bartley, E. J., Sibille, K. T., Glover, T. L., Herbert, M. S., Bulls, H. W., Addison, A., Staud, R., Redden, D., Bradley, L. A., & Fillingim, R. B. (2017). Physical performance and movement-evoked pain profiles in community-dwelling individuals at risk for knee osteoarthritis. *Experimental Gerontology*, *98*, 186–191. https://doi.org/10.1016/j.exger.2017.08.026

da Silva, T., Mills, K., Brown, B. T., Herbert, R. D., Maher, C. G., & Hancock, M. J. (2017). Risk of Recurrence of Low Back Pain: A Systematic Review. *The Journal of Orthopaedic and Sports Physical Therapy*, *47*(5), 305–313. https://doi.org/10.2519/jospt.2017.7415

Dahlhamer, J. (2018). Prevalence of Chronic Pain and High-Impact Chronic Pain Among Adults—United States, 2016. *MMWR. Morbidity and Mortality Weekly Report*, *67*. https://doi.org/10.15585/mmwr.mm6736a2

Daneshjou, K., Jafarieh, H., & Raaeskarami, S.-R. (2012). Congenital Insensitivity to Pain and Anhydrosis (CIPA) Syndrome; A Report of 4 Cases. *Iranian Journal of Pediatrics*, *22*(3), 412–416.

Davenport, P. J., O'Connor, S. J., Szychowski, J. M., Landry, A. Y., & Hernandez, S. R. (2017). The relationship between emergency department wait times and inpatient satisfaction. *Health Marketing Quarterly*, *34*(2), 97–112. https://doi.org/10.1080/07359683.2017.1307066

Davis, T. C., Federman, A. D., Bass, P. F., Jackson, R. H., Middlebrooks, M., Parker, R. M., & Wolf, M. S. (2009). Improving Patient Understanding of Prescription Drug Label Instructions. *Journal of General Internal Medicine*, *24*(1), 57–62. https://doi.org/10.1007/s11606-008-0833-4

Demyttenaere, K., Bruffaerts, R., Lee, S., Posada-Villa, J., Kovess, V., Angermeyer, M. C., Levinson, D., de Girolamo, G., Nakane, H., Mneimneh, Z., Lara, C., de Graaf, R., Scott, K. M., Gureje, O., Stein, D. J., Haro, J. M., Bromet, E. J., Kessler, R. C., Alonso, J., & Von Korff, M. (2007). Mental disorders among persons with chronic back or neck pain: Results from the World Mental Health Surveys. *Pain*, *129*(3), 332–342. https://doi.org/10.1016/j.pain.2007.01.022

Deyo, R. A., Dworkin, S. F., Amtmann, D., Andersson, G., Borenstein, D., Carragee, E., Carrino, J., Chou, R., Cook, K., DeLitto, A., Goertz, C., Khalsa, P., Loeser, J., Mackey, S., Panagis, J., Rainville, J., Tosteson, T., Turk, D., Von Korff, M., & Weiner, D. K. (2014). Report of the NIH Task Force on Research Standards for Chronic Low Back Pain. *The Journal of Pain*, *15*(6), 569–585. https://doi.org/10.1016/j.jpain.2014.03.005

Deyo, R. A., Mirza, S. K., & Martin, B. I. (2006). Back Pain Prevalence and Visit Rates: Estimates From U.S. National Surveys, 2002. *Spine*, *31*(23), 2724–2727. https://doi.org/10.1097/01.brs.0000244618.06877.cd

Deyo, R. A., Mirza, S. K., Turner, J. A., & Martin, B. I. (2009). Overtreating Chronic Back Pain: Time to Back Off? *Journal of the American Board of Family Medicine : JABFM*, *22*(1), 62–68. https://doi.org/10.3122/jabfm.2009.01.080102

Dick, B. D., Verrier, M. J., Harker, T. K., & Rashiq, S. (2008). Disruption of cognitive function in fibromyalgia syndrome. *Pain*, *139*(3), 610–616. https://doi.org/10.1016/j.pain.2008.06.017

Dong, H.-J., Larsson, B., Levin, L.-Å., Bernfort, L., & Gerdle, B. (2018). Is excess weight a burden for older adults who suffer chronic pain? *BMC Geriatrics*, *18*(1), 270. https://doi.org/10.1186/s12877-018-0963-4

Dow, C. M., Roche, P. A., & Ziebland, S. (2012). Talk of frustration in the narratives of people with chronic pain. *Chronic Illness*, *8*(3), 176–191. https://doi.org/10.1177/1742395312443692

Dowell, D., Haegerich, T., & Chou, R. (2016). CDC Guideline for Prescribing Opioids for Chronic Pain—United States, 2016. *MMWR. Recommendations and Reports*, *65*. https://doi.org/10.15585/mmwr.rr6501e1er

Downar, J., Mikulis, D. J., & Davis, K. D. (2003). Neural correlates of the prolonged salience of painful stimulation. *NeuroImage*, *20*(3), 1540–1551. https://doi.org/10.1016/S1053-8119(03)00407-5

Dreisinger, T. E. (2014). Exercise in the Management of Chronic Back Pain. *The Ochsner Journal*, *14*(1), 101–107.

Droit-Volet, S. (2013). Time perception, emotions and mood disorders. *Journal of Physiology, Paris*, *107*(4), 255–264. https://doi.org/10.1016/j.jphysparis.2013.03.005

Droit-Volet, S., & Meck, W. H. (2007). How emotions colour our perception of time. *Trends in Cognitive Sciences*, *11*(12), 504–513. https://doi.org/10.1016/j.tics.2007.09.008

Dufton, B. D. (1989). Cognitive failure and chronic pain. *International Journal of Psychiatry in Medicine*, *19*(3), 291–297. https://doi.org/10.2190/JDJK-0795-5BFL-5N6K

Dunn, L. K., Durieux, M. E., Fernández, L. G., Tsang, S., Smith-Straesser, E. E., Jhaveri, H. F., Spanos, S. P., Thames, M. R., Spencer, C. D., Lloyd, A., Stuart, R., Ye, F., Bray, J. P., Nemergut, E. C., & Naik, B. I. (2018). Influence of catastrophizing, anxiety, and depression on in-hospital opioid consumption, pain, and quality of recovery after adult spine surgery. *Journal of Neurosurgery. Spine*, *28*(1), 119–126. https://doi.org/10.3171/2017.5.SPINE1734

Eccleston, C. (1994). Chronic pain and attention: A cognitive approach. *The British Journal of Clinical Psychology*, *33*(4), 535–547. https://doi.org/10.1111/j.2044-8260.1994.tb01150.x

Eccleston, C., & Crombez, G. (1999). Pain demands attention: A cognitive–affective model of the interruptive function of pain. *Psychological Bulletin*, *125*(3), 356–366. https://doi.org/10.1037/0033-2909.125.3.356

Edwards, R. R., Cahalan, C., Calahan, C., Mensing, G., Smith, M., & Haythornthwaite, J. A. (2011). Pain, catastrophizing, and depression in the rheumatic diseases. *Nature Reviews. Rheumatology*, *7*(4), 216–224. https://doi.org/10.1038/nrrheum.2011.2

