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Understanding Language Use Patterns of People with Chronic Pain: A Novel Assessment Approach

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UNDERSTANDING LANGUAGE USE PATTERNS OF PEOPLE WITH CHRONIC PAIN: A NOVEL ASSESSMENT APPROACH

by

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Abstract

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It is estimated that 35% of Americans or 116 million people report experiencing chronic pain daily (Nahin, 2015). Due to the unique and individualized nature of chronic pain, successful treatment of this condition is difficult to achieve. The heterogeneity and complexity in presentation may help explain why, as all methods of treatment have fallen short of providing consistent and reliable outcomes (Finnerup et al., 2015; Lumley & Schubiner, 2019), resulting in unsuccessful treatment approaches that can lead to compounding negative consequences such as hyperalgesia (Garland et al., 2013) and even death (Scholl, Seth, Kariisa, Wilson, & Baldwin, 2019). As such, the current study sought to addresses the need for a more comprehensive assessment protocol to evaluate chronic pain conditions by using natural language analysis to examine how differences in linguistic style reveal important information related to attentional focus, social connectedness, cognitive bias and other clinical dimension in a sample of data collected from a pilot study of individuals with chronic pain.

This study found that, when compared to population data, significant differences in language use predicted pain severity and pain disability outcomes. Further, when examined at an individual level, data on linguistic style offered incremental information not reliant on self-report measures or subject to self-report bias that may enhance existing approaches to clinical formulations of this multifaceted condition. Taken together, these findings suggest that language use analysis may represent a promising diagnostic tool and assessment measure for better understanding the chronic pain experience at an individual level that improves treatment matching protocols and ultimately overall treatment outcomes.

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Chapter 1: Statement of the Problem

It is estimated that 35% of Americans, or 116 million people report experiencing chronic pain daily (Nahin, 2015). Nearly 54% of adults living with chronic pain report having done so for five years or more, and over 41% percent of those individuals report more than one pain condition (Kantar Health, 2016). In addition, 80% of people living with chronic pain are treated with opioid therapy (Pezalla et al., 2017). However, a growing body of evidence has confirmed that opioids are neither an effective nor safe treatment for this condition (Agency for Healthcare Research and Quality [AHRQ], 2014; Chang, Bijur, Esses, Barnaby, & Baer, 2017; Shaheed, Maher, Williams, Day, & McLachlan, 2016). Risk factors for long-term opioid therapy include prescription misuse (Voon, Karamouzian, & Kerr, 2017), addiction (Wachholtz & Gonzalez, 2014), hyperalgesia, or increased sensitivity (Garland et al., 2013), and death. To illustrate, over 400,000 people have died from an opioid-related overdose in the past 20 years, representing more than half of all overdose deaths in that period (Scholl, Seth, Kariisa, Wilson, & Baldwin, 2019), and prescription opioid related deaths remain steady. In 2019, opioid-related fatalities accounted for 71% of all fatalities from overdose, which are continuing to trend upward after a brief and moderate decline in 2018 (National Institute on Drug Abuse [NIDA], 2021).

While alternative treatments such as other pharmacological, surgical, and non-pharmacological approaches have been extensively examined and reviewed in the literature, their efficacy is somewhat limited (Borsook & Kalso, 2013; Chang, Bijur, Esses, Barnaby, & Baer, 2017; Chou et al., 2017; Chou et al., 2017). Effective approaches toward enhancing the existing assessment and treatment approaches to chronic pain are an urgent community health issue.

The Disease of Chronic Pain

Part of the challenge of establishing consistently effective assessment and intervention strategies for chronic pain syndromes lies in the complexity involved in the development and maintenance of chronic pain. Chronic pain involves sensory, cognitive, and affective factors and complex psychological processing (Melzak & Katz, 2014; Williams & Craig, 2016). Chronic pain is distinct from acute pain, as chronic pain often endures in the absence of a noxious stimulus or tissue damage. Also, the processing of pain signals in the brain relies on a combination of different neural networks that are dependent on previous experiences, thoughts, and feelings about pain and the context in which pain is triggered (Simons, Elman, & Borsook, 2014). As a result, the individual experience of pain is unique and reflects a multidimensional interaction among attentional, affective, and memory neural circuitry as well as afferent sensory inputs (Baliki & Apkarian, 2015).

Human and animal studies further suggest that long-term activation of pain neural networks influence structural reorganization (Seifert & Maihofner, 2011), as well as altered physiological and psychological processing (Apkarian, Bliki, & Geha, 2009) that in turn influence the high level of resistance and inconsistent results evidenced in most chronic pain interventions. Ultimately, awareness of this complexity helps in understanding why the experience and presentation of chronic pain are idiosyncratic.

To better acknowledge the idiosyncratic nature of pain, in 2019, the International Association for the study of Pain (IASP) revised their definition of pain. The revised

version defines pain as an "unpleasant sensory and emotional experience associated with or resembling that associated with, actual or potential tissue damage" (Raja et al., 2020, p. 2). The definition was accompanied by a detailed notes section emphasizing pain as a subjective experience with individualized symptomology as well as varying modes of expression and decoupled these
factors from actual or potential tissue damage allowing for psychological, cognitive and emotional pathways to pain. More specifically, Raja and colleagues (2020) describe pain as an experience that varies greatly from person to person based on biological, psychological and social factors. The authors distinguish pain from nociception, and highlight the role operant learning plays in the concept of pain. Further, the authors recognize pain can be present without verbal report, accomodating the notion that many behaviors (e.g., wincing, blocking, crying, etc.) can be expressions of pain. These detailed notes considerably enhanced the definition of pain by illustrating pain sensation is actually *constructed* in the brain as a result of many factors, rather than a one-to-one reflexive condition driven by activity in afferent neurons due to tissue damage or excessive stimulation (i.e., nociception).

According to the IASP, this philosophical shift was made to "…better convey the nuances…and with the hope it would lead to better assessment and management to those with pain" (International Association for the study of Pain [IASP], 2020). This was an essential and needed change as existing assessment and treatment protocols face many challenges because they were not developed in accordance with a model of pain that incorporates the biological (e.g., associative neural networks, neuroadaptations, genetic predispositions, tissue damage or dysfunction, etc.) psychological (e.g., cognitive and emotional functioning, etc.) and social factors (e.g., previous life experiences, environment, interpersonal functioning, etc.) involved in constructing it.

Treatment of Chronic Pain

Given the updated and expanded definition above, emphasizing the unique, complex and individualized nature of chronic pain, successful treatment of this condition is difficult to achieve. The heterogeneity in presentation may help explain why, as all methods of treatment (non-surgical, surgical, non-pharmacological, and pharmacological) have fallen short of providing consistent and reliable outcomes (Finnerup et al., 2015; Lumley & Schubiner, 2019). A comprehensive review of each treatment option for chronic pain is beyond the scope of this dissertation, but the literature consistently demonstrates most methods have delivered results that can be considered disappointing (Borsook & Kalso, 2013) with small to moderate effect sizes, often only slightly larger than placebo (AHRQ, 2018; Finnerup et al., 2015). Lower back pain is the most extensively funded and studied of all musculoskeletal conditions (Chronic Pain Research Alliance [CPRA], 2015), yet most common lumbar MRI findings are unable to correlate the presence or absence of symptoms or their severity (Ract et al., 2015). Interestingly, a meta-analysis of 22 out of 28 subgroups of patients treated with epidural injections and placebo indicated no difference in treatment effects (Kay et al, 2015). In part in recognition of such evidence, recent published guidelines emphasize non-pharmacological interventions above surgical and pharmacological treatment (Foster et al., 2018).

While non-pharmacological treatments for chronic pain have demonstrated the ability to reduce pain symptoms in experimental and quasi-experimental studies, the effects of these interventions are also limited. Ample evidence supports the effectiveness of cognitive-behavioral therapy (Edhe, Dillworth, & Turner, 2014; Fenton & Morley, 2013; Pike, Hearn, & Williams, 2016; Turk, Swanson, Tunks, &, 2008), mindfulness strategies (Cramer et al., 2012; Hilton et al., 2017), acceptance and commitment therapy (Veehof, Oskam, Schreurs, & Bohlmeijer, 2011) emotional awareness and expression therapy (Lumley et al, 2017), and behavioral methods (Turk, Swanson, Tunks, &, 2008) in the treatment of chronic pain. However, experimental trials report a range of small to moderate effect sizes across each treatment type (d = .25 to d = .5), and considerable variability is reported within trials examining each treatment modality.

Due to this variability, prognostic insight into which patients may be best suited to receive which treatment and why remains extremely difficult. Clinicians and medical professionals are often challenged to refer individual patients to the most appropriate treatment given the degree of uncertainty in expected outcomes (Gereau et al., 2014). This has likely contributed to the growing opioid crisis and limits the likelihood that a solution to this crisis will be identified quickly.

Many researchers investigating chronic pain outcomes express the need for specific patient (Kerns, Sellinger, & Goodin, 2011) or treatment matching protocols (Broderick et al., 2016) as well as additional experimental studies that help address this dilemma. Healthcare professionals working with patients with chronic pain speak to the critical need for a mechanism that effectively determines what constellation of treatments will be the best match for an individual's constellation of symptoms (Turk, Swanson, Tunks, &, 2008). An assessment protocol that effectively evaluates the intersection of the physical, psychological and social factors contributing to and maintaining the pain experience is indicated. However, despite decades of research on these factors, a multidimensional, integrated assessment approach has yet to be identified and evaluated.

Despite the challenges in finding factors that can effectively match patients to treatments, a few factors have been identified to predict successful pain outcomes. These include patient expectancy (Cormier, Lavigne, Choiniere, & Rainville, 2016), personality characteristics such as neuroticism and extraversion (Paine, Kishor, Worthen, Gregory, & Aziz, 2009) as well as other characteristics such as age that make individuals more likely to be responsive to treatment (Ehde, Dilworth, & Turner, 2014). Other studies identify emotional regulation (Koechlin, Coakley, Schechter, Werner, & Kossowsky, 2018), the presence of meaning in one's life (Dezutter, Luyckx, & Wacholtz, 2015), and dominant coping style and pain acceptance (Krantz, Bollinger, & Nilges, 2010) as predictors of pain reduction. Yet, due to the complexity of how pain is experienced at an individual level, an understanding of persistent pain on a unidimensional level is not sufficient (Dworkin et al., 2016).

While these studies identify interesting psychological constructs and variables that contribute to and predict specific aspects of pain (e.g., pain persistence, interference, pain self-efficacy, as well as pain intensity) they are inconclusive and insufficient alone in establishing a comprehensive representation of an individual's chronic pain experience. Evidence suggests that individuals suffering from chronic pain are not able to reliably distinguish between the multidimensional aspects of the pain experience (Chapman et al., 2001), implying that the current self-report measures deemed as the "gold standard" used in assessing these variables may not provide reliable measures of pain-related conditions, nor do they allow for a clear identification of the most effective treatment protocols.

In addition, these variables do not effectively integrate the cumulative impact of sensory experience, neurological functioning, and cognitive appraisal processes that are reflected in the individual's experience of pain or account for responsivity to treatment that is heavily influenced by the individuals' history, context, genetics and social environment (Elman & Borsook, 2016). Engel (1977) recognized the importance of psychosocial factors when he introduced the biopsychosocial approach to chronic pain that is now generally accepted as the most utilized model to evaluate and treat pain. Unfortunately, while multiple standardized approaches to operationalizing the biopsychosocial model have been proposed within psychology (Bruns & Disorbio, 2015), neuroscience (Wijma et al, 2016), and medicine (Cheatle, 2016), a single comprehensive and commonly accepted interprofessional approach has not yet been established. Additional assessment instruments must be developed that incorporate objective methods of evaluating the neurological, physiological, cognitive, and emotional pathology involved in persistent pain conditions

Neurobiological Pathology: Adaptations

From a neurobiological perspective, the chronicity of a pain condition is the combined physical and psychological presentation resulting from the reorganization of the nervous system. Such changes in neural network circuitry result from repetitive and/or novel and emotionally charged excitatory/inhibitory events (i.e., pain behaviors and experiences) and sensitized/desensitized states (i.e., psychological processes including mood) that influence specific neural connections or atrophy of connections

(Simons, Elman & Borsook, 2014). Over time, neuronal adaptations, as well as structural and functional changes to physiological and psychological systems, maintain enduring pain signals in the brain, often even after tissue damage is no longer present (Elman & Borsook, 2016; Di Lernia, Serino & Riva, 2016; Greenwald & Shafriz, 2018). In addition, the neurological-psychological process interaction is iterative and bidirectional. In a meta-analysis of 55 studies, Tatu and colleagues (2018) concluded that network changes occur in chronic pain patients in a systematic pattern in accordance with symptom-related changes by identifying these differences in brain tissue and neuroanatomy.

