# THE EXPRESSION OF CHRONIC PAIN: A MULTIMODAL ANALYSIS OF CHRONIC PAIN PATIENTS

By

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**1.0 Abstract**

There is currently no viable objective methods to validate a patient is suffering from chronic pain. In order to investigate the face and voice of chronic pain, a pilot analysis was run using publicly available videos from a dental clinic and neurology clinic. The stimuli include patients discussing their pain in addition to segments where the patients discuss how they feel after an efficacious pain-relieving procedure. The patients in the videos suffer from sciatic pain or pain from temporomandibular joint disorder (TMD) and are real patients who have undergone a physical examination. The relevant sections from the clips were coded using a manual FACs, and a pilot stimulus was run using layered vocal analysis (LVA) software provided by Nemesysco.

The results of this experiment provide valuable and applicable insight into the expression of chronic pain. This may be helpful in determining true pain patients from drug and attention-seeking individuals. In addition, these methodologies could provide a way to examine pain in individuals that may not be able to express themselves, including patients with mental disorders. The insights from this experiment suggest that these analytic methods may be applicable for additional study and possible implementation in a medical setting.

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## 1.0 Introduction

Diagnosis is often the result of objective tests: techniques such as blood samples, MRIs, and X-rays provide concrete evidence of disorders. No such objective techniques exists to test for pain. Pain lies at an intersection between physical and emotional, and as such it is difficult to quantify or even validate. Instead, diagnosis is commonly based on patient's answers to the familiar refrain, "rate your pain from one to ten, ten being the most intense pain you can image." This scale is in use in medical practices across the US (Williamson & Hoggart, 2005). It is almost entirely subjective, in part out of necessity. Pain is not uniform, affecting individuals differently and to different degrees (Dansie & Turk, 2013). These differences can range from genetic predispositions to emotional states. Regardless, the end result is the same: pain is only partially correlated to the severity of the injury. Because of this, an identical injury in two individuals may have completely different pain profiles.

## 1.1 Pain and the Experience of Pain

Pain is multi-dimensional experience, further complicating the attempt to categorize or quantify it. Pain has two interconnected aspects: an affective component that is referred to as suffering and somatosensory component that is the result of nociception. While pain has a sensory component, it is defined as an experience, combining sensory, environmental, and emotional influences (Wood, 1992). The sensory component of pain is called nociception. Nociception occurs as a physiological result tissue injury. Afferent fibers, primarily c-fibers and A-delta fibers, carry information from pain sensitive neurons known as nociceptor to the brain. The nociceptors respond to a variety of noxious stimuli such as pain, extreme temperatures, and certain chemicals (Wiech, Ploner, & Tracey, 2008). Nociception is a progenitor to pain, but nociception can occur without pain and pain can exist in the absence of nociception. Pain involves activation of several brain regions, including somatosensory regions, the anterior cingulate cortex, and bilateral anterior insular cortex (J. Decety, 2011). These areas have also been related to negative affective states, and are thought to be responsible for the affective dimensions of pain, i.e. suffering. There is also some evidence for areas such as the amygdala and pre-frontal cortex to be involved in pain modulation and experience; however, these connections are less clear and may be due to associated emotions (Panerai, 2011).

### 1.2 Modulating Factors in the Experience of Pain

Pain is modulated by a variety of factors ranging from genetic predispositions, physical aspects of the nervous system, past experiences and emotional states (Eastman, 2009; Lumley et al., 2011; Rainville, Bao, & Chrétien, 2005; Wiech et al., 2008). These factors affect the intensity of pain felt, duration of pain, and conceptualization of pain. There may also be gender effects in how pain is felt and expressed. Past research has suggested that women seem to experience more pain, which may be due to physiological factors as well as psychosocial factors that make women more likely to seek treatment and express their pain (Linda LeResche, 2011). Physical differences also exist in endogenous pain modulation systems and the responsiveness of pain receptors and neurons. Cognitive affections such as attention, expectation, and reappraisal of pain also serve to modulate the subjective experience of pain and the variability in pain felt across individuals (Wiech et al., 2008).

### 1.3 Pain and Emotion

Despite the affective experiential nature of pain, it is not typically classified as an emotion (Kappesser & Williams, 2002). Pain is conceptualized as a type of warning system that motivates specific behaviors (Williams, 2002). It also serves a homeostatic function, serving as a signal to motivate a return to homeostasis (Panerai, 2011). In this way, it helps an organism survive injury by limiting mobility. It also prevents unnecessary exposure to noxious stimuli as that stimuli is perceived as noxious in addition to creating physical damage. Interestingly, the feeling of pain is thought to be maximally developed in humans, perhaps due to the large role played by insula, which is a structure that is more developed in humans than other animals including other primates (Williams, 2002). Even when looking at pain from the perspective of behavioral modification and self-environment interaction, similarities between pain and emotion can be found and research methodologies used in emotion studies often transfer well to the study of pain (Kappesser & Williams, 2002). While variance exists in intensity, pain, like emotion, seems to transcend culture and individual differences (K. M. Prkachin, 1992). While there are individuals who feel no pain, this is due to a genetic anomaly causing a loss of function in a voltage gated sodium channel (Nav1.7) do not invalidate the overall universality (Diatchenko, Nackley, Tchivileva, Shabalina, & Maixner, 2007) . Similarly to emotion, pain has an affective component, modulates behavior, and is thought to have a discrete facial expression. It also is highly motivational, with individuals consciously or unconsciously modifying behavior due to the fear of pain or in an attempt to avoid pain. Seeing other's pain provokes empathy and other reactions such as threat response in most individuals (Jean Decety, 2009; Fan & Han, 2008; Yang, Decety, Lee, Chen, & Cheng, 2009). Despite the many similarities to emotion, it is possible to conceptualize pain as an experience of a negative sensation, without necessarily evoking emotion. This definition, like that of pain being an emotion, only explain part of the experience of pain. In this way, pain lies in a gray area: part emotion and part physiological response.

**1.4 Expression of Pain**

Pain vocalization and expression serve an evolutionary purpose. Like pain itself, the manifestations of pain are highly varied and depend on circumstances, individual's personality, and the pain felt. Research has shown that the social context influences pain (McGrath, 1994; Wiech et al., 2008). In addition, personality traits such as neuroticism, extroversion, and lower order traits such as body hypervigilance may increase the perception of pain (Lee, 2008; Mongini et al., 2009; Nash, Inzlicht, & McGregor, 2012). There are also modulating factors that come into play even in a medical settings, where patients must balance showing enough pain for treatment but avoiding over dramatizing their pain to avoid the stigma of being labeled attention seeking or being perceived as "faking" pain. Patients that are considered "difficult" or less likable