Eggermont, L. H. P., Penninx, B. W. J. H., Jones, R. N., & Leveille, S. G. (2012). Depressive symptoms, chronic pain, and falls in older community-dwelling adults: The MOBILIZE Boston Study. *Journal of the American Geriatrics Society*, *60*(2), 230–237. https://doi.org/10.1111/j.1532-5415.2011.03829.x

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion*, *6*(3–4), 169–200. https://doi.org/10.1080/02699939208411068

Elman, I., & Borsook, D. (2016). Common Brain Mechanisms of Chronic Pain and Addiction. *Neuron*, *89*(1), 11–36. https://doi.org/10.1016/j.neuron.2015.11.027

Emerson, K., Boggero, I., Ostir, G., & Jayawardhana, J. (2018). Pain as a Risk Factor for Loneliness Among Older Adults. *Journal of Aging and Health*, *30*(9), 1450–1461. https://doi.org/10.1177/0898264317721348

Ferreira-Valente, A., Queiroz-Garcia, I., Pais-Ribeiro, J., & Jensen, M. P. (2020). <p>Pain Diagnosis, Pain Coping, and Function in Individuals with Chronic Musculoskeletal Pain</p>. *Journal of Pain Research*, *13*, 783–794. https://doi.org/10.2147/JPR.S236157

Fichtel, A., & Larsson, B. (2002). Psychosocial impact of headache and comorbidity with other pains among Swedish school adolescents. *Headache*, *42*(8), 766–775. https://doi.org/10.1046/j.1526-4610.2002.02178.x

Fields, H. L. (2000). Chapter 18 - Pain modulation: Expectation, opioid analgesia and virtual pain. In E. A. Mayer & C. B. Saper (Eds.), *Progress in Brain Research* (Vol. 122, pp. 245–253). Elsevier. https://doi.org/10.1016/S0079-6123(08)62143-3

Fillingim, R. B. (2017). Individual differences in pain: Understanding the mosaic that makes pain personal. *PAIN*, *159*. https://doi.org/10.1097/j.pain.0000000000000775

Forgeron, P. A., King, S., Stinson, J. N., McGrath, P. J., MacDonald, A. J., & Chambers, C. T. (2010). Social functioning and peer relationships in children and adolescents with chronic pain: A systematic review. *Pain Research & Management*, *15*(1), 27–41. https://doi.org/10.1155/2010/820407

Gan, T., Wang, N., Zhang, Z., Li, H., & Luo, Y. (2009). Emotional influences on time perception: Evidence from event-related potentials. *Neuroreport*, *20*(9), 839–843. https://doi.org/10.1097/WNR.0b013e32832be7dc

Gatchel, R. J., Peng, Y. B., Peters, M. L., Fuchs, P. N., & Turk, D. C. (2007). The biopsychosocial approach to chronic pain: Scientific advances and future directions. *Psychological Bulletin*, *133*(4), 581–624. https://doi.org/10.1037/0033-2909.133.4.581

Gibbon, J. (1977). Scalar expectancy theory and Weber's law in animal timing. *Psychological Review*, *84*(3), 279–325. https://doi.org/10.1037/0033-295X.84.3.279

Gibbon, J., Church, R. M., & Meck, W. H. (1984). Scalar timing in memory. *Annals of the New York Academy of Sciences*, *423*, 52–77. https://doi.org/10.1111/j.1749-6632.1984.tb23417.x

Gil, S., & Droit-Volet, S. (2011). “Time flies in the presence of angry faces”… depending on the temporal task used! *Acta Psychologica*, *136*(3), 354–362. https://doi.org/10.1016/j.actpsy.2010.12.010

Goudsmit, E. M., Nijs, J., Jason, L. A., & Wallman, K. E. (2012). Pacing as a strategy to improve energy management in myalgic encephalomyelitis/chronic fatigue syndrome: A consensus document. *Disability and Rehabilitation*, *34*(13), 1140–1147. https://doi.org/10.3109/09638288.2011.635746

Grol-Prokopczyk, H. (2017). Sociodemographic disparities in chronic pain, based on 12-year longitudinal data. *Pain*, *158*(2), 313–322. https://doi.org/10.1097/j.pain.0000000000000762

Gureje, O., Von Korff, M., Simon, G. E., & Gater, R. (1998). Persistent pain and well-being: A World Health Organization Study in Primary Care. *JAMA*, *280*(2), 147–151. https://doi.org/10.1001/jama.280.2.147

Haldeman, S., & Dagenais, S. (2008). What have we learned about the evidence-informed management of chronic low back pain? *The Spine Journal: Official Journal of the North American Spine Society*, *8*(1), 266–277. https://doi.org/10.1016/j.spinee.2007.10.026

Hardt, J., Jacobsen, C., Goldberg, J., Nickel, R., & Buchwald, D. (2008). Prevalence of Chronic Pain in a Representative Sample in the United States. *Pain Medicine*, *9*(7), 803–812. https://doi.org/10.1111/j.1526-4637.2008.00425.x

Harman, K., & Ruyak, P. (2005). Working Through the Pain: A Controlled Study of the Impact of Persistent Pain on Performing a Computer Task. *The Clinical Journal of Pain*, *21*(3), 216–222. https://doi.org/10.1097/00002508-200505000-00004

Hartvigsen, J., Hancock, M. J., Kongsted, A., Louw, Q., Ferreira, M. L., Genevay, S., Hoy, D., Karppinen, J., Pransky, G., Sieper, J., Smeets, R. J., Underwood, M., & Lancet Low Back Pain Series Working Group. (2018). What low back pain is and why we need to pay attention. *Lancet (London, England)*, *391*(10137), 2356–2367. https://doi.org/10.1016/S0140-6736(18)30480-X

Hellström, C., & Carlsson, S. g. (1997). Busy with pain: Disorganization in subjective time in experimental pain. *European Journal of Pain*, *1*(2), 133–139. https://doi.org/10.1016/S1090-3801(97)90071-9

Heuch, I., & Foss, I. S. (2013). Acute low back usually resolves quickly but persistent low back pain often persists. *Journal of Physiotherapy*, *59*(2), 127. https://doi.org/10.1016/S1836-9553(13)70166-8

Hogg, M. N., Kavanagh, A., Farrell, M. J., & Burke, A. L. J. (2021). Waiting in Pain II: An Updated Review of the Provision of Persistent Pain Services in Australia. *Pain Medicine*, *22*(6), 1367–1375. https://doi.org/10.1093/pm/pnaa374

Holloway, I., Sofaer-Bennett, B., & Walker, J. (2007). The stigmatisation of people with chronic back pain. *Disability and Rehabilitation*, *29*(18), 1456–1464. https://doi.org/10.1080/09638280601107260

Holmes, J. A., & Stevenson, C. A. (1990). Differential effects of avoidant and attentional coping strategies on adaptation to chronic and recent-onset pain. *Health Psychology*, *9*(5), 577–584. https://doi.org/10.1037/0278-6133.9.5.577