Although the neural adaptations have been observed to occur in a systematic and observable pattern, research suggests there are multiple pathways that can lead to these changes due to the multiple areas of functioning that are dysregulated in chronic pain. Examples of these include alterations to physical (e.g., cardiovascular, immunological, endocrine), psychological (e.g., perception, motivation, and emotion), and cognitive (attention, executive functioning, learning, and memory) domains. Dysfunction across each domain can increase the body's overall allostatic load and contribute to longer-term changes in the brain (Simons, Elman & Borsook, 2014).

Simons, Elman & Borsook (2016) outlined these neurobiological changes and the psychological processing of pain in noting reliable anatomical (e.g., PFC, hypothalamus, thalamus, amygdala, habenula, and insula) neurochemical (glutamate, opioids, GABA, cannabinoids, NE, Ach, Leptin, Orexin, insulin, and CCK) and autonomic adaptations that place the chronic pain patient in a persistent psychological and physiological state of imbalance. Such imbalances influence alterations of reward-related processes such as increasing pain-related cognitions (i.e., fear conditioning, catastrophizing), emotions (i.e., feelings of depression and anxiety), and motivation (i.e., pain-relief seeking and avoidance,) and increased emotional sensitivity (Nees & Becker, 2018). Dysregulated neurobiological processes can also impact pain behavior (e.,g. escape/avoidance), alterations in sensation (e.g,. hyperalgesia, allodynia), cognitive functioning (e.g., pain catastrophizing and attentional bias), learning and memory problems, and emotional regulation (Simons, Elman & Borsook, 2016).

Interoception, or the individual's ability to effectively detect and accurately interpret one's physiology, is also theorized to be dysregulated (DiLernia, Serino & Riva, 2016) in patients with chronic pain. Changes in interoceptive ability influence hypervigilance, attentional bias, fear learning, and increased sensitivity to pain and pain stimulus. The Fear Avoidance Model (Crombez et al, 2012) proposes that social, operant, and classical learning intersect in chronic pain experiences to promote avoidance as the primary factor in maintaining pain. Reversing the fear learning response is complex because, in chronic pain, implicit learning (unconscious behavioral change) is often involved making it difficult to "unlearn" or extinguish reinforcing pain avoidance or pain relief behaviors that maintain chronic pain conditions (Nees & Becker, 2018).

Finally, emotional dysregulation also plays an important role in chronic pain. Structural and connectivity changes in the ACC, orbitofrontal cortex, insula, and the nucleus accumbens often result in emotional difficulties and likely in part account for the high incidence of anxiety and depression evidenced in individuals with chronic pain (Bushnell, Ceko & Low, 2013). These areas of the brain, also known as the reward circuitry, influence motivation as well as emotional control. In patients with chronic pain, seeking pain relief becomes the primary reward pursued (analogous to changes observed in addiction), and relief-seeking behaviors become the primary focus (Garland et al, 2015; DosSantos, Moura & DaSilva, 2017; Simon, Elman & Borsook, 2016). This helps explain the exaggerated attention to pain and a bias toward pain avoidance/escape cognitions and behaviors often observed in chronic pain patients.

This brief review of how physical changes in the brain influence the course and progression of chronic pain conditions assists in understanding the neurobiological complexity and level of dysregulation involved in the development and maintenance of this condition. Notably, some evidence exists to suggest that these structural and functional abnormalities can be reversed. Such reversals have been observed after spinal cord stimulation (Sinclair et al., 2016), cognitive-behavioral therapy (Kregel et al, 2017), and mindfulness-based therapies (Garland & Howard, 2013). Assessment techniques able to evaluate and prioritize the nature of these changes would undoubtedly enhance existing self-report approaches.

Cognitive Pathology: Maladaptive Appraisal

Due in part to physical changes in the brain, people living with chronic pain often process information and events differently than individuals who do not experience chronic pain (Pincus & Morley, 2001; Rusu et al., 2019). One of the primary mechanisms of cognitive dysfunction in people with chronic pain can be explained by the Transactional Theory of Stress (Folkman, Lazarus, Dunkell-Schetter, DeLongis, & Gruen, 1986). This theory describes the cognitive process by which an individual evaluates a situation or event in terms of the degree of threat (e.g., primary appraisal) and ability to cope with or overcome the obstacle related to the situation (e.g., secondary appraisal). A threat appraisal occurs when an individual perceives the stimulus to be life-threatening or dangerous, and they perceive themselves as unable to overcome the threat using their own resources. A challenge appraisal occurs when an individual perceives a threat or danger but believes they are able to overcome the threat using their own resources.

Lazarus and many subsequent researchers extended this cognitive appraisal process to explore how it influences emotional and behavioral responses as the primary process by which human beings inform their day to day lives (Scherer & Moors, 2019). Cognitive appraisal is the mechanism by which individuals interpret the stimulus they encounter as well as evaluate their ability to successfully or unsuccessfully address them. For example, primary and secondary appraisal have been linked to individual coping response (Higgins, Bailey, LaChapelle, Harman, & Hadjistavropoulos, 2015), levels of anxiety and depression, as well as positive and negative affect in young adults (Andreotti et al., 2013) and physical functioning and pain levels in older adults (Ilves et al., 2018).

A cross-section of the cognitive appraisal literature highlights the influence the experience of pain has on the cognitive appraisal process. This research suggests persistent pain may disturb the cognitive appraisal process resulting in an increased number of threat appraisals and decreased number of challenge appraisals. These findings seem to suggest that over time chronic pain patients become less and less able to perceive effective ways of coping with pain (Hermsen et al, 2016; Ziadni, Sturgeon & Darnall, 2018).

Disturbances to the cognitive appraisal process influence adverse outcomes on various pain measures (i.e., pain intensity, severity, interference, etc.). In a meta-analysis examining 22 individual studies representing a sample of 2,031 participants, researchers concluded threat appraisals in response to experimental pain were associated with increased pain perception, passive coping, lower pain tolerance, and higher pain intensity. In contrast, challenge appraisals were associated with active coping responses, less aversion to pain, and higher pain tolerance (Jackson, Wang, & Fan, 2014). Similar results were observed by the same authors across another meta-analysis of 59 experimental studies of individuals with chronic pain (*N* = 9,135), further supporting the idea that the pain experience affects the cognitive appraisal process by increasing cognitive bias (e.g., attentional, interpretive, and memory).

Cognitive bias. Most of the research on the cognitive appraisal process in patients with chronic pain suggests that cognitive bias plays an important role (Schoth, Beaney, Broadbent, Zhang & Liossi, 2019; Schoth & Liossi, 2016; Todd, Dimitri, van Ryckeghem, Sharpe & Crombez, 2018). Cognitive bias is believed to alter cognitive processing in maladaptive ways that maintain harmful thoughts, beliefs, and cognitive patterns. Cognitive processing refers to the information-processing mechanism responsible for the cognitive appraisal process and involves attention, interpretation, and memory (Pincus, Morley, &, 2001). A considerable base in the literature suggests that attentional, interpretational, and memory bias are relevant challenges for individuals with extended pain histories (Todd et al, 2015; Van Damme, Legrain, Vogt & Crombez, 2010).

Attentional bias. Rusu and colleagues (2019) describe attentional bias as the preferential allocation of attention to pain-related information or stimuli. These authors summarized studies examining attentional bias in chronic pain patients and confirmed that when given ambiguous or pain-related stimuli, patients will pay more attention (measured as time spent on a task or visual gaze time via eye-tracking devices) to pain-related stimuli.

In a study designed to measure attentional bias, a sample of university students completed a dot-probe task (where individuals are simultaneously presented word pairs of threat and neutral words and must track and choose the location of a dot on a computer screen while processing time for the task is measured). Then, they were administered measures of pain disability, pain catastrophizing, pain vigilance, pain anxiety, pain acceptance, as well as trait-anxiety and illness sensitivity. Multiple analyses determined that participants with chronic pain had significantly higher visual attention scores than controls, but only for those words that were sensory-related. These results were consistent even after controlling for reaction time. The researchers concluded that psychological measures accounted for longer processing time (e.g., the higher the levels of catastrophizing and vigilance, the longer the processing time related to pain and neutral words overall), but did not account for differences in attention. The authors interpreted this difference to suggest that individuals with chronic pain display an attentional bias toward threat/sensory-related words, and higher levels of catastrophizing and vigilance contribute to this bias (Fashler & Katz, 2014).

Interpretation bias. Interpretation bias in chronic pain patients refers to the process of interpreting ambiguous stimuli as threatening or representing future harm (Pincus et al., 2001). Interpretation bias influences the cognitive appraisal process as well, yet it has been studied much less extensively than experimental work related to attention and memory bias.

A recent study conducted in Tehran examined the responses of chronic back pain patients and healthy controls to an incidental learning task to test for interpretation bias. Participants were provided pain-related stimuli (pain facial expressions), happiness-related stimuli (smiling facial expressions), and ambiguous stimuli (neutral facial expressions) in combination with a learned target on the screen. Pain-related stimuli were matched to targets appearing on the right side, happiness to the screen's left side. Over the course of the learning trials, participants were asked to identify the target location as quickly as possible (i.e., learning the pattern of target and stimuli matches over two trials). Participants were also administered measures of pain severity, catastrophizing, and fear of pain. Results indicated participants with chronic pain responded faster than healthy controls to pain-related stimuli, and response time was associated with pain catastrophizing. The authors interpreted these findings as support for an interpretation bias to pain (Khatibi, Sharpe, Jafari, Gholami, & Dehgani, 2015)

A more prevalent approach investigating interpretation bias in chronic pain patients utilizes the homophone task. In this task, participants are presented a list of word pairs that are pronounced the same but have two different interpretations (i.e., flew and flu). According to a synthesis of several studies by Pincus & Morley (2001), individuals with chronic pain have higher response rates favoring pain-related words, and these associations are correlated with pain intensity.

Taken together, these studies suggest that chronic pain patients often interpret their environment (i.e., neutral or ambiguous stimuli) as threatening even when no inherent threat exists, and this interpretation bias appears to correlate with how much they feel and how severe their pain is. This may help explain an additional component of how the overall cognitive appraisal process contributes to the severity and maintenance of the chronic pain experience.

Memory bias. Memory bias entails the predisposition for recalling specific memories or events above others. The role of memory bias is known to influence levels of both trait and state anxiety, as well as predict higher rates of threat appraisal in experimental paradigms (Large, MacLeod, Clarke, & Notebaert, 2016) Therefore, it is no surprise that, in ways similar to the relationship between interpretation and attentional bias, connections between memory bias and pain-related stimuli have been observed in chronic pain patients as well.

For example, researchers utilized a series of experimental methods to test group differences in memory bias between individuals with chronic headaches and healthy controls. These methods included interpretation and attentional bias tests involving incidental learning and sentence generation tasks that featured sensory-pain and neutral stimuli (words) as well as a free recall task (i.e., participants were asked to recall as many words as possible from each trial) to test for memory bias. Participants were also administered measures of mood (e.g., anxiety, depression) and pain (e.g., intensity, interference, acceptance, and disability). Interestingly, while researchers found evidence of interpretation and attentional bias differences between groups, no group differences were present in memory bias. However, both groups remembered more sensory-related words than ambiguous words. The authors suggest their findings may be a result of differences between headache pain versus musculoskeletal pain or relate to the sequence and nature of their methodology for each test (Schoth, Beaney, Broadbent, Zhang, & Liossi, 2018).

While this research did not identify a clear difference in memory bias between groups, it does provide evidence to support that, in general, individuals tend to remember pain-related stimuli above and beyond neutral stimuli. In the case of individuals with chronic pain, the literature supports that their overall perception is colored by interpretation bias, and therefore it is likely that they (more often than not) interpret stimuli in their environment as threatening (i.e., interpretation bias) and when they do, they often focus a higher percentage of their attention on harmful or threatening stimuli (attentional bias).