Howe, C. Q., Robinson, J. P., & Sullivan, M. D. (2015). Psychiatric and psychological perspectives on chronic pain. *Physical Medicine and Rehabilitation Clinics of North America*, *26*(2), 283–300. https://doi.org/10.1016/j.pmr.2014.12.003

Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., Blyth, F., Woolf, A., Vos, T., & Buchbinder, R. (2012). A systematic review of the global prevalence of low back pain. *Arthritis & Rheumatism*, *64*(6), 2028–2037. https://doi.org/10.1002/art.34347

Hoy, D., March, L., Brooks, P., Blyth, F., Woolf, A., Bain, C., Williams, G., Smith, E., Vos, T., Barendregt, J., Murray, C., Burstein, R., & Buchbinder, R. (2014). The global burden of low back pain: Estimates from the Global Burden of Disease 2010 study. *Annals of the Rheumatic Diseases*, *73*(6), 968–974. https://doi.org/10.1136/annrheumdis-2013-204428

Hylands-White, N., Duarte, R. V., & Raphael, J. H. (2017). An overview of treatment approaches for chronic pain management. *Rheumatology International*, *37*(1), 29–42. https://doi.org/10.1007/s00296-016-3481-8

Indovina, P., Barone, D., Gallo, L., Chirico, A., De Pietro, G., & Giordano, A. (2018). Virtual Reality as a Distraction Intervention to Relieve Pain and Distress During Medical Procedures: A Comprehensive Literature Review. *The Clinical Journal of Pain*, *34*(9), 858–877. https://doi.org/10.1097/AJP.0000000000000599

Institute of Medicine (US) Committee on Advancing Pain Research, Care, and Education. (2011). *Relieving Pain in America: A Blueprint for Transforming Prevention, Care, Education, and Research*. National Academies Press (US). http://www.ncbi.nlm.nih.gov/books/NBK91497/

IsHak, W. W., Wen, R. Y., Naghdechi, L., Vanle, B., Dang, J., Knosp, M., Dascal, J., Marcia, L., Gohar, Y., Eskander, L., Yadegar, J., Hanna, S., Sadek, A., Aguilar-Hernandez, L., Danovitch, I., & Louy, C. (2018). Pain and Depression: A Systematic Review. *Harvard Review of Psychiatry*, *26*(6), 352–363. https://doi.org/10.1097/HRP.0000000000000198

Jacobs, J. M., Hammerman-Rozenberg, R., Cohen, A., & Stessman, J. (2006). Chronic back pain among the elderly: Prevalence, associations, and predictors. *Spine*, *31*(7), E203-207. https://doi.org/10.1097/01.brs.0000206367.57918.3c

Jakobsson, U. (2006). A literature review on fatigue among older people in pain: Prevalence and predictors. *International Journal of Older People Nursing*, *1*(1), 11–16. https://doi.org/10.1111/j.1748-3743.2006.00004.x

Jamieson-Lega, K., Berry, R., & Brown, C. A. (2013). Pacing: A concept analysis of the chronic pain intervention. *Pain Research & Management*, *18*(4), 207–213. https://doi.org/10.1155/2013/686179

Jamison, R. N., Link, C. L., & Marceau, L. D. (2009). Do pain patients at high risk for substance misuse experience more pain? A longitudinal outcomes study. *Pain Medicine (Malden, Mass.)*, *10*(6), 1084–1094. https://doi.org/10.1111/j.1526-4637.2009.00679.x

Jamison, R. N., Sbrocco, T., & Parris, W. C. (1988). The influence of problems with concentration and memory on emotional distress and daily activities in chronic pain patients. *International Journal of Psychiatry in Medicine*, *18*(2), 183–191. https://doi.org/10.2190/ftr1-f9vx-cb8t-wpmc

Jaremka, L. M., Andridge, R. R., Fagundes, C. P., Alfano, C. M., Povoski, S. P., Lipari, A. M., Agnese, D. M., Arnold, M. W., Farrar, W. B., Yee, L. D., Carson, W. E., Bekaii-Saab, T., Martin, E. W., Schmidt, C. R., & Kiecolt-Glaser, J. K. (2014). Pain, depression, and fatigue: Loneliness as a longitudinal risk factor. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, *33*(9), 948–957. https://doi.org/10.1037/a0034012

Jensen, M. P., & Karoly, P. (1991). Control beliefs, coping efforts, and adjustment to chronic pain. *Journal of Consulting and Clinical Psychology*, *59*(3), 431–438. https://doi.org/10.1037//0022-006x.59.3.431

Jensen, M. P., & Karoly, P. (2011). Self-report scales and procedures for assessing pain in adults. In *Handbook of pain assessment, 3rd ed* (pp. 19–44). The Guilford Press.

Jensen, M. P., Keefe, F. J., Lefebvre, J. C., Romano, J. M., & Turner, J. A. (2003). One- and two-item measures of pain beliefs and coping strategies. *Pain*, *104*(3), 453–469. https://doi.org/10.1016/S0304-3959(03)00076-9

Jensen, M. P., & Turk, D. C. (2014). Contributions of psychology to the understanding and treatment of people with chronic pain: Why it matters to ALL psychologists. *American Psychologist*, *69*(2), 105–118. https://doi.org/10.1037/a0035641

Jensen, M. P., Turner, J. A., Romano, J. M., & Karoly, P. (1991). Coping with chronic pain: A critical review of the literature. *Pain*, *47*(3), 249–283. https://doi.org/10.1016/0304-3959(91)90216-K

Jensen, T., & Gebhart, G. F. (2008). *New pain terminology: A work in progress*. https://journals-lww-com.ezproxy.bu.edu/pain/Fulltext/2008/12000/New_pain_terminology__A_work_in_progress.3.aspx

Jones, L. A., Poliakoff, E., & Wells, J. (2009). Good vibrations: Human interval timing in the vibrotactile modality. *Quarterly Journal of Experimental Psychology (2006)*, *62*(11), 2171–2186. https://doi.org/10.1080/17470210902782200

Juth, P., Lundqvist, D., Karlsson, A., & Ohman, A. (2005). Looking for foes and friends: Perceptual and emotional factors when finding a face in the crowd. *Emotion (Washington, D.C.)*, *5*(4), 379–395. https://doi.org/10.1037/1528-3542.5.4.379

Kapoor, S., White, J., Thorn, B. E., & Block, P. (2016). Patients Presenting to the Emergency Department with Acute Pain: The Significant Role of Pain Catastrophizing and State Anxiety. *Pain Medicine (Malden, Mass.)*, *17*(6), 1069–1078. https://doi.org/10.1093/pm/pnv034

Karp, J. F., Reynolds, C. F., Butters, M. A., Dew, M. A., Mazumdar, S., Begley, A. E., Lenze, E., & Weiner, D. K. (2006). The relationship between pain and mental flexibility in older adult pain clinic patients. *Pain Medicine (Malden, Mass.)*, *7*(5), 444–452. https://doi.org/10.1111/j.1526-4637.2006.00212.x

Kashikar-Zuck, S., Goldschneider, K. R., Powers, S. W., Vaught, M. H., & Hershey, A. D. (2001). Depression and functional disability in chronic pediatric pain. *The Clinical Journal of Pain*, *17*(4), 341–349. https://doi.org/10.1097/00002508-200112000-00009

Keefe, F. J., Rumble, M. E., Scipio, C. D., Giordano, L. A., & Perri, L. M. (2004). Psychological aspects of persistent pain: Current state of the science. *The Journal of Pain*, *5*(4), 195–211. https://doi.org/10.1016/j.jpain.2004.02.576

Kewman, D. G., Vaishampayan, N., Zald, D., & Han, B. (1991). Cognitive impairment in musculoskeletal pain patients. *International Journal of Psychiatry in Medicine*, *21*(3), 253–262. https://doi.org/10.2190/FRYK-TMGA-AULW-BM5G

Koes, B. W., van Tulder, M. W., & Thomas, S. (2006). Diagnosis and treatment of low back pain. *BMJ (Clinical Research Ed.)*, *332*(7555), 1430–1434. https://doi.org/10.1136/bmj.332.7555.1430

Koestler, A. J., & Myers, A. (2002). *Understanding Chronic Pain*. Univ. Press of Mississippi.

Kraaimaat, F. W., & Evers, A. W. M. (2003). Pain-coping strategies in chronic pain patients: Psychometric characteristics of the pain-coping inventory (PCI). *International Journal of Behavioral Medicine*, *10*(4), 343–363. https://doi.org/10.1207/s15327558ijbm1004_5

Krismer, M., & Tulder, M. (2007). The Low Back Pain Group of the Bone and Joint Health Strategies for Europe Project. Strategies for prevention and management of musculoskeletal conditions. Low back pain (non-specific). *Best Practice &*

Research. Clinical Rheumatology, *21*, 77–91. https://doi.org/10.1016/j.berh.2006.08.004

Kuner, R. (2010). Central mechanisms of pathological pain. *Nature Medicine*, *16*(11), 1258–1266. https://doi.org/10.1038/nm.2231

Langley, P. C., Ruiz-Iban, M. A., Molina, J. T., De Andres, J., & Castellón, J. R. G.-E. (2011). The prevalence, correlates and treatment of pain in Spain. *Journal of Medical Economics*, *14*(3), 367–380. https://doi.org/10.3111/13696998.2011.583303

Lawlor, P. G. (2002). The panorama of opioid-related cognitive dysfunction in patients with cancer: A critical literature appraisal. *Cancer*, *94*(6), 1836–1853. https://doi.org/10.1002/cncr.10389

Leavitt, F., & Katz, R. S. (2006). Distraction as a key determinant of impaired memory in patients with fibromyalgia. *The Journal of Rheumatology*, *33*(1), 127–132.

Lee, M., & Tracey, I. (2013). Neuro-genetics of persistent pain. *Current Opinion in Neurobiology*, *23*(1), 127–132. https://doi.org/10.1016/j.conb.2012.11.007

Leeuw, M., Goossens, M. E. J. B., Linton, S. J., Crombez, G., Boersma, K., & Vlaeyen, J. W. S. (2007). The fear-avoidance model of musculoskeletal pain: Current state of scientific evidence. *Journal of Behavioral Medicine*, *30*(1), 77–94. https://doi.org/10.1007/s10865-006-9085-0

Legrain, V., Damme, S. V., Eccleston, C., Davis, K. D., Seminowicz, D. A., & Crombez, G. (2009). A neurocognitive model of attention to pain: Behavioral and neuroimaging evidence. *Pain*, *144*(3), 230–232. https://doi.org/10.1016/j.pain.2009.03.020

Lerman, S. F., Rudich, Z., Brill, S., Shalev, H., & Shahar, G. (2015). Longitudinal associations between depression, anxiety, pain, and pain-related disability in chronic pain patients. *Psychosomatic Medicine*, *77*(3), 333–341. https://doi.org/10.1097/PSY.0000000000000158

Li, J., Chen, J., Qin, Q., Zhao, D., Dong, B., Ren, Q., Yu, D., Bi, P., & Sun, Y. (2018). Chronic pain and its association with obesity among older adults in China. *Archives of Gerontology and Geriatrics*, *76*, 12–18. https://doi.org/10.1016/j.archger.2018.01.009

Liao, Z. T., Pan, Y. F., Huang, J. L., Huang, F., Chi, W. J., Zhang, K. X., Lin, Z. M., Wu, Y. Q., He, W. Z., Wu, J., Xie, X. J., Huang, J. X., Wei, Q. J., Li, T. W., Wu, Z., Yu, B. Y., & Gu, J. R. (2009). An epidemiological survey of low back pain and axial spondyloarthritis in a Chinese Han population. *Scandinavian Journal of Rheumatology*, *38*(6), 455–459. https://doi.org/10.3109/03009740902978085

Liddy, C., Poulin, P. A., Hunter, Z., Smyth, C., & Keely, E. (2017). Patient perspectives on wait times and the impact on their life: A waiting room survey in a chronic pain clinic. *Scandinavian Journal of Pain*, *17*(1), 53–57. https://doi.org/10.1016/j.sjpain.2017.07.015

Liebschutz, J. M., Saitz, R., Weiss, R. D., Averbuch, T., Schwartz, S., Meltzer, E. C., Claggett-Borne, E., Cabral, H., & Samet, J. H. (2010). Clinical factors associated with prescription drug use disorder in urban primary care patients with chronic pain. *The Journal of Pain*, *11*(11), 1047–1055. https://doi.org/10.1016/j.jpain.2009.10.012

Linton, S. J., Nicholas, M. K., MacDonald, S., Boersma, K., Bergbom, S., Maher, C., & Refshauge, K. (2011). The role of depression and catastrophizing in musculoskeletal pain. *European Journal of Pain (London, England)*, *15*(4), 416–422. https://doi.org/10.1016/j.ejpain.2010.08.009

Liu, M., McCurry, S. M., Belza, B., Dobra, A., Buchanan, D. T., Vitiello, M. V., & Von Korff, M. (2019). Effects of Osteoarthritis Pain and Concurrent Insomnia and Depression on Health Care Use in a Primary Care Population of Older Adults. *Arthritis Care & Research*, *71*(6), 748–757. https://doi.org/10.1002/acr.23695

Loisel, P., Lemaire, J., Poitras, S., Durand, M.-J., Champagne, F., Stock, S., Diallo, B., & Tremblay, C. (2002). Cost-benefit and cost-effectiveness analysis of a disability prevention model for back pain management: A six year follow up study. *Occupational and Environmental Medicine*, *59*(12), 807–815. https://doi.org/10.1136/oem.59.12.807

Luerding, R., Weigand, T., Bogdahn, U., & Schmidt-Wilcke, T. (2008). Working memory performance is correlated with local brain morphology in the medial frontal and anterior cingulate cortex in fibromyalgia patients: Structural correlates of pain-cognition interaction. *Brain: A Journal of Neurology*, *131*(Pt 12), 3222–3231. https://doi.org/10.1093/brain/awn229

Lui, M. A., Penney, T. B., & Schirmer, A. (2011). Emotion Effects on Timing: Attention versus Pacemaker Accounts. *PLOS ONE*, *6*(7), e21829. https://doi.org/10.1371/journal.pone.0021829