The current literature appears to suggest that cognitive appraisal plays an essential role in the lives of people with chronic pain conditions. It influences how and where they allocate their attention, how they understand and perceive their world, and what they remember. In a sense, it holistically affects their entire experience. This may help explain why physical or somatic solutions such as surgical or pharmacological interventions are often unsuccessful, and pain endures. At the same time, the literature also suggests that cognitive and cognitive-behavioral interventions must be more precisely tuned to address the multifaceted dysregulation that exists in the cognitive processing of people with chronic pain. Instead, each aspect of cognitive bias must be in essence ‘re-wired’ or ‘re-programmed’ to ensure that the individual is not unintentionally maintaining their own negative pain experience.

Chapter II: Review of the Literature

An Integrated Model for Chronic Pain

The neurobiological, psychological, and cognitive processing of chronic pain has been extensively studied in recent years, resulting in a detailed understanding of the multidimensional nature of this condition. Pain sensation is activated via nociceptive signals in the body, but specific areas of the brain and interconnected neural networks construct the feeling and experience of pain (Bruns, 2019). Distinct and overlapping neural networks integrate sensory information with pain cognitions or beliefs, memories of pain, emotion, movement as well as context and mood (Simons, Elman, & Borsook, 2014), the scope of which is not captured in an integrated framework in existing assessment and treatment paradigms.

An accurate framework for chronic pain must acknowledge the complex set of factors outlined above and address the full spectrum of psychological and biomechanical aspects contributing to the maintenance of ongoing pain. Assessments or interventions that do not encompass each of these elements are likely to fall short of successfully treating chronic pain conditions. Lack of an integrated framework may help illustrate why existing interventions, though effective in reducing scores on a variety of pain measures, do so only some of the time (Chou, Deyo, Friedly, Skelly, Hashimoto, et al., 2017; Chou, Deyo, Friedly, Skelly, Weimer, et al., 2017).

For example, cognitive-behavioral therapy (CBT) has demonstrated efficacy in treating patients with chronic pain (Ehde, Dilworth, & Turner, 2014) but mainly targets the cognitive appraisal processes. Mindfulness-based cognitive behavioral therapy (MBCT) and acceptance commitment and therapy (ACT) arguably address both the cognitive appraisal process and increase somatic awareness with demonstrated success in reducing pain and depression symptoms (Hilton et al., 2017; Veehof, Oskam, Schreursa, & Bohlmeijeraa, 2010), yet differential outcomes have been observed depending on the level of autonomic reactivity observed at baseline as measured by ECG, suggesting MBCT may not be the most effective first-line approach for individuals whose physiology is primary or when tissue damage is present (Day et al, 2019). Meanwhile, emotional awareness and expression therapy (EAET) incorporates several elements from CBT, MCBT, and ACT but extends treatment targets to uniquely encourage trauma and emotional processing (Lumley & Schubiner, 2019). Behavioral therapy effectively targets the socio-environmental factors or reinforcers in the environment that contribute to and maintain chronic pain and often addresses physical, interpersonal, and occupational functioning (Keefe, 2015). Finally, surgeries and pharmacological therapies attempt to address the somatic aspects of the pain experience with small to moderate effects on disability and pain severity outcomes (Chou et al., 2017).

Collectively, evidence suggests that most treatments are effective at some level but almost without exception, more robust outcomes result from a combination of interventions (Dale & Stacy, 2016; Kaiser, Mooreville, & Kannan, 2016), collaborative care models, and multidisciplinary intervention programs (Kamper et al., 2015) that inherently address an increased number of factors that impact the persistence of pain. However, a closer and broader look at these outcome studies suggests that integrated program effects are also variable and inconsistent. A meta-analysis of randomized controlled and controlled trials examined data from over 462 multidisciplinary rehabilitation pain program studies. It concluded that effects were ambiguous, inconclusive, and, in general, offered weak evidence to support a multidisciplinary approach due to small sample sizes, bias, incomplete or inconsistent measures, or a combination of these factors (Dragioti et al., 2018).

Similarly, Salathé and colleagues (2018) conducted a systematic review of 13 longitudinal studies in Europe examining the treatment effects of multidisciplinary biopsychosocial rehabilitation programs for lower back pain. These authors reported small to moderate short and long-term effects on the level of disability and pain intensity but less evidence for an improved quality of life and ability to return to work. However, these authors acknowledged a deficit in high-quality research design across studies and noted the uneven outcomes were difficult to interpret broadly.

Recently, researchers published a clustered, randomized controlled trial involving 398 participants comparing the effects of a collaborative care program for pain and depression with treatment as usual over 12 months (Aragonès et al., 2019). Results indicated that the program moderately reduced depression scores but did not have a positive effect on overall pain. The authors noted a lack of adherence by participants and physicians as limitations to the study. Taken together, these results seem to suggest, similar to individual treatment programs, collaborative care models, and multidisciplinary biopsychosocial programs, underperform despite the fact they are designed to address the many aspects of pain.

These findings seem to imply an underlying gap exists in the ability to consistently identify and deliver the most effective treatments for chronic pain. This gap may originate from deficits in the level of detail and specificity of the information gathered in the current pain assessment paradigm rather than shortfalls in the type, nature of, or approach to care. It may actually be that a more vigorous and comprehensive assessment could better assist providers with where to begin, what aspects of pain to focus on first, and which intervention approach would be most effective for which individuals, rather than emphasizing self-reported, general measures of pain severity and disability.

A more integrated chronic pain assessment would require healthcare providers and clinical researchers to incorporate assessment measures that consider the multidimensional nature of pain. Patients would significantly benefit from treatment regimens customized to their specific constellation of pain symptoms and circumstances. Other advantages of an updated assessment approach to chronic pain evaluations would likely include better resource utilization, better outcomes, and less disability (Hulla et al., 2019). Such a customized diagnostic may be possible by incorporating a mechanism for quantifying the effect of cognitive, physiological, and psychosocial factors and how these factors contribute to and influence the person's pain experience, as Engel (1977) initially envisioned.

A more reliable pain assessment would necessarily include measures that accurately examine the cognitive and psychosocial dimensions of the pain experience. Results of such an assessment may further reveal important aspects of each individual's unique pain experience. This could allow for the selection of a more effective intervention that could, in theory, systematically target dysregulated aspects of functioning from the most pronounced to least, in order to methodically 'reorganize' the brain, reduce allostatic load, and restore the body/brain to homeostasis.

Such a diagnostic may be possible by objectively assessing the individual's cognitive and psychosocial profile. Unfortunately, while the assessment of pain has received a lot of research attention, the field primarily relies on self-report measures as a primary mechanism for understanding pain rather than an unbiased, standardized cognitive and psychosocial evaluation.

Background in Pain Assessment

Historically, pain severity, intensity, interference, and psychosocial impairment have been assessed via patient report (e.g., structure and semi-structured interviews and questionnaires) and autonomic measures. In most cases, standardized assessment measures have been established to evaluate pain intensity, pain quality, pain location, pain coping, functional impact and interference, as well as pain beliefs, mood, and cognitions (Turk & Melzack, 2011). However, due to the wide range of variables evaluated, considerable variability exists within and across the psychometric strength of measures in each of these dimensions.

A recent systematic review evaluated 61 self-report pain measures for psychometric quality. Though the authors discovered consistently acceptable validity and reliability in pain instruments, little attention to other factors such as measurement error, test-retest metrics, and internal consistency was found. The authors also noted most pain assessment instruments are often conducted in diverse populations (e.g., fibromyalgia, lower back pain, etc.), for specific purposes, and with small sample sizes, calling into question the generalizability of the findings (Mehta, Claydon, Hendrick, Cook, & Baxter, 2015).

Self-Report Assessment

Historically, the initiative on methods, measurements, pain assessment in clinical trials (IMMPACT), and the European Federation of Neurological Societies (EFN) have published guidelines for the assessment of pain by outlining the most important domains to consider and related assessment tools (Dworkin et al., 2005; Cruccu et al., 2010;). Pain researchers have published a similar set of criteria for selecting the most appropriate pain assessment based on clinical or research objectives, patient population, or outcomes (direct or indirect) being evaluated (Turk & Melzack, 2011). While such guidelines and criteria are useful, the inconsistent application and lack of allegiance to a standardized measure remains a challenge in the assessment of pain.

A more recent study identified the patient-reported outcomes measurement information system (PROMIS) measures, established by the National Institute of Health (NIH) in 2004, as the "gold standard" in pain assessment (Licciardone, Kishno, Worzer, Hartzell, & Gatchel, 2017). The authors recognized the need to standardize pain assessment and concluded the PROMIS measures could meet this objective due to the level of accessibility, robust psychometrics, and generalizability of the measures. The PROMIS measures utilize t-scores and have been normed against the general populations with a clinical sample. The PROMIS measures utilize patient-reported (i.e., self-report) responses to questions from the domains of pain interference, impairment in functioning, social functioning, pain behavior, and pain severity (NIH, 2019). According to the most recent publication on the PROMIS website, these measures have been used in over 1,000 publications and on an international basis.

Although the PROMIS measures have relative strengths, other researchers argue that these measures fall short of measuring the biopsychosocial factors contributing to the experience of chronic pain. Bruns & Disorbio (2014) introduced the Battery for Health Improvement 2 (BHI2) based on the Vortex Model of pain. The Vortex Model, an extension of Engel's Biopsychosocial Model (1977), attempts to explain the etiology of chronic pain and attributes the development of the condition to illness and injury risk factors (e.g., unhealthy lifestyle, genetic predisposition, stress, etc.) psychological vulnerabilities (e.g., history of depression, characterological profile, the tendency towards somatization, etc.) and psychosocial vulnerabilities (e.g., lack of support, history of trauma, secondary gain, etc.). Through the BHI2, the authors sought to establish a comprehensive and reliable measure for assessing the full range of the patient's symptoms and facilitate more effective diagnosis and treatment (see Bruns & Disorbio, 2014 for a full review).

Self-report psychological pain measures, such as the PROMIS measures (Licciardone, Kishno, Worzer, Hartzell, & Gatchel, 2017), have been deemed the 'gold standard' (Dworkin et al., 2005) and extensively studied. These measures provide an important but incomplete understanding of the pain experience resulting from the inherent obstacles involved in patient-reported outcomes. Such obstacles include challenges with social desirability bias (Logan, Claar & Scharff, 2008), response bias (Robinson et al., 1997), as well as malingering and exaggeration (Tuck, Johnson & Bean, 2019). Additional assessment approaches such as examining language use patterns may offer incremental information and unique value by enhancing our understanding of the cognitive processing and psychosocial aspects of the chronic pain experience. This may be a critical option as natural language use is not subject to the same interference or distortion that patient-reported outcomes are.

Natural Language Use

Previous research on the use of language as an indicator of pain has been restricted to studies examining the language of pain catastrophizing (Jungaenel, Schneider & Broderick, 2017), cognitive reappraisal (Alparone, Pagliaro & Rizzo, 2015), and general physical health (Campbell & Pennebaker, 2003) rather than utilizing language as a diagnostic indicator. Though research into the language of the patient has been suggested as a new direction for improving clinical outcomes across medical settings (Poindexter, Koithan & Bell, 2009), to date, this avenue has not extensively been explored.

The science of language is the study of how humans communicate and understand meaning. It does this by examining how words influence and reflect internal and external processes and behavior, as well as social interaction and connectivity (Krieger & Gallois, 2017; Mehl & Pennebaker, 2003). The average English-speaking person speaks 150-160 words per minute (Yuan, Liberman, & Cieri, 2006) and is exposed to 14 million words per year (Moore, 2003). There is a large body of scientific literature that reveals how an understanding of the content (i.e., what is said) and style and structure (i.e., how it is said) of language can inform our understanding of how people think, feel, process information, connect with others, and cope with difficulties.

Natural language use research methodology was introduced in the mid 1990's with groundbreaking experimental work by James Pennebaker and his research team at the University of Texas at Austin. Pennebaker published the first in a series of studies that demonstrated that engaging in expressive writing was associated with better health outcomes (Pennebaker & Seagal, 1999). His findings were replicated across cultures in over a dozen different studies (Pennebaker & Graybeal, 2001). As Pennebaker continued to explore the characteristics and dimensions of individual linguistic style, he and his research lab at UT developed computer software called the Linguistic Inquiry Word Count (LIWC). This software automated word counting by assigning each word in written text to a program-based dictionary. The resulting dictionaries were created using a panel of judges and interrater comparisons that determine how a word would be categorized across 80 dimensions (See Chung & Pennebaker, 2007 for a detailed review). According to Pennebaker and colleagues, "word use is a meaningful marker and occasional mediator of natural social and personality processes" (Pennebaker, Mehl & Niederhoffer, 2003 p. 548).