Luo, X., Pietrobon, R., Sun, S. X., Liu, G. G., & Hey, L. (2004). Estimates and patterns of direct health care expenditures among individuals with back pain in the United States. *Spine*, *29*(1), 79–86. https://doi.org/10.1097/01.BRS.0000105527.13866.0F

Maher, C., Underwood, M., & Buchbinder, R. (2017). Non-specific low back pain. *Lancet (London, England)*, *389*(10070), 736–747. https://doi.org/10.1016/S0140-6736(16)30970-9

Malanga, G., & Wolff, E. (2008). Evidence-informed management of chronic low back pain with nonsteroidal anti-inflammatory drugs, muscle relaxants, and simple analgesics. *The Spine Journal*, *8*(1), 173–184. https://doi.org/10.1016/j.spinee.2007.10.013

Mansfield, K. E., Sim, J., Jordan, J. L., & Jordan, K. P. (2016). A systematic review and meta-analysis of the prevalence of chronic widespread pain in the general population. *Pain*, *157*(1), 55–64. https://doi.org/10.1097/j.pain.0000000000000314

Marshall, P. W. M., Schabrun, S., & Knox, M. F. (2017). Physical activity and the mediating effect of fear, depression, anxiety, and catastrophizing on pain related disability in people with chronic low back pain. *PLOS ONE*, *12*(7), e0180788. https://doi.org/10.1371/journal.pone.0180788

Marttinen, M. K., Kautiainen, H., Haanpää, M., Pohjankoski, H., Vuorimaa, H., Hintikka, J., & Kauppi, M. J. (2019). Pain-related factors in older adults. *Scandinavian Journal of Pain*, *19*(4), 797–803. https://doi.org/10.1515/sjpain-2019-0039

McBeth, J., Nicholl, B. I., Cordingley, L., Davies, K. A., & Macfarlane, G. J. (2010). Chronic widespread pain predicts physical inactivity: Results from the prospective EPIFUND study. *European Journal of Pain (London, England)*, *14*(9), 972–979. https://doi.org/10.1016/j.ejpain.2010.03.005

McCaul, K. D., & Malott, J. M. (1984). Distraction and coping with pain. *Psychological Bulletin*, *95*(3), 516–533.

McCracken, L. M., & Iverson, G. L. (2001). Predicting complaints of impaired cognitive functioning in patients with chronic pain. *Journal of Pain and Symptom Management*, *21*(5), 392–396. https://doi.org/10.1016/s0885-3924(01)00267-6

Meck, W. H., Penney, T. B., & Pouthas, V. (2008). Cortico-striatal representation of time in animals and humans. *Current Opinion in Neurobiology*, *18*(2), 145–152. https://doi.org/10.1016/j.conb.2008.08.002

Melloh, M., Röder, C., Elfering, A., Theis, J.-C., Müller, U., Staub, L. P., Aghayev, E., Zweig, T., Barz, T., Kohlmann, T., Wieser, S., Jüni, P., & Zwahlen, M. (2008). Differences across health care systems in outcome and cost-utility of surgical and conservative treatment of chronic low back pain: A study protocol. *BMC Musculoskeletal Disorders*, *9*, 81. https://doi.org/10.1186/1471-2474-9-81

Miaskowski, C., Blyth, F., Nicosia, F., Haan, M., Keefe, F., Smith, A., & Ritchie, C. (2020). *Biopsychosocial Model of Chronic Pain for Older Adults*.

https://academic-oup-com.ezproxy.bu.edu/painmedicine/article/21/9/1793/5679926

Miron, D., Duncan, G. H., & Bushnell, C. M. (1989). Effects of attention on the intensity and unpleasantness of thermal pain. *PAIN*, *39*(3), 345–352. https://doi.org/10.1016/0304-3959(89)90048-1

Mirsky, A. F., Anthony, B. J., Duncan, C. C., Ahearn, M. B., & Kellam, S. G. (1991). Analysis of the elements of attention: A neuropsychological approach. *Neuropsychology Review*, *2*(2), 109–145. https://doi.org/10.1007/BF01109051

Mogil, J. S., & Bailey, A. L. (2010). Chapter 9—Sex and gender differences in pain and analgesia. In I. Savic (Ed.), *Progress in Brain Research* (Vol. 186, pp. 140–157). Elsevier. https://doi.org/10.1016/B978-0-444-53630-3.00009-9

Moore, D. J., Meints, S. M., Lazaridou, A., Johnson, D., Franceschelli, O., Cornelius, M., Schreiber, K., & Edwards, Robert. R. (2019). The Effect of Induced and Chronic Pain on Attention. *The Journal of Pain*, *20*(11), 1353–1361. https://doi.org/10.1016/j.jpain.2019.05.004

Moriarty, O., McGuire, B. E., & Finn, D. P. (2011). The effect of pain on cognitive function: A review of clinical and preclinical research. *Progress in Neurobiology*, *93*(3), 385–404. https://doi.org/10.1016/j.pneurobio.2011.01.002

Morlion, B. (2013). Chronic low back pain: Pharmacological, interventional and surgical strategies. *Nature Reviews. Neurology*, *9*(8), 462–473. https://doi.org/10.1038/nrneurol.2013.130

Mortensen, J., Kristensen, L. Q., Brooks, E. P., & Brooks, A. L. (2015). Women with fibromyalgia's experience with three motion-controlled video game consoles and indicators of symptom severity and performance of activities of daily living. *Disability and Rehabilitation. Assistive Technology*, *10*(1), 61–66. https://doi.org/10.3109/17483107.2013.836687

Mouraux, A., Diukova, A., Lee, M. C., Wise, R. G., & Iannetti, G. D. (2011). A multisensory investigation of the functional significance of the "pain matrix." *NeuroImage*, *54*(3), 2237–2249. https://doi.org/10.1016/j.neuroimage.2010.09.084

Mouraux, A., & Iannetti, G. D. (2009). *Nociceptive Laser-Evoked Brain Potentials Do Not Reflect Nociceptive-Specific Neural Activity*. https://journals.physiology.org/doi/full/10.1152/jn.91181.2008

Mouraux, A., & Iannetti, G. D. (2018). *The search for pain biomarkers in the human brain*. https://academic.oup.com/brain/article/141/12/3290/5194498

Muñoz, M., & Esteve, R. (2005). Reports of memory functioning by patients with chronic pain. *The Clinical Journal of Pain*, *21*(4), 287–291. https://doi.org/10.1097/01.ajp.0000173993.53733.2e

Nafziger, A. N., & Barkin, R. L. (2018). Opioid Therapy in Acute and Chronic Pain. *The Journal of Clinical Pharmacology*, *58*(9), 1111–1122. https://doi.org/10.1002/jcph.1276

Narayanan, V. (1996). Oral and maxillofacial manifestations of hereditary sensory neuropathy. *The British Journal of Oral & Maxillofacial Surgery*, *34*(5), 446–449. https://doi.org/10.1016/s0266-4356(96)90105-9

Navratilova, E., Morimura, K., Xie, J. Y., Atcherley, C. W., Ossipov, M. H., & Porreca, F. (2016). Positive emotions and brain reward circuits in chronic pain. *The Journal of Comparative Neurology*, *524*(8), 1646–1652. https://doi.org/10.1002/cne.23968

Nicholas, M. K., Linton, S. J., Watson, P. J., Main, C. J., & "Decade of the Flags" Working Group. (2011). Early identification and management of psychological risk factors ("yellow flags") in patients with low back pain: A reappraisal. *Physical Therapy*, *91*(5), 737–753. https://doi.org/10.2522/ptj.20100224

Ogden, R. S., Moore, D., Redfern, L., & McGlone, F. (2015a). The effect of pain and the anticipation of pain on temporal perception: A role for attention and arousal. *Cognition & Emotion*, *29*(5), 910–922. https://doi.org/10.1080/02699931.2014.954529

Ogden, R. S., Moore, D., Redfern, L., & McGlone, F. (2015b). The effect of pain and the anticipation of pain on temporal perception: A role for attention and arousal. *Cognition and Emotion*, *29*(5), 910–922. https://doi.org/10.1080/02699931.2014.954529

Ojala, T., Häkkinen, A., Karppinen, J., Sipilä, K., Suutama, T., & Piirainen, A. (2014). The Dominance of Chronic Pain: A Phenomenological Study. *Musculoskeletal Care*, *12*(3), 141–149. https://doi.org/10.1002/msc.1066

Ojeda, B., Salazar, A., Dueñas, M., Torres, L. M., Micó, J. A., & Failde, I. (2014). The impact of chronic pain: The perspective of patients, relatives, and caregivers. *Families, Systems, & Health*, *32*(4), 399–407. https://doi.org/10.1037/fsh0000069

Onen, S.-H., & Onen, F. (2018). Chronic Medical Conditions and Sleep in the Older Adult. *Sleep Medicine Clinics*, *13*(1), 71–79. https://doi.org/10.1016/j.jsmc.2017.09.007

Oosterman, J. M., Derksen, L. C., van Wijck, A. J. M., Veldhuijzen, D. S., & Kessels, R. P. C. (2011). Memory functions in chronic pain: Examining contributions of attention and age to test performance. *The Clinical Journal of Pain*, *27*(1), 70–75. https://doi.org/10.1097/ajp.0b013e3181f15cf5

Ornstein, R. E. (1969). *On the experience of time*. Penguin.

Pain terms: A list with definitions and notes on usage. Recommended by the IASP Subcommittee on Taxonomy. (1979a). *Pain*, *6*(3), 249.

Pain terms: A list with definitions and notes on usage. Recommended by the IASP Subcommittee on Taxonomy. (1979b). *Pain*, *6*(3), 249.

Park, D. C., Glass, J. M., Minear, M., & Crofford, L. J. (2001). Cognitive function in fibromyalgia patients. *Arthritis and Rheumatism*, *44*(9), 2125–2133. https://doi.org/10.1002/1529-0131(200109)44:9<2125::AID-ART365>3.0.CO;2-1

Parmelee, P. A., Harralson, T. L., McPherron, J. A., & Schumacher, H. R. (2013). The structure of affective symptomatology in older adults with osteoarthritis.

International Journal of Geriatric Psychiatry, *28*(4), 393–401. https://doi.org/10.1002/gps.3837

Patrick, N., Emanski, E., & Knaub, M. A. (2014). Acute and Chronic Low Back Pain. *Medical Clinics of North America*, *98*(4), 777–789. https://doi.org/10.1016/j.mcna.2014.03.005

Pengel, L. H. M., Herbert, R. D., Maher, C. G., & Refshauge, K. M. (2003). Acute low back pain: Systematic review of its prognosis. *BMJ (Clinical Research Ed.)*, *327*(7410), 323. https://doi.org/10.1136/bmj.327.7410.323

Qaseem, A., Wilt, T. J., McLean, R. M., & Forciea, M. A. (2017). Noninvasive Treatments for Acute, Subacute, and Chronic Low Back Pain: A Clinical Practice Guideline From the American College of Physicians. *Annals of Internal Medicine*, *166*(7), 514–530. https://doi.org/10.7326/M16-2367

Raak, R., & Wahren, L. K. (2006). Health experiences and employment status in subjects with chronic back pain: A long-term perspective. *Pain Management Nursing: Official Journal of the American Society of Pain Management Nurses*, *7*(2), 64–70. https://doi.org/10.1016/j.pmn.2006.02.001

Ramond, A., Bouton, C., Richard, I., Roquelaure, Y., Baufreton, C., Legrand, E., & Huez, J.-F. (2011). Psychosocial risk factors for chronic low back pain in primary care—A systematic review. *Family Practice*, *28*(1), 12–21. https://doi.org/10.1093/fampra/cmq072

Rasmussen, P. (1996). The congenital insensitivity-to-pain syndrome (analgesia congenita): Report of a case. *International Journal of Paediatric Dentistry*, *6*(2), 117–122. https://doi.org/10.1111/j.1365-263x.1996.tb00223.x

Ratcliffe, M. (2012). Varieties of temporal experience in depression. *The Journal of Medicine and Philosophy*, *37*(2), 114–138. https://doi.org/10.1093/jmp/jhs010

Rey, A. E., Michael, G. A., Dondas, C., Thar, M., Garcia-Larrea, L., & Mazza, S. (2017). Pain dilates time perception. *Scientific Reports*, *7*(1), 15682. https://doi.org/10.1038/s41598-017-15982-6

Rhudy, J. L., & Meagher, M. W. (2000). Fear and anxiety: Divergent effects on human pain thresholds. *Pain*, *84*(1), 65–75. https://doi.org/10.1016/S0304-3959(99)00183-9

Richmond, N. L., Meyer, M. L., Hollowell, A. G., Isenberg, E. E., Domeier, R. M., Swor, R. A., Hendry, P. L., Peak, D. A., Rathlev, N. K., Jones, J. S., Lee, D. C., Jones, C. W., & Platts-Mills, T. F. (2018). Social Support and Pain Outcomes After Trauma Exposure Among Older Adults: A Multicenter Longitudinal Study. *The Clinical Journal of Pain*, *34*(4), 366–374. https://doi.org/10.1097/AJP.0000000000000545

Rischer, K. M., González-Roldán, A. M., Montoya, P., Gigl, S., Anton, F., & van der Meulen, M. (2020). Distraction from pain: The role of selective attention and pain catastrophizing. *European Journal of Pain*, *24*(10), 1880–1891. https://doi.org/10.1002/ejp.1634

Rizzo, J. A., Abbott, T. A., & Berger, M. L. (1998). The labor productivity effects of chronic backache in the United States. *Medical Care*, *36*(10), 1471–1488. https://doi.org/10.1097/00005650-199810000-00006

Rode, S., Salkovskis, P. M., & Jack, T. (2001). An experimental study of attention, labelling and memory in people suffering from chronic pain. *PAIN*, *94*(2), 193–203. https://doi.org/10.1016/S0304-3959(01)00356-6