These insights are collected by capturing an individual's natural use of language in a non-intrusive way that is not reliant on self-report and therefore not vulnerable to the same response bias (e.g., social desirability, acquiescence; test bias) generally recognized in the use of self-report assessment measures (Arnold & Feldman, 1981; Hill et al., 2018; Hu & Rahnev, 2019; Schriesheim & Hill, 1981). Natural language analysis is able to predict social status (Kacewicz, Pennebaker, Davis, Jeon & Graes, 2014), personality traits like overconfidence and narcissism (Holtzmann et al., 2019), need states (Pennebaker & King, 1999), acts of deception (Newman, Pennebaker, Berry & Richards, 2003), overall health status (Ziemer & Kormaz, 2017), mental distress (Lyons, Deniz, Aksayli & Brewer, 2018), and depression (Tackman et al., 2019). Natural language use analysis is also able to identify linguistic indicators (e.g., use and the number of specific words and utterances) that signal distinct psychological processes such as psychological distancing (Nook, Schleider & Somerville, 2017) and psychological change (Cohen, Mehl & Pennebaker, 2004).

Studies examining linguistic style have a simple but eloquent format that, in most cases, utilizes the LIWC software to generate quantitative linguistic profile scores across 80 language dimensions and correlate these dimension scores with reliable measures of the primary variable being studied such as the Beck Depression Inventory (Beck & Steer, 1990) for depression. Language dimensions include 21 standard linguistic categories computed by identifying the percentage of words in the text that are pronouns, articles, auxiliary verbs, etc., over the total words used in the narrative sample. These standardized dimensions (i.e., function words, time orientation, drives) allow for an objective measure of the structure and function of the words contained in an individual's language pattern. In addition, and interestingly, among these dimensions, there are 41 additional word categories tapping psychological constructs (e.g., affect, cognition, biological processes), six personal concern categories (e.g., work, home, leisure activities), five informal language markers (assents, fillers, swear words, netspeak), and 12 punctuation categories (periods, commas, etc.). LIWC dictionaries have been developed for Spanish, German, Chinese, and many other languages. It is recommended that language analysis is conducted using a language dictionary native to the speaker and narrative text of at least 300 words for the highest level of accuracy. (For a full review of the dictionary and software details, see Pennebaker, Boyd, Jordan & Blackburn, 2015).

Language use and chronic pain. Remarkably, relatively few studies have examined linguistic style in people suffering from chronic pain. Nevertheless, those studies that have been published illustrate the opportunity for future exploration of linguistic style as a marker for chronic pain conditions. In a study of participants with chronic pain, researchers administered the Pain Catastrophizing Scale, the NEO Personality Inventory (NEO-PI-R), and the Multidimensional Pain Inventory (MPI) and collected writing samples related to participant's life with chronic pain. The authors identified small to moderate correlations between pain catastrophizing and greater use of first-person singular pronouns (e.g., I, me, my), more pronouns referencing others (e.g., they, them, he) as well as negative emotions words (e.g., hurt, ugly, nasty) and anger (e.g., hate, killed, annoyed). Regression models using a composite of the significant linguistic dimensions accounted for 13% of the variance in models predicting pain catastrophizing after accounting for pain severity, neuroticism, gender, age, and length of writing sample. The authors interpreted their results as confirmation that pain catastrophizing can be detected via linguistic style. Individuals with high levels of pain catastrophizing have a heightened attentional bias on themselves (e.g., high use of personal pronouns) as well as sensitivity to others (e.g., use of third-person pronouns) (Junghaenel, Schneider & Broderick, 2017).

Similar to autonomic outputs, language style is not governed by conscious awareness. Pennebaker (2011) outlined the subtle social, cultural, and relational aspects of how function word use signals psychological states. These included attentional focus (indicated by use of pronouns and verb tense) and social relationships and emotions (implied by use of articles and emotion words). Finally, perhaps most importantly, thinking styles illustrated by the use of prepositions, nouns, and causal words (for a full review, see Pennebaker, 2011).

Given the complexity of quantifying the multidimensional factors in chronic pain assessments, it is theoretically possible that language style may allow for an unobtrusive approach toward assessing an individual's cognitive processing, social connectedness, and relational status resulting from systemic alterations in physiological, cognitive, and psychological functioning induced by experiencing persistent pain over time. This incremental information might help identify important links between word use and linguistic style and symptoms, outcomes, and/or markers for identifying specific aspects of chronic pain such as attentional bias, catastrophizing, mood dysregulation or dominance of fear, and maladaptive cognitive appraisal processes.

Summary, Purpose, and Hypotheses

Chronic pain is a significant problem in the United States, and the most prevalent treatment for pain (opioid therapy) has severe side-effects that, with prolonged use, can lead to addiction and even death. Although empirical evidence exists for alternative and much safer non-pharmacological treatments, the inconsistency in effectiveness and treatment protocols and complexity of the chronic pain experience evade a clear solution. Clinicians and researchers acknowledge the need for a more precise assessment of pain that encompasses many elements of functioning, including the cognitive, affective, emotional, and environmental contingencies implicated in treatment. Past efforts to establish reliable predictors, profiles, and physiological models of pain continue to frustrate progress in better addressing this condition. Furthermore, fundamental distinctions and divisions between medical and psychological paradigms have acted as barriers to progress as chronic pain spans both domains, but the existing research is not synthesized, and key findings across disciplines and areas of expertise are rare.

The proposed research study addresses the need for a more comprehensive assessment protocol to evaluate chronic pain conditions. The primary aim of this pilot study and exploratory design is to compare the language style and word use of chronic pain patients with population data to identify group differences as well as determine if language dimensions (e.g., function word use, affective words, or cognitive process words, etc.) predict pain outcome variables (i.e., persistence, severity, interference, intensity, etc.).

Hypothesis

The author hypothesizes the following; (1) significant differences in word use patterns and linguistic style will be observed between chronic pain patients and the general population; (2) differences in linguistic style will highlight differences in cognitive and emotional functioning often observed in the literature (i.e., increased patterns of catastrophizing, rumination and depression, attentional bias, fear appraisal, etc.) and (3) differences in word use patterns from the general population will predict pain outcomes.

Chapter III: Methods

Participants

Participants were 31 chronic pain patients (11 male and 20 female) recruited from a community neurology clinic. They were 54.4 (*SD* = 11.5) years old on average. The majority of the participants (58.6%) self-identified as White, with another 20.7% self-identifying as Black, 10.2% as Hispanic, and 6.9% Asian.

Measures

PROMIS. The first scale included the Patient-Reported Outcomes Measurement Information System (PROMIS) measures designed to address pain symptoms across eight domains including physical function, depression, anxiety, fatigue, pain interference, pain intensity, satisfaction with participation in social roles, and sleep. These measures have demonstrated acceptable validity as patient-outcome measures based on item response theory (IRT) and are often referred to as the 'gold-standard' in intervention effectiveness studies (Cook et al., 2016). All scores are anchored to a representative US population (*M* = 50 and *SD* = 10), use 'past 7 days', and use 5-point Likert scales for item responses. These measures have demonstrated high internal consistency (α = .98) on physical and mental health factors as well as a factor structure that correlates well to other health-quality measures (Hays, Spritzer, Schalet, & Cella, 2018)

The PROMIS 29 Profile is a 29-question assessment designed to assess for level of physical functioning, anxiety, depression, fatigue, sleep, participation, pain interference, and intensity in the 'past 7 days' with a series of questions. Examples of these questions include 'Are you able to run errands and shop' with participants selecting 1 = without any difficulty, 2 = with a little difficulty, 3 = with some difficulty, 4 = with much difficulty, and 5 = unable to do so. This measure has demonstrated high internal consistency (α = .98) on physical and mental health (α = .97) factors as well as a factor structure that correlates well to other health-quality measures (Hays, Spritzer, Schalet, & Cella, 2018). This measure demonstrated high internal consistency (α = .90) on the study sample as well.

The PROMIS Pain Interference Profile is a 40-item assessment designed to assess in considerable detail the level of interference pain has on specific activities as well as how the individual feels about this interference. Examples of these questions include ‘How often did your pain keep you from socializing with others?’ and “How often did was pain distressing to you” with participants selecting 1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = always. This measure also assesses for specific impact to the amount of time pain interfered including questions such as “How often did pain prevent you from sitting for 10 minutes” and “How often did pain keep you from standing for more than 30 minutes” allowing for an understanding of the level and nature of impaired functioning and disability. This measure has also demonstrated high internal consistency (α = .99), and items are strongly correlated with other known pain measures such as BPI Interference subscales (rho = .90) and SF-36 Bodily Pain Subscale (rho = -84) (Amtmann et al., 2011). Similar to the PROMIS 29, this measure demonstrated high internal consistency (α = .92) in the study sample.

The PROMIS Pain Behavior Profile is a 36-item questionnaire designed to assess the behavioral patterns of individuals suffering from chronic pain. Examples of these questions include “When I was in pain, I used a cane or something else for support” or “when I was in pain I grimaced” with the participant selecting 1 = Had no pain, 2 =

never, 3 = rarely, 4 = sometimes, 5 = often and 6 = always allowing for an understanding of how the individual responds behaviorally to their pain symptoms. This measure has also demonstrated high internal consistency (α = .98) and items had acceptable correlations with self-reported pain intensity scores .68 (p = .001) and -.48 (p = .001) (Revicki et al., 2009). The internal consistency (α = .79) for this measure was lower than the others for the sample but within the acceptable range.

The Battery for Health Improvement 2. The Battery for Health Improvement 2 (Bruns & Disorbio, 2015) is composed of the following scales: Defensiveness, Pain Complaints, Somatic Complaints, Functional Complaints, Depression, and Anxiety, Self-Disclosure, Borderline Traits, Family Dissatisfaction, Chronic Maladjustment, and Job Dissatisfaction. These scales represent the majority of known factors to impact the course of chronic pain. These additional scales will provide a more comprehensive view of each participant the PROMIS battery does not include or address. BHI2 test authors reported individual internal consistency scores for each dimension above with a range (α = .97 to α = .81). Similarly, authors found moderate to high correlations with the SF-36 Function Pain Sensitivity Scale *(r* = -.64) and McGill Pain Questionnaire (r = .74) respectively (Bruns & Disorbio, 2015). This measure also demonstrated high internal consistency (α = .92) for the study sample.

Procedure

Each participant was pre-screened for participation in the study by the licensed neurologist to determine if the patient has chronic pain syndrome defined by having consistent pain for six months or longer. Referred participants partook in the informed consent process detailed in the overall procedural and methodological proposal approved by the Nova Institutional Review Board (2018-240) that included a verbal explanation of the project and required a signature of the participant. Signed informed consent documents are on file in a HIPPA-compliant locked cabinet on site at the sponsoring neurology clinic. For the purpose of the study, participants were excluded if they experienced a traumatic brain injury, were actively suicidal, or suffered from cancer-related pain.

Participants were then administered a brief demographic survey to collect age, gender, race, and education. Next, the battery of psychometric tests was administered, including several assessments from the patient-reported outcomes measurement information system (PROMIS) funded by the NIH (Cella et al, 2010). The specific assessments administered included: the Promis -29 Profile, Pain Interference, and Pain Behavior scales. Participants were also administered the Battery for Health Improvement 2 (Bruns & Disorbio, 2015), a comprehensive self-report biopsychosocial evaluation for patients with chronic pain. Participants were then asked to provide a 300-word minimum response to the following prompt: "*Please think about your life and injury and/or overall pain. How has your life changed since you have been experiencing pain? Feel free to include details about your daily activities, mood, thoughts, feelings and quality of life and family may have been impacted*". Participant verbal responses were transcribed by a Research Assistant and captured in a Microsoft Word document until the 300-word minimum was met. Research Assistants were instructed to capture exact word use, utterances, and slang.