Roelofs, J., Boissevain, M. D., Peters, M. L., de Jong, J. R., & Vlaeyen, J. W. (2002). Psychological treatments for chronic low back pain: Past, present and beyond. *Pain Reviews*, *9*(1), 29–40. https://doi.org/10.1191/0968130202pr187ra

Routhier, S. (2020, March 11). *States with the Longest Emergency Room Wait Times*. https://www.autoinsurance.org/longest-emergency-room-waits/

Salomons, T., Iannetti, G. D., Liang, M., & Wood, J. (2016). *The "Pain Matrix" in Pain-Free Individuals*. https://jamanetwork.com/journals/jamaneurology/fullarticle/2516854

Schofield, P. (2008). Assessment and management of pain in older adults with dementia: A review of current practice and future directions. *Current Opinion in Supportive and Palliative Care*, *2*(2), 128–132. https://doi.org/10.1097/SPC.0b013e3282ffb406

Shade, M., Rector, K., & Kupzyk, K. (2021). Voice Assistant Reminders and the Latency of Scheduled Medication Use in Older Adults With Pain: Descriptive Feasibility Study. *JMIR Formative Research*, *5*(9), e26361. https://doi.org/10.2196/26361

Shumway-Cook, A., & Woollacott, M. (2000). Attentional demands and postural control: The effect of sensory context. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *55*(1), M10-16. https://doi.org/10.1093/gerona/55.1.m10

Sibille, K. T., Steingrímsdóttir, Ó. A., Fillingim, R. B., Stubhaug, A., Schirmer, H., Chen, H., McEwen, B. S., & Nielsen, C. S. (2016). Investigating the Burden of Chronic Pain: An Inflammatory and Metabolic Composite. *Pain Research & Management*, *2016*, 7657329. https://doi.org/10.1155/2016/7657329

Sidiq, M., Alenazi, W., Kashoo, F. Z., Qasim, M., Lopez, M. P., Ahmad, M., Mani, S., Shaphe, M. A., Khodairi, O., Almutairi, A., & Mir, S. A. (2021). Prevalence of non-specific chronic low-back pain and risk factors among male soldiers in Saudi Arabia. *PeerJ, 9*, e12249. https://doi.org/10.7717/peerj.12249

Sjøgren, P., Christrup, L. L., Petersen, M. Aa., & Højsted, J. (2005). Neuropsychological assessment of chronic non-malignant pain patients treated in a multidisciplinary pain centre. *European Journal of Pain*, *9*(4), 453–462. https://doi.org/10.1016/j.ejpain.2004.10.005

Smith, J. A., & Osborn, M. (2007). Pain as an assault on the self: An interpretative phenomenological analysis of the psychological impact of chronic benign low back pain. *Psychology & Health*, *22*(5), 517–534. https://doi.org/10.1080/14768320600941756

Smith, T. O., Dainty, J. R., Williamson, E., & Martin, K. R. (2019). Association between musculoskeletal pain with social isolation and loneliness: Analysis of the English

Longitudinal Study of Ageing. *British Journal of Pain*, *13*(2), 82–90. https://doi.org/10.1177/2049463718802868

Snelgrove, S., & Liossi, C. (2009). An interpretative phenomenological analysis of living with chronic low back pain. *British Journal of Health Psychology*, *14*(Pt 4), 735–749. https://doi.org/10.1348/135910709X402612

Snow-Turek, L. A., Norris, M. P., & Tan, G. (1996). Active and passive coping strategies in chronic pain patients. *Pain*, *64*(3), 455–462. https://doi.org/10.1016/0304-3959(95)00190-5

Stewart, D. E., & Yuen, T. (2011). A systematic review of resilience in the physically ill. *Psychosomatics: Journal of Consultation and Liaison Psychiatry*, *52*(3), 199–209. https://doi.org/10.1016/j.psym.2011.01.036

Stewart, W. F., Ricci, J. A., Chee, E., Morganstein, D., & Lipton, R. (2003). Lost productive time and cost due to common pain conditions in the US workforce. *JAMA*, *290*(18), 2443–2454. https://doi.org/10.1001/jama.290.18.2443

Strunin, L., & Boden, L. I. (2004). Family consequences of chronic back pain. *Social Science & Medicine (1982)*, *58*(7), 1385–1393. https://doi.org/10.1016/S0277-9536(03)00333-2

Subnis, U. B., Starkweather, A., & Menzies, V. (2016). A Current Review of Distraction-Based Interventions for Chronic Pain Management. *European Journal of Integrative Medicine*, *8*(5), 715–722.

Sullivan, M. D., Von Korff, M., Banta-Green, C., Merrill, J. O., & Saunders, K. (2010). Problems and concerns of patients receiving chronic opioid therapy for chronic non-cancer pain. *Pain*, *149*(2), 345–353. https://doi.org/10.1016/j.pain.2010.02.037

Tan, G., Nguyen, Q., Anderson, K. O., Jensen, M., & Thornby, J. (2005). Further validation of the chronic pain coping inventory. *The Journal of Pain*, *6*(1), 29–40. https://doi.org/10.1016/j.jpain.2004.09.006

Thomas, E. A. C., & Weaver, W. B. (1975). Cognitive processing and time perception. *Perception & Psychophysics*, *17*(4), 363–367. https://doi.org/10.3758/BF03199347

Torrance, N., Smith, B. H., Elliott, A. M., Campbell, S. E., Chambers, W. A., Hannaford, P. C., & Johnston, M. (2011). Potential Pain Management Programmes in primary care. A UK-wide questionnaire and Delphi survey of experts. *Family Practice*, *28*(1), 41–48. https://doi.org/10.1093/fampra/cmq081

Tracey, I., Ploghaus, A., Gati, J. S., Clare, S., Smith, S., Menon, R. S., & Matthews, P. M. (2002). Imaging attentional modulation of pain in the periaqueductal gray in humans. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *22*(7), 2748–2752. https://doi.org/20026238

Tse, P. U., Intriligator, J., Rivest, J., & Cavanagh, P. (2004). Attention and the subjective expansion of time. *Perception & Psychophysics*, *66*(7), 1171–1189. https://doi.org/10.3758/BF03196844

Tüzün, E. H. (2007). Quality of life in chronic musculoskeletal pain. *Best Practice & Research. Clinical Rheumatology*, *21*(3), 567–579. https://doi.org/10.1016/j.berh.2007.03.001

Urquhart, D. M., Shortreed, S., Davis, S. R., Cicuttini, F. M., & Bell, R. J. (2009). Are low levels of low back pain intensity and disability associated with reduced well-being in community-based women? *Climacteric: The Journal of the International Menopause Society*, *12*(3), 266–275. https://doi.org/10.1080/13697130802635645

van der Leeuw, G., Eggermont, L. H. P., Shi, L., Milberg, W. P., Gross, A. L., Hausdorff, J. M., Bean, J. F., & Leveille, S. G. (2016). Pain and Cognitive Function Among Older Adults Living in the Community. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *71*(3), 398–405. https://doi.org/10.1093/gerona/glv166

van der Leeuw, G., Leveille, S. G., Dong, Z., Shi, L., Habtemariam, D., Milberg, W., Hausdorff, J. M., Grande, L., Gagnon, P., McLean, R. R., & Bean, J. F. (2018). Chronic Pain and Attention in Older Community-Dwelling Adults. *Journal of the American Geriatrics Society*, *66*(7), 1318–1324. https://doi.org/10.1111/jgs.15413

van Hecke, O., Torrance, N., & Smith, B. H. (2013). Chronic pain epidemiology and its clinical relevance. *British Journal of Anaesthesia*, *111*(1), 13–18. https://doi.org/10.1093/bja/aet123

van Tulder, M., Becker, A., Bekkering, T., Breen, A., del Real, M. T. G., Hutchinson, A., Koes, B., Laerum, E., Malmivaara, A., & COST B13 Working Group on Guidelines for the Management of Acute Low Back Pain in Primary Care. (2006). Chapter 3. European guidelines for the management of acute nonspecific low back pain in primary care. *European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the*