The text was then analyzed by the Linguistic Inquiry and Word Count program (LIWC; Pennebaker, Boyd, Jordan & Blackburn, 2015). This software counts and analyzes the use of pronouns, conjunctions, articles and auxiliary verbs (function words) and nouns, regular verbs and adjectives (content words) to establish patterns of language use, cognitive mechanisms, social connectedness, and emotional valence across 80 dimensions and word categories (Pennebaker et al, 2015). Percentage scores for each dimension and text category were computed for each verbal response.

Psychometric scores, demographic information, and each participant's narrative was captured in an online, secured RedCap database. Raw scores and t-scores were calculated based on the normative data provided by publishers (Health Measures and Pearson) for the PROMIS measures and the BHI2.

All procedures took place at the local neurology clinic. The assessments were administered by Research Assistants. All Research Assistants were clinical psychology doctoral students who had received training for the administration of all measures. All tests were administered from an electronic tablet.

Statistical Analysis

First, descriptive statistics were conducted for demographic variables. Next descriptive statistics were conducted to determine the distribution, normality, and central tendency of the pain outcome measures, and group differences were examined by gender, age, education, social support, and race. Next, a z-test for means was conducted comparing the mean for the language dimension scores of the chronic pain sample to the normed grand mean value of the population and standard deviation (Pennebaker et. al, 2015).

Based on the results of the z-tests, a composite variable, *Chronic Pain Language* (CPL), was created by combining the dimension category scores (i.e., function, grammar, affect, social, cognitive process, perceptual process, drives and needs, biological processes and time orientation) where statistical differences between the sample and the population were observed. Given previous work in this area, a *Cognitive Processing Composite* (CPC) variable was also created by isolating and combining only the cognitive processing dimension category scores where statistically significant differences between the sample and the population were observed.

In order to test the role of chronic pain language (CPL) and cognitive processing composite (CPC) in predicting pain outcomes (e.g., severity and overall impact), two hierarchical regression models were estimated. In the first model (Model 1), the CPL variable will be used to predict pain severity and overall pain outcomes. Age and education were included as covariates in the model to account for group differences. In the second model (Model 2), the cognitive processing composite variable (CPC) was used to predict pain severity and overall pain outcomes. (See Figure 1. for additional details).

Figure 1. Analytic Plan

Research question	Statistical Test	Description
Describe sample used in the study.	Descriptive statistics of sample and pain outcome variables	• Age, gender, education, race, social support • Pain severity and pain outcomes
Are there differences in pain outcomes by group?	t Test statistic to test group differences by covariates	• Differences of pain outcomes by gender, education, social support and race
Are there significant differences in language use between chronic pain patients and the population?	z Test statistic to test group differences vs. population	• Differences of language dimensions when compared with population data (M, SD) including effect size
Do observed differences language use predict pain outcomes?	Hierarchical regression computed with covariates in step 1 (age, education and depression scores) and step 2 language variable (CPL, CPC)	• Language composite variable created by computing total for all language categories where differences were observed • Chronic pain language composite variable (CPL) = composite of all language dimensions statistically different than language use observed in general population
Does the language of pain catastrophizing predict pain outcomes?	Hierarchical regression computed with covariates in step 1 (age, education and depression scores) and step 2 language variable (CPC)	• Cognitive processing composite variable (CPC) variable. CPC = composite of causation, tentative, differentiation and certainty language dimensions based on literature for pain catastrophizing

Chapter IV: Results

First, descriptive statistics were conducted for demographic variables to determine the distribution, normality, and central tendency of the pain outcome measures (Table 1). The sample ($N = 31$, 64.5% female, $M_{age} = 54.4$, $SD = 11.5$) reported moderate to high levels of pain at time of testing ($M = 6.2$, $SD = 2.6$) and pain intensity ($M = 7.1$, $SD = 1.8$) over the past 7 days as well as an elevated level of pain interference and disability ($M = 67.4$, $SD = 5.3$). Group differences in pain outcomes were examined by gender, age, education, race, and social support using t-test and analysis of variance (ANOVA) analyses. Significant differences were observed in pain outcomes by education ($F(3, 26) = 3.884$, $p = .021$, $\eta^2 = .318$). However, no systematic differences were observed by gender($t(29) = 1.210$, $p = .24$, $d =.45$), race ($F(3, 26) = 2.031$, $p = .134$, $\eta^2 = .19$), or social support ($F(3, 27) = 0.331$, $p = .803$, $\eta^2 = .04$). Assumption analyses included histograms of all dependent variables to assess for outliers and an examination of the data for skewness and kurtosis. Data were normally distributed with the exception of the pain behavior variable, which must be interpreted with caution. For each dependent variable, there was homogeneity of variances, as assessed by Levene's test for equality.

Table 1. Demographic Characteristics of Participants (N = 31)

Characteristics	*n*	%
Sex		
Female	20	64.5
Male	11	35.5
Race		
White	19	61.3
African American	6	19.4
Hispanic	3	9.7
Asian/Pacific Islander	2	6.5
Education		
Less than high school	6	19.4
High school graduate	4	12.9
Some college	12	38.7
College graduate	8	25.8
Social Support		
Single, Never Married	4	12.9
Married, Cohabitating	14	45.2
Divorced, Widowed	11	35.5

*Note. A*ge ($M = 54.4$, $SD = 11.5$)

Primary Aim 1: Compare the language style and word use of chronic pain patients with population data to identify group differences.

A z-test for means was conducted comparing the mean for the language dimension scores of the sample to the normed grand mean value of the population (Pennebaker et. al, 2015). The results were statistically significant, with effect size ranging from small to very large (d = .31 – 4.87) for 65 of the 82 linguistic dimensions analyzed, as illustrated in Table 2. Individuals in the chronic pain sample used more words in 43.9% or 36 of the language categories, while they used less in only 29 categories or 35.3%.

The sample used the 1st person singular (I, me, mine) (M = 12.0, SD = 2.8) more than twice the number of the population (M_{μ} = 5.0, SD = 2.5). The differences with the strongest effect size included more health ($d = 4.87$), negative emotion ($d = 2.32$), feeling ($d = 4.72$), causation ($d = 4.87$), risk focused ($d = 1.23$), and present focused ($d = 1.77$) words as well as more conjunctions (e.g., and, but), negations (no, not, never) and many other dimensions. Interestingly, sample scores were significantly higher on a composite of authenticity ($d = 2.04$) measuring deception and honesty. In contrast, the sample used significantly less 3rd person singular ($d = -1.01$), social processes ($d = -1.48$), see (d = -0.85), affiliation ($d = -0.60$), future focused ($d = -0.53$) and work-oriented words ($d = -0.74$). Sample scores were also significantly lower on composite variables reflecting social status ($d = -2.67$) and abstract thinking ($d = -1.47$) than the population.

Table 2. Language Difference Dimensions Observed Between Chronic Pain Patients and Population

Language Dimensions	*Sample M (SD)*	*Population M (SD)*	*p*	*d*
Function Words	59.8 (3.6)	51.9 (5.1)	.000	**1.54**
1st Person singular (I, me, mine)	12.0 (2.8)	5.0 (2.5)	.001	**2.85**
Negations (no, not, never)	3.2 (1.7)	1.7 (0.9)	.000	**1.75**
Conjunctions (and, but, where)	7.6 (2.0)	5.9 (1.6)	.000	**1.07**
Auxiliary words (am, will, have)	10.2 (2.3)	8.5 (2.0)	.000	**0.84**
Impersonal pronouns (it, it's, those)	6.6 (2.2)	5.3 (1.6)	.000	**0.84**
Common adverbs (very, really)	5.8 (1.8)	5.3 (1.6)	.045	**0.31**
1st Person plural (we, us, our)	0.2 (0.4)	0.7 (0.8)	.000	**-0.66**
2nd Person (you, your, thou)	0.7 (1.2)	1.7 (1.4)	.000	**-0.77**
Articles (a, an, the)	5.1 (1.5)	6.5 (1.8)	.000	**-0.80**
3rd Person singular (she, her, him)	0.3 (0.6)	1.9 (1.5)	.000	**-1.01**
3rd Person plural (they, their, they'd)	0.5 (0.5)	0.7 (0.6)	.143	-0.19
Prepositions (to, with, above)	13.0 (2.4)	13.0 (2.0)	.460	.018
Other Grammar				
Common verbs (eat, come, carry)	19.9 (3.1)	16.4 (2.9)	.000	**1.18**
Comparisons (great, better, best)	3.3 (1.5)	2.23 (1.0)	.001	**1.15**
Quantifiers (few, many, much)	2.8 (1.3)	2.0 (2.8)	.000	**0.94**
Numbers (second, thousand)	1.1 (0.9)	2.1 (2.0)	.005	**-0.47**
Interrogatives (how, when, what)	1.6 (0.9)	1.64 (0.8)	.420	0.03
Common adjectives (free, happy)	4.8 (1.7)	4.5 (1.3)	.083	0.25
Psychological Processes				
Negative emotion (hurt, ugly, nasty)	4.4 (1.9)	1.8 (1.1)	.000	**2.32**
Sadness (crying, grief, sad)	0.7 (0.6)	0.4 (0.4)	.000	**0.75**
Affective process (happy, cried)	7.0 (2.1)	5.6 (2.0)	.000	**0.68**
Family (daughter, dad, aunt)	0.8 (0.7)	0.4 (0.6)	.003	**0.51**
Anxiety (worry, fearful)	0.4 (0.6)	0.3 (0.3)	.020	**0.38**
Social processes (mate, talk, they)	4.8 (2.3)	9.7 (0.3)	.000	**-1.48**
Male references (boy, his, dad)	0.5 (0.7)	1.7 (1.3)	.000	**-.087**
Positive emotion (love, nice, sweet)	2.4 (1.2)	3.7 (1.6)	.000	**-0.77**
Friends (buddy, neighbor)	0.1 (0.2)	0.4 (0.1)	.000	**-0.72**
Female reference (girl, her, mom)	0.3 (0.4)	1.0 (0.3)	.001	**-0.56**
Anger (hate, kill, annoyed)	0.1 (0.1)	0.1 (0.3)	.235	-0.13

Perceptual Processes				
Feeling (feel, touch)	3.1 (1.8)	0.6 (0.5)	.000	**4.72**
See (view, saw, seen)	0.3 (0.4)	0.8 (0.6)	.000	**-0.85**
Hear (listen, hearing)	0.3 (0.4)	0.8 (0.6)	.000	**-0.79**
Cognitive Processes				
Causation (because, effect)	2.7 (1.1)	1.4 (0.7)	.000	**1.72**
Tentative (maybe, perhaps)	3.7 (1.6)	2.5 (1.1)	.000	**1.05**
Differentiation (hasn’t, but, else)	4.1 (1.6)	3.0 (1.2)	.000	**0.95**
Certainty (always, never)	1.7 (0.7)	1.4 (1.7)	.003	**0.50**
Insight (think, know)	2.2 (1.1)	2.2 (1.1)	.370	0.06
Discrepancy (should, would)	1.5 (1.0)	1.4 (1.5)	.382	0.06
Drives and Needs				
Risk focus (danger, doubt)	1.0 (0.7)	0.5 (0.4)	.000	**1.23**
Reward (take, prize, benefit)	2.0 (1.1)	1.5 (0.8)	.000	**0.66**
Achievement (win, success, better)	1.8 (1.1)	1.3 (0.8)	.000	**0.61**
Affiliation (ally, friend, social)	1.3 (1.2)	2.1 (1.3)	.000	**-0.60**
Power (superior, bully)	1.9 (0.9)	2.4 (1.9)	.010	**-0.43**
Biological Processes				
Health (clinic, flue, pill)	3.8 (1.4)	0.6 (0.7)	.000	**4.87**
Body (cheek, hands, spit)	1.8 (0.9)	0.7 (0.6)	.000	**1.65**
Sexual (horny, love, incest)	0.1 (0.1)	0.1 (0.1)	.073	-0.27
Ingestion (eat, dish, pizza)	0.4 (0.5)	0.6 (0.8)	.077	-0.26
Time Orientation				
Present focus (today, is, now)	14.9 (4.0)	10 (2.8)	.000	**1.77**
Future focus (may, will, soon)	0.9 (0.7)	1.4 (0.9)	.002	**-0.53**
Past focus (ago, did, talked)	3.9 (2.1)	4.6 (2.1)	.017	**-0.39**
Relativity				
Time (end, until, season)	6.2 (2.0)	5.5 (1.8)	.010	**0.43**
Motion (arrive, car, go)	2.5 (1.1)	2.2 (1.0)	.029	**0.35**
Space (down, in, thin)	6.8 (1.9)	6.9 (2.0)	.420	**-0.04**
Personal Concerns				
Home (kitchen, landlord)	0.7 (0.7)	0.6 (0.6)	.046	**0.31**
Work (jobs, majors, xerox)	1.2 (0.7)	2.6 (1.8)	.000	**-0.74**
Money (audit, cash, owe)	0.2 (0.3)	0.7 (0.8)	.001	**-0.57**
Leisure (cook, chat, movie)	0.9 (0.8)	1.4 (0.9)	.012	**-0.41**
Religion (altar, church)	0.1 (0.3)	0.3 (0.6)	.036	**-0.32**
Death (bury, coffin, kill)	0.1 (0.2)	0.2 (0.3)	.199	-0.15

Summary Variables				
Clout (relative status)	11.2 (11.1)	58.0 (17.5)	.000	**-2.67**
Analytic (abstract thinking)	30.6 (9.8)	56.3 (17.6)	.000	**-1.47**
Authentic (honesty vs. deception)	91.8 (20.6)	49.2 (20.9)	.000	**2.04**
Emotional Tone (>50 negative tone).	15.4 (18.8)	54.2 (23.7)	.000	**-1.64**

Note. One sample z test computed using grand mean and standard deviation provided by LIWC Language Manual (Pennebaker et. al, 2015).

Primary Aim 2: Determine if language dimensions (e.g. function word use, affective words, or cognitive process words, etc.) predict pain outcome variables.

Three hierarchical regression models were used to test the relationship between a series of chronic pain outcomes. In the first step, age and education were used to predict the highest pain score. Based on the results of the group differences tests and the existing literature, age, education and depression were included in the first block of the model to control for the impact of each variable on pain outcomes. The CPL variable was added in the second block (see Tables 3 for details). An analysis of standard residuals was carried out, which showed that the data contained no outliers (Std. Residual Min = -1.712, Std. Residual Max = 2.05). Tests to see if the data met the assumption of collinearity indicated that multicollinearity was not a concern (CPL, Tolerance = .79, VIF = 1.09). The normal P-P plot of standardised residuals showed points that were not completely on the line, but close. Each test of assumptions was conducted for models 2 (Std. Residual Min = -1.859, Std. Residual Max = 2.35, Tolerance = .92, VIF = 1.27) and 3 (Std. Residual Min = -1.76, Std. Residual Max = 2.04, Tolerance = .92, VIF = 1.08) with similar results.

Results revealed the chronic pain language composite variable (CPL) was significant in predicting the highest pain (ΔF (1, 26) = 19.4, $p = .000$, $\Delta R^2 = .319$), range of pain reported (ΔF (1, 26) = 7.35, $p = .005$, $\Delta R^2 = .162$), and pain at time of testing reported (ΔF (1, 26) = 7.35, *p* = .005, ΔR^2= .162), accounting for between 16.2% and 32% of the variance in each of the models.

Table 3. Hierarchical Regression Analysis Predicting Pain Severity and Disability With Chronic Pain Language Variable

Step and predictor variable Pain Severity	R^2	ΔR^2	*sr*	β
Step 1	.25*	.25*		
Age			.40*	.44*
Education			.13	-.26
Depression			.10	.31
Step 2				
CPL language variable	.58**	.32**	.57**	.64

Step and predictor variable Pain interference	R^2	ΔR^2	*sr*	β
Step 1	.35*	.35*		
Age			.25	.27
Education			.18	.18
Depression			.58**	.63**
Step 2				
CPL language variable	.41*	.06*	.25*	.28*

Note. sr = semipartial correlation coefficient. * $p < .05$, ** $p < .001$. Chronic pain language composite variable (CPL) = composite of all language dimensions statistically different than language use observed in general population.

In the second group of models (Model 2), the cognitive processing composite variable (CPC) was added to the second block using the same dependent variables in model 1. Results indicated the cognitive processing variable only predicted pain at the time of testing (ΔF (1, 26) = 2.68, *p* = .038, ΔR^2= .071), uniquely accounting for 7.1% of the variance in the model. (See Table 4.). An analysis of standard residuals was carried out, which showed that the data contained no outliers (Std. Residual Min = -2.401, Std. Residual Max = 2.028). Tests to see if the data met the assumption of collinearity indicated that multicollinearity was not a concern (CPC, Tolerance = .92, VIF = 1.09). The normal P-P plot of standardised residuals showed points that were not completely on the line, but close. Each test of assumptions was conducted for all dependent variables in model 2 with similar results.

Table 4. Hierarchical Regression Predicting Pain Severity and Disability With Cognitive Processing Language Variable

Step and predictor variable Pain ATT	R^2	ΔR^2	*sr*	β
Step 1	.24*	.24*		
Age			.40*	.29
Education			-.20	-.20
Depression			.41*	.45*
Step 2				
CPC language variable	.31*	.07*	.27	.28

Step and predictor variable Pain interference	R^2	ΔR^2	*sr*	β
Step 1	.35*	.35*		
Age			.25	.27
Education			.18	.18
Depression			.58**	.63**
Step 2				
CPC language variable	.35*	.00*	-.03	-.04

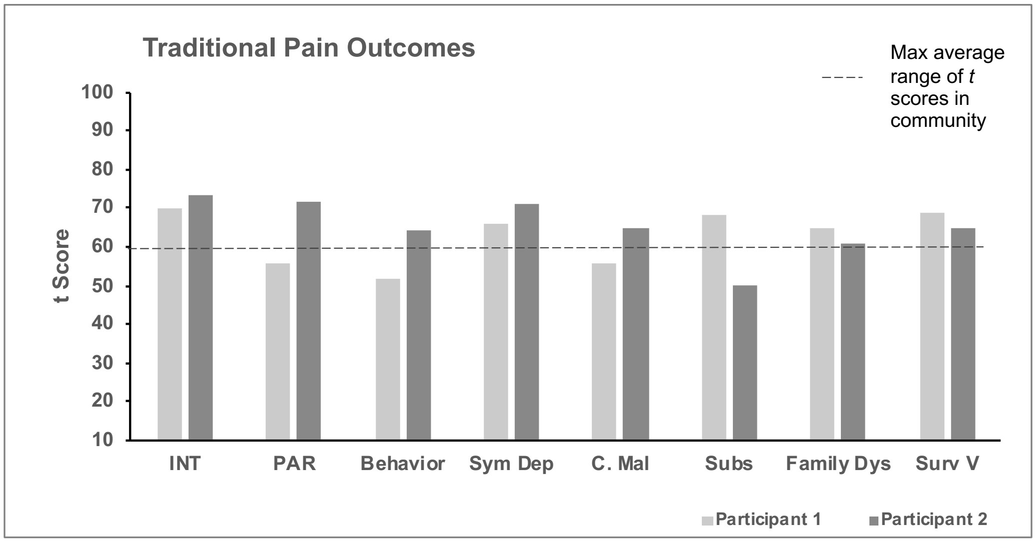
Note. sr = semipartial correlation coefficient. *p < .05, ** p < .001. Cognitive processing composite variable (CPC) variable. CPC = composite of causation, tentative, differentiation and certainty language dimensions. ATT: pain reported at time of testing

In order to test the contribution of cognitive processing to the overall language use in a model predicting pain at the time of testing, a third hierarchical regression analysis was computed (Model 3), including the covariates in the first block, the CPL variable in the second block and the CPC variable in the third block. Model 3 results (F (1, 23) = 23.125, *p* = .000, R^2= .528) were significant and the predictors accounted for 51.8% of the variance in the model. However, a closer look at the model exposed the cognitive processing variable did not account for additional variance in the model (ΔF (1, 23) = .007, *p* = .932, ΔR^2= .007), suggesting the cognitive processing variable is accounted for within the language composite variable rather than a unique contributor to predicting acute pain or pain at the time of testing.

Finally, an exploratory analysis was conducted to explore the potential utility of examining the pain outcome data and language analysis scores at the individual level. Two individual participants were randomly selected based on the chronological number of their research id. Participant data was subjected to individual analysis to determine if language scores would contribute incremental information to an enhanced clinical picture of each participant.

Figure 2. below displays the t scores from the primary PROMIS pain outcome measures as well as the psychosocial composite variables from the BHI-2. Participant 1 is a married, 60-year-old, White, male diagnosed with chronic neck and lower back pain who has been suffering with persistent pain for over 30 years. Participant 2 scores are from a single, 42-year-old, Hispanic, female diagnosed with chronic neck and back pain three years ago.

Figure 2. Individual-Level Pain Disability, Mood & Psychosocial Outcome Measures



Note. INT = pain interference; PAR = participation in daily activities; Behavior = pain behavior; Sym Dep = symptom dependency; C. Mal = chronic maladjustment; Subs = substance abuse; Family Dys = family dysfunction; Surv V = survivor of violence. All scores are t scores within 40 – 60 fall within the average range in community samples.

As seen in Figure 2., both participants reported above average levels of pain interference, symptom dependency, family dysfunction and both endorsed being a survivor of violence. In addition, participant 1 endorsed items suggesting a history of or current substance abuse and chemical dependency. Participant 2 scored in the high range on a measure of chronic maladjustment indicating she has experienced difficulty achieving the expected milestones involved in and stability of an adult life. It should also be noted that both participants reported a pain severity score of 9/10 with 0 indicating no pain at all and 10 the worst pain imaginable. In addition, both participants endorsed clinical levels of anxiety and depression, with participant 1 endorsing higher levels of depression and anxiety levels just above the cut-off and participant 2 endorsing moderately high levels of depression and very high sympotms of anxiety.

To examine the language use of participants, a z-test for means was conducted comparing the mean for the language dimension scores of each participant (i.e., the sample) to the normed grand mean value of the population and the mean of the chronic pain sample from this study (i.e., pain). Only results that were statistically significant when compared with either or both samples are illustrated in Tables 5 and 6 below.

Table 5. Participant 1- Individual Level Language Differences

		Population		Pain Sample	
Language Dimensions	*M*	*M*	*d*	*M*	*d*
Feeling (feel, touch)	1.8	0.6*	2.21	3.1*	-2.50
Drives (affiliate, achieve, reward, risk)	2.8	7.0*	-2.02	7.3*	-2.20
Neg emotion (hurt, ugly nasty)	2.1	1.8	0.19	4.4*	-2.13

Note. Sample above represents a married, 60-year-old, male diagnosed with chronic neck and lower back pain who has been suffering persistent pain for over 30 years.
* *p* < .05, ** *p* < .01, *** *p <.000*

Table 6. Participant 2 - Individual Level Language Differences

Language Dimensions		Population		Pain Sample	
	M	*M*	*d*	*M*	*d*
Sadness (crying, grief, sad)	1.8	0.4***	3.35	0.7**	2.60
Neg emotion (hurt, ugly nasty)	7.0	1.8***	4.73	4.4*	2.41

Note. Sample above represents a separated, 42-year-old, Hispanic female diagnosed with chronic neck and back pain who has been suffering with persistent pain for 3 years.
* $p < .05$, ** $p < .01$, *** $p < .000$

Participant 1 used feeling words three times the number of the the population but significantly fewer than the chronic pain sample in this study. He also used significantly fewer risk-focused words than both the population and the chronic pain group and fewer negative emotion words than the chronic pain sample. These results are consistent with his self-reported depression scores ($t = 73.3$), which indicated a clinical level of depression was present. In comparison, participant 2 used significantly more sadness and negative emotion words than both the population and the chronic pain sample with very large effect sizes ranging from $d = 2.41$ to 4.73. These results are less consistent with PROMIS measures scores of depression and anxiety. The participant endorsed only slightly elevated depression scores ($t = 60.5$) but highly elevated anxiety symptoms ($t = 81.6$). Interestingly, an increased use of cognitive processing or anxiety-related words which would be expected with such an elevated anxiety score, *was not* observed.