European Section of the Cervical Spine Research Society, *15 Suppl 2*, S169-191. https://doi.org/10.1007/s00586-006-1071-2

Veldhuijzen, D. S., Kenemans, J. L., van Wijck, A. J. M., Olivier, B., Kalkman, C. J., & Volkerts, E. R. (2006). Processing capacity in chronic pain patients: A visual event-related potentials study. *Pain*, *121*(1–2), 60–68. https://doi.org/10.1016/j.pain.2005.12.004

Vos, T., Flaxman, A. D., Naghavi, M., Lozano, R., Michaud, C., Ezzati, M., Shibuya, K., Salomon, J. A., Abdalla, S., Aboyans, V., Abraham, J., Ackerman, I., Aggarwal, R., Ahn, S. Y., Ali, M. K., Alvarado, M., Anderson, H. R., Anderson, L. M., Andrews, K. G., … Memish, Z. A. (2012). Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: A systematic analysis for the Global Burden of Disease Study 2010. *Lancet (London, England)*, *380*(9859), 2163–2196. https://doi.org/10.1016/S0140-6736(12)61729-2

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences*, *9*(12), 585–594. https://doi.org/10.1016/j.tics.2005.10.011

Walker, J., Sofaer, B., & Holloway, I. (2006). The experience of chronic back pain: Accounts of loss in those seeking help from pain clinics. *European Journal of Pain (London, England)*, *10*(3), 199–207. https://doi.org/10.1016/j.ejpain.2005.03.007

Wallman, K. E., Morton, A. R., Goodman, C., Grove, R., & Guilfoyle, A. M. (2004). Randomised controlled trial of graded exercise in chronic fatigue syndrome. *The*

Medical Journal of Australia, *180*(9), 444–448. https://doi.org/10.5694/j.1326-5377.2004.tb06019.x

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Webster, L. R., & Harden, R. N. (2013). Why we need narratives of healing and qualitative pain research. *Pain Medicine (Malden, Mass.)*, *14*(12), 1811–1812. https://doi.org/10.1111/pme.12291

Weiner, D. K., Rudy, T. E., Morrow, L., Slaboda, J., & Lieber, S. (2006). The relationship between pain, neuropsychological performance, and physical function in community-dwelling older adults with chronic low back pain. *Pain Medicine (Malden, Mass.)*, *7*(1), 60–70. https://doi.org/10.1111/j.1526-4637.2006.00091.x

White, R. S., Jiang, J., Hall, C. B., Katz, M. J., Zimmerman, M. E., Sliwinski, M., & Lipton, R. B. (2014). Higher Perceived Stress Scale scores are associated with higher pain intensity and pain interference levels in older adults. *Journal of the American Geriatrics Society*, *62*(12), 2350–2356. https://doi.org/10.1111/jgs.13135

White, S., & Siebold, C. (2008). Walk a mile in my shoes: An auto-ethnographic study. *Contemporary Nurse*, *30*(1), 57–68. https://doi.org/10.5172/conu.673.30.1.57

Wilson, P. R., Watson, P. J., Haythornthwaite, J., & Jensen, T. S. (2008). *Clinical pain management: Chronic pain, second edition*. CRC Press. https://jhu.pure.elsevier.com/en/publications/clinical-pain-management-chronic-pain-second-edition

Wittmann, M., Simmons, A. N., Aron, J. L., & Paulus, M. P. (2010a). Accumulation of neural activity in the posterior insula encodes the passage of time. *Neuropsychologia*, *48*(10), 3110–3120. https://doi.org/10.1016/j.neuropsychologia.2010.06.023

Wittmann, M., Simmons, A. N., Aron, J. L., & Paulus, M. P. (2010b). Accumulation of neural activity in the posterior insula encodes the passage of time. *Neuropsychologia*, *48*(10), 3110–3120. https://doi.org/10.1016/j.neuropsychologia.2010.06.023

Wittmann, M., Vollmer, T., Schweiger, C., & Hiddemann, W. (2006). The relation between the experience of time and psychological distress in patients with hematological malignancies. *Palliative & Supportive Care*, *4*(4), 357–363. https://doi.org/10.1017/s1478951506060469

Wong, A. Y., Karppinen, J., & Samartzis, D. (2017). Low back pain in older adults: Risk factors, management options and future directions. *Scoliosis and Spinal Disorders*, *12*, 14. https://doi.org/10.1186/s13013-017-0121-3

Wood, B. M., Nicholas, M. K., Blyth, F., Asghari, A., & Gibson, S. (2016). The mediating role of catastrophizing in the relationship between pain intensity and depressed mood in older adults with persistent pain: A longitudinal analysis.

Scandinavian Journal of Pain, 11, 157–162. https://doi.org/10.1016/j.sjpain.2015.12.009

Wright, D., Hoang, M., Sofine, A., Silva, J. P., & Schwarzkopf, R. (2017). Pain catastrophizing as a predictor for postoperative pain and opiate consumption in total joint arthroplasty patients. *Archives of Orthopaedic and Trauma Surgery*, *137*(12), 1623–1629. https://doi.org/10.1007/s00402-017-2812-x

Yam, M. F., Loh, Y. C., Tan, C. S., Khadijah Adam, S., Abdul Manan, N., & Basir, R. (2018). General Pathways of Pain Sensation and the Major Neurotransmitters Involved in Pain Regulation. *International Journal of Molecular Sciences*, *19*(8), 2164. https://doi.org/10.3390/ijms19082164

Yang, B., Chan, R. C. K., Zou, X., Jing, J., Mai, J., & Li, J. (2007). Time perception deficit in children with ADHD. *Brain Research, 1170,* 90–96. https://doi.org/10.1016/j.brainres.2007.07.021

Young, A. E., Wasiak, R., Phillips, L., & Gross, D. P. (2011). Workers' perspectives on low back pain recurrence: "it comes and goes and comes and goes, but it's always there." *Pain*, *152*(1), 204–211. https://doi.org/10.1016/j.pain.2010.10.033

Zhang, J., Wang, G., Jiang, Y., Dong, W., Tian, Y., & Wang, K. (2012). The Study of Time Perception in Migraineurs. *Headache: The Journal of Head and Face Pain, 52*(10), 1483–1498. https://doi.org/10.1111/j.1526-4610.2012.02222.x

CURRICULUM VITAE

[redacted]

[redacted]