Chapter V: Discussion

Given the prevalence of chronic pain, the purpose of the current dissertation study is to address the need for a more comprehensive assessment protocol to evaluate chronic pain conditions. There were three primary aims of the current investigation:

(a) Compare the linguistic style and word use of participants with chronic pain with the population data; (b) Determine if language dimensions (e.g., function word use, affective words, or cognitive process words, etc.) predict pain outcome variables (i.e., persistence, severity, interference, intensity); and (c) Explore if differences in linguistic style highlight differences in cognitive and emotional functioning often observed in the literature (i.e., increased patterns of catastrophizing, rumination and depression, attentional bias, fear appraisal, etc.).

The first aim of the study was to test for differences in language use between the sample and the population. Specifically, it was predicted that individuals with chronic pain would evidence different language use patterns than the population. Results supported this hypothesis, as differences in word use and linguistic style were present with individuals with chronic pain using significantly more of 36 word dimensions and significantly fewer of 25 other dimensions.

Differences in Language Use

Function words. Individuals with chronic pain used significantly more function words, including pronouns, conjunctions, auxiliary verbs, impersonal pronouns, adverbs, articles, and negations, than the population. The most pronounced differences were found in the use of the personal pronouns (e.g., I, me, mine), negations (e.g., no, not, never), and conjunctions (e.g., and, but, where). To illustrate, the sample used personal pronouns approximately three times more than the population. Previous work has identified increased use of the personal pronoun “I” may reflect an increased level of self-consciousness, focus on the self, or the desire to draw attention to self (Pennebaker, 2011). Increased use of personal pronouns has also been observed in people with depression (Choudhury, Count & Horvitz, 2013), lower social status (Kacewicz, Pennebaker, Davis, Jeon, & Graesser, 2009), narcissism (Holtzman et. al, 2017), and negative emotionality (Tackman, et al., 2019).

These factors may influence or account for a portion of the observed differences as people with chronic pain are often more depressed and have lower socioeconomic status than their peers (Alhowimel et al., 2018). However, increased use of personal pronouns could also result from an increased focus and attention to the self, as a consequence of the challenge of living with the stigma of a condition with psychological underpinnings and unverifiable symptoms. People with chronic pain often report feelings of invalidation and associated conflicts with spouses and caregivers (Edmond & Keefe, 2015). This consistent invalidation could increase self-consciousness and maladaptive focus on the self, as reflected in the increased use of personal pronouns. Further, the sample evidenced significantly less use of pronouns referencing other people, which may compound the effect of being self-focused by paying less attention to others as well.

Higher usage of negation words such as no, not, and never has previously been associated with unwillingness, cognitive rigidity, and difficulty detaching from one’s own ideas (Cassidy, Sherman & Jones, 2012) as well as a dismissive attachment style (Cassidy et al., 2012). Cognitive rigidity is described as a cognitive-emotional process that commonly manifests as stubbornness and a heightened level of importance to one’s belief over other's beliefs (Cohen, 2017). The sample used almost twice as many negation words as the population, which may indicate that an important contributor of distress dominant in the group may be related to a higher level of rigidity and lower level of flexibility. Believed to occur along a continuum, increased cognitive rigidity has been identified as a transdiagnostic process that maintains psychopathology across a range of disorders (Morris & Mansell, 2018). These preliminary findings may suggest that chronic pain conditions may be amongst them.

Psychological processes. Chronic pain patients used more negative emotion words than the population and slightly more sadness and anxiety words. Meanwhile, they used fewer positive emotion, social processes (e.g., mate, talk), male and female references, and friend oriented words.

The most pronounced differences in words reflective of psychological processes were in the increased use of negative emotion words. Participants in the study used nearly four times as many words signaling negativity as the population sample. Given that chronic pain patients also used fewer positive emotion words, their word patterns seem to highlight the magnitude of affective differences and negative valence in the sample compared to the average person. In other words, the sample expresses not only more pessimism but also less optimism, which may contribute to the degree to which pain interferes with their mood and daily activities. These results are consistent with ample research that recognizes negative affect as one of the leading predictors of disability in patients with chronic pain (Albrecht et. al, 2019; Evans et al., 2017; Geisser et al., 2000).

The combined use of social process-oriented and positive emotion words has been linked with extraversion (Chen et al., 2020), social interaction, and social connectedness

(Stone & Pennebaker, 2002). The pattern of lower use of these words in individuals with chronic pain may be expected due to the heightened risk of social isolation resulting from functional, interpersonal, and emotional impairment associated with the disorder (Bannon et al., 2021). A brief analysis of the use of this word pairing may allow for a rapid assessment of the degree to which loneliness and disconnection with others contribute to the maintenance of chronic pain as the degree of social support and relationship quality are both known predictors of pain outcomes (Che et al., 2018; López-Martínez et al., 2008; Uysal et al., 2016).

Perceptual processes. The perceptual process dimension incorporates words related to the primary senses, including feeling, touching, and hearing. Prior research has demonstrated that this category of words is associated with avoidance symptoms common in PTSD, and hearing specifically acted as a marker for overall PTSD severity (Paquet & Davis, 2020). Other research examining trauma-related narratives versus group controls identified statistical differences between the use of perceptual processing words. Fernando-Lansac and colleagues (2017) determined participants writing narratives about their trauma experienced more anxiety during the task and used more perceptual processing words than those who wrote about a neutral event. The authors interpreted these and other differences to indicate increased perceptual processing words as signaling the experience of reliving difficult or distress-inducing events. Other studies have interpreted an increased use of perceptual words to increased mindfulness and perceptual acuity (Kaplan et al., 2018). Therefore it seems that context is an important factor for consideration in understanding the implications and applicability of perception words.

The study sample utilized over five times more feeling words (feel, touch) than the general population. This is a significant difference and may suggest that individuals with chronic pain in general feel emotion as well as sensation more often and perhaps in a more pronounced way than their peers. This finding may be partially explained by the fact that individuals with chronic pain exhibit greater pain sensitivity (Studer et al., 2016), which may be related to the changes in the default mode network area of the brain (van Ettinger-Veenstra et al., 2019), as well as hyperalgesia in individuals who have been prescribed opioid therapy (Yi & Pryzbylkowski, 2015). Increased use of feeling words may also be related to the increased emotional reactivity (Koechlin et al., 2018) and decreased emotional regulation and awareness (Lumley et al., 2011) that is often comorbid with chronic pain conditions.

At the same time, the study sample used almost three times fewer seeing and hearing words. This finding may help to understand perceptual differences in this group in a more precise way. While these individuals may tend to feel much more, in combination with an attentional bias toward self (i.e., greater use of personal pronoun I and less use of second person pronouns you and them), they may be less likely to report listening to others or seeing another's perspective. This interpretation is further supported by the paucity in social process words and implied lower level of social connectivity present in the sample. Additional research is needed to validate this assertion.

Cognitive processes. One of the most interesting findings in the study results are the differences in word use and word use combinations that signal identifiable cognitive processes. According to Pennebaker (2011), distinct thinking styles can be detected by examining the use of causal, tentative, differentiation, and certainty-oriented words.

For example, higher usage of both causal and insight words may imply an increased in incidences of cognitive reappraisal. In previous work, higher use of these combined categories in narrative text written about a traumatic event at six different points resulted in improved emotional and physical functioning outcomes (Pennebaker, Mayne, & Francis, 1997). The authors interpreted the results to suggest this word combination signals active cognitive appraisal and processing and promotes movement toward resolution of suffering and distress.

Meanwhile, the extent to which tentative (e.g., maybe, perhaps) and certainty words (e.g., always, never) are used may help illustrate the degree to which insecurity and inflexibility are present. Finally, words indicating differentiation between concepts (i.e., hasn't, but, else) has been associated with cognitive complexity (Pennebaker & Graybeal, 2001).

In the study sample, chronic pain patients used significantly more causal but not insight words, which may suggest they are actively seeking an understanding of the cause of their circumstances, pain, etc., yet are unable to identify a definitive source or find resolution. In combination with the increased use of tentative, differentiation, and certainty-oriented words, it seems that, in general, individuals with chronic pain may spend a disproportionate amount of time thinking about their difficulties but may be unable to identify an effective approach to resolving them.

Drives and needs. The one-sample z test also identified significant differences in the amount of risk, reward, and achievement words use in narratives written by the sample. Participants used twice as many references to risk (e.g., danger, doubt, etc.) than the population. While there is sparse research available on this dimension, it is reasonable to imagine this increase may indicate that individuals experiencing chronic pain would feel a greater sense of danger and doubt in their day to day lives given the constant threat of pain they face as well as the fact that chronic pain is often predicated by a traumatic injury, event or both.

The language dimensions of reward and achievement have been examined in greater detail. Words that signal reward (e.g., take, prize, benefit) and achievement (e.g. win, success, better) have been associated with agency motivation and sensitivity to motivational arousal (Schultheiss, 2013). Individuals with chronic pain often seek pain relief as their primary reward state above previously rewarding stimuli (e.g., interpersonal relationships, occupational success, and recreational activities). When pain relief is repeatedly not achieved over time, the ability to derive pleasure from other activities (via the release of dopamine into the brain) is diminished, which can lead to anhedonia and depression (Elman & Borsook, 2016). With time, neurobiological adaptations to the motivation-reward circuitry and neural networks in the brain are believed to contribute to the resistance to treatment as the sensation of pain can be stimulated by physical as well as cognitive, emotional, and psychological stimuli such as fear, anger, or environmental factors (Apkarian et al., 2009; DosSantos et al., 2017). These adaptations may be reflected in the increased use of these word combinations in this group.

Additional research is needed, but these preliminary findings may indicate that increased achievement and reward-oriented word use could be used to detect neurophysiological alterations as well as act as a measure of the change in reward circuity before, during, and after treatment.

Language Use as a Predictor of Pain

The second aim of the study was to determine if the composite language variable (e.g., chronic pain language variable, CPL representing the sum of all differences in word use patterns from the general population) would predict pain outcomes. The author hypothesized that, if language style is an accurate marker for biological, psychological, and social changes related to a chronic pain condition, it would be expected that language use would predict pain outcomes.

Predictors of chronic pain outcomes. Results from a series of hierarchical regressions indicated that the general chronic pain language composite, as well as a subcomponent variable (e.g., cognitive processing), were able to predict pain outcomes after controlling for known covariates such as age, education, and depression. However, further testing indicated that cognitive processing was not a unique predictor of pain outcomes. This was an important finding as a considerable amount of literature has linked pain severity to cognitive processes such as pain catastrophizing (e.g., rumination, helplessness, and magnification) (Vowles et al., 2007; Wertli et al., 2014; Craner, & Gilliam, et al., 2016; Wolff et al., 2007). The current study's findings are in line with other work that has not observed this association (Craner et al., 2016) and suggest that the relationship between pain cognitions and pain severity is more nuanced. Cognitive processing appears to interact with other state and trait factors such as the presence of negative affect and neuroticism (McHugh et al., 2019; Kadimpati et al., 2015). It seems that isolating a variable uniquely reflecting cognitive functioning does not account for pain severity or disability. This finding makes sense as biological, psychological, and social components alone do not account for the transition from acute pain to chronic pain.

Language use. As hypothesized, the chronic pain language composite variable predicted pain severity and disability outcomes, including the level of the highest pain reported, the range of pain experienced as well pain experienced at the time of testing (i.e., a measure of contextual pain) and pain interference (i.e., a measure of impairment in daily activities and disability). These results seem to suggest the chronic pain language composite is a relatively comprehensive predictor of pain and encompasses the main factors that influence severity and subsequent impairment. This may be due to the integrative nature of the composite language variable. This variable includes word dimension scores along the biopsychosocial continuum and is not subject to self-report bias or cognitive filters.

More specifically, the language composite variable incorporates the status of many known moderators and mediators of chronic pain outcomes, including patient expectancy, personality traits, cognitive bias including attentional, interpretational, and memory bias, as well as coping styles and social support. Patient expectancy and interpretational bias can be accounted for by the degree of negative affect present as well as the positive-negative affect ratio calculated in the emotional tone category dimension. Personality traits such as extroversion/introversion are captured by the combined total of words related to social process, male and female references, as well as friends and positive emotion categories. Attentional bias is indicated by differential use of pronouns, either focusing language use toward or away from self and to or away from others. Coping style is represented by words suggesting cognitive flexibility and/or rigidity.

Social support can be assessed by examining the number of social processes referenced in combination with attentional bias.

Individual-level analysis. The individual-level exploratory analysis examining participant profiles seemed to provide incremental clinical information that with development could potentially lead to a more individualized, targeted treatment planning process. As Figure 2. illustrates, the existing gold standard measures provide a variety of information when compared with community samples, but often do not effectively differentiate symptom profiles between individuals. This may be in part because, like the participant profiles used in the exploratory analysis, this population reports higher incident rates of trauma (Carleton et al., 2018), post-traumatic stress (Akhtar et al., 2019) as well as substance abuse (Hurstak et al., 2017). These factors complicate the overall individual clinical picture and underscore the need for more specific, individualized approach to treatment.

In the example of participant 1, his reduced use of drive-oriented language (affiliate, achieve, reward, risk) in combination with an increased negative tone may signal a dearth in overall motivation and presence of emotional negativity that could suggest an intervention strategy such as motivational interviewing may be indicated even before pain-related treatment is initiated. Given that this participant has suffered from chronic pain for over three decades and endorsed clinical levels of depression, it would make sense that his confidence in recovery and intrinsic motivation may be lower. Lower motivation could also impact overall expectancies and reduce the effectiveness of any treatment modality attempted in his case.

A review of participant 2’s linguistic analysis seems to imply that the participant may suffer from symptoms of depression using over four times the number of sadness-related words than the population and twice as many as the rest of the chronic pain sample. Previous research has noted comorbid symptoms of anxiety and depression are difficult to differentiate via language analysis but individuals with depression and anxiety used more sadness words while individuals with anxiety but no depression used more anxiety words (Sonnenschein et al., 2018). In combination with this participant’s reported history of trauma and difficulties with stability, it would seem that the primary treatment priority may be to address her mood as an important source of pain in her life as well as perform a risk assessment. Interestingly, a review of her PROMIS and BHI-2 self-reported measures would suggest a different path to treatment (via anxiety), which could lead to the utilization of different and potentially less effective interventions and approaches.

Future research is needed to support these assertions and observations. However, it seems that language use analysis does represent an incremental diagnostic tool to assist practitioners and researchers with understanding the chronic pain experience and those factors that maintain it at an individual level.

Clinical Implications

This study has important clinical implications.

Diagnostic tool. Analyzing language data could potentially assist healthcare practitioners in objectively prioritizing and selecting the best treatment approach for the psychosocial contributors to pain. Table 7. illustrates the multi-dimensional and interrelated ways that natural language use could be be interpreted. It seems that there is much to be gained by examining the gestalt of language use differences to gain a clear picture of the differences in psychosocial and cognitive functioning of people with chronic pain as compared to their peers. Previous research offers a rich body of information and word use correlates from which to review and interpret these key findings (Chen et al., 2020; Chung & Pennebaker, 2007; Kacewicz et al., 2014; Pennebaker, 2011; Pennebaker et al., 2003; Pennebaker & King, 1999).

Table 7. Preliminary Interpretation and Implications for Treatment Selection for patients with chronic pain using a linguistic analysis

Function Words	***Chronic pain sample***	***Potential Marker for***	***Preliminary Interpretation***	***Potential Implications***
1st Person singular (I, me, mine)	More	depression, lower social status, narcissism and negative emotionality	Increased self-focus, attentional bias, pessimism	The combined results of these variables may help illustrate attentional bias. Interventions should be selected that balance rather than exacerbate any excessive focus internally versus externally.
2nd Person singular (you, your)	Fewer	Higher status,	Reduced focus on others	
Negations (no, not, never)	More	Stubbornness, cognitive rigidity, dismissive attachment	Cognitive rigidity may promote inflexibility of thought and pain beliefs as well as resistance to new approaches to treatment or alternatives	Interventions that address cognitive flexibility such as Acceptance Commitment Therapy (ACT) may be indicated if prominent in overall contributor to profile.
Psychological Processes				
Negative emotion (hurt, ugly, nasty)	More	Negativity, pessimism	The combination of increased use of negative affect and reduced positive affect may have a profound effect on functioning as well as an important impact on intervention selection.	For individuals that experience reduced or very little positive affect, positive psychology interventions may be indicated to bolster deficits in ability to experience positive emotions while also addressing symptoms of pain, distress and suffering.
Positive emotion (love, nice, sweet)	Fewer	Optimism, positivity		
Social processes (mate, talk, they)	Fewer	Social connectedness vs. isolation, interpersonal functioning and social support	Social process language may act as a marker for measuring the degree to which isolation and lack of social support as well as interpersonal functioning is operative	Interventions such as behavioral therapy, interpersonal psychotherapy, and even psychodynamic therapy may be indicated if impairment in social aspects of life are most pronounced.
Male references (boy, his, dad)	Fewer			
Friends (buddy, neighbor)	Fewer			
Female reference (girl, her, mom)	Fewer			
Perceptual Processes				
Feeling (feel, touch)	More	May signal orientation to primary sensation mode	Increased feeling may be in part due to hyperalgesia and emotional dysregulation with reduced attention to observing surroundings and listening to others	Interventions must be selected carefully at an individual level to determine the nature of impairments. Distress tolerance, emotional regulation, interpersonal communication and relational strategies may be employed here to promote higher level of functioning
See (view, saw, seen)	Fewer			
Hear (listen, hearing)	Fewer			

Cognitive Processes

Causation (because, effect)	More	Increased cognitive appraisal, active cognitive process	Lack of insight words may suggest active processing without resolution (i.e., rumination, catastrophizing)	Interventions designed to address cognitions such as cognitive behavioral therapy may be most effective if this dimension is most out of balance
Tentative (maybe, perhaps)	More			
Differentiation (hasn't, but, else)	More			
Certainty (always, never)	More			

Drives and Needs

Risk focus (danger, doubt)	More	Reward/ achievement associated with agency motivation and sensitivity to motivational arousal, reduced feelings of power and affiliation	Pain relief may act as primary reward, goal but over time lack of success in reaching goal may encourage withdrawal and avoidance as well as reduced agency and connection to others and groups	Mindfulness-oriented recovery enhancement therapy may be indicated in order to actively adjust reward-seeking behaviors. Group interventions may help address deficits in affiliation.
Reward (take, prize, benefit)	More			
Achievement (win, success, better)	More			
Affiliation (ally, friend, social)	Fewer			
Power (superior, bully)	Fewer			

Note. For illustration purposes only. Additional research is needed to validate this interpretation and the assumptions outlined above.

This approach would likely provide the most utility at an individual level as word use may offer a reliable method to ordering and assigning interventions customized for the individual patient. Historically, this has been a significant challenge as traditional self-report assessments provide ample information about pain severity and disability but little information related to the source or etiology of the factors maintaining the condition.

For example, in an individual linguistic profile where significantly higher use of the word "I" and significantly lower use of the word "you" was observed [from both chronic pain and population data] it would broadly suggest a maladaptive level of self-focus. Further investigation into known correlates of excessive attentional focus on the self (e.g., depression, self-esteem, self-efficacy, anxiety, narcissism, etc.) would be warranted as a link between increased use of singular, personal pronouns and each of these factors has been consistently been demonstrated (Bosson et al., 2000; Edwards & Holtzman, 2017; Havigerová et al., 2019; Holtzman et al., 2019). A more comprehensive analysis would include an examination of the expanded linguistic profile including a review of all language dimensions (as illustrated in Table 7). This data in combination with the existing self-reported and psychosocial pain measures may enhance treatment selection protocols by avoiding primary treatment options not designed or intended to address these factors (i.e., surgical interventions or physical therapy) as briefly illustrated in the examples of participants 1 and 2.

Progress monitoring. Word use and linguistic style may also provide a method for improved treatment monitoring strategies for people with chronic pain. Prior research has demonstrated that language analysis methods can detect psychological change at the group (Cohen et. al, 2004) and individual levels (North, Meyerson, Brown, & Holahan, 2013). These studies reveal shifts from negative to positive valence in word choice, increased use of insight words, and directional change in use from past to present words. Furthermore, these methods have shown to be reliable in detecting individual differences in attention, attitudes, and emotions reflecting psychological change over time (Pennebaker, 2011).

It seems reasonable that monitoring differences in chronic pain language composite and the most relevant language dimensions could accurately and reliably reflect changes in overall pain outcomes as well as critical psychosocial factors and cognitive styles that maintain pain conditions. This is an important capability as monitoring symptom and clinical improvement is often tricky because objective measures do not exist for the treatment of chronic pain (Zis et al, 2017), and patient-reported measures do not always effectively account for variability in presentation related to cultural, socioeconomic, gender, or age differences (Nemeroff, 2007; Santor, Gregus, & Welch, 2006).

Although in its nascency, researchers have begun to use such innovative clinical strategies to understand micro-level patterns, experiences, and behaviors as well as monitor the development and course of illnesses like depression. Van der Zanden and colleagues (2014) utilized language analysis techniques within a randomized control trial design to test whether word use predicted changes in severity and specific symptoms of depression following a web-based cognitive-behavioral intervention. The authors found that increased use of discrepancy words (i.e., should and would, etc.) was significantly correlated with a change in levels of depression, and interestingly more social words (i.e., mate, talk, etc.) and lower discrepancy words predicted program adherence from baseline. It could be that language use could act similarly for patients with chronic pain.

Limitations

As with all research, there are limitations to this study. Primarily, this research relied on a small sample size, limiting the generalizability of the findings, posing threats to external validity and difficulties with replicability. The sample used was a convenience sample of individuals with heterogeneous chronic pain conditions, which may also limit the generalizability of this research to other populations.

The population mean and standard deviation data provided by the software publisher was comprised of narrative text derived from varying sources that included blogs, expressive writing, natural speech, NY Times, and Twitter. Each of these sources represents different contexts and formats, and therefore comparisons in language use made to the narrative text collected in this study and the grand mean across all these formats may be somewhat misleading. Furthermore, the prompt used to elicit the narrative text may have influenced the language use of the participants in their responses given the effect size of the increased use of words referencing biological processes and health. However, it should be noted that the prompt would not inadvertently impact the individual's linguistic style (i.e., use of pronouns, and other function words) and the composite linguistic style variable did indeed predict pain outcomes, providing evidence that limits the risk of the prompt's impact as a weakness in the research design.

A final limitation involves the uncertainty related to the directionality of the relationship between chronic pain and language use. The design, hypotheses and statistical analyses in this study tested the ability of a chronic pain variable to predict pain outcomes. While the results of this pilot study confirmed this hypothesis, it may also be true that pain outcomes would predict language use reflecting a bidirectional relationship between these factors. Additional research and statistical testing is indicated to examine the strength and directionality of these variables which may further explain the mechanism behind language change and the interaction of language differences from the population and with pain severity and pain disability outcomes.

These limitations may have influenced the magnitude of differences in some cases, such as the significant differences observed in the biological processes dimension. However, despite these shortcomings, the general findings from the study have merit. Statistical tests accounted for large effects suggesting that even with the confounding factors articulated above, the conclusions observed are valid enough to warrant future exploration. Future studies with a larger, more homogenous population would allow additional insight into the utility and reliability of these findings. Studies that monitor language use and change over time would yield additional insight into which interventions are the most effective and for whom. Finally, it would be useful to explore the role of each language dimension identified above in more detail to test if they will reliability act as a useful marker for specific etiology and symptom maintenance in assessment, treatment selection, and therapeutic change.

Conclusion

The study of the science of language has contributed a significant amount of insight into our overall understanding of how people think, feel, connect and behave. However, to date, this interesting body of work has not been broadly applied to evaluating complex clinical problems. This dissertation sought to closely examine chronic pain as a complex clinical problem and explore the utility of analyzing group and individual linguistic data to determine if people with chronic pain use language differently than the population and if so, whether those differences predict pain severity and disability. The ultimate goal of this work was to determine if language analsyis could enhance the overall effectiveness of existing assessment and monitoring tools.

The results from this pilot study revealed that individuals with chronic pain do indeed use language differently than the general population and these differences, when combined, do predict pain severity and disability, suggesting a link can be made between language and chronic pain specifically. A closer look at individual level data illustrated distinctive differences such as level of motivation or severity of depression emerge and may be crucial in assisting providers in more effectively prioritizing treatment targets and selecting the most appropriate approach to treatment overall. While research has begun supporting this effort, additional work is needed to validate these findings and explore this multidisciplinary intersection. Future work must better define and specify how language analysis may be systematically and reliably used to enhance existing chronic pain assessment protocols moving forward.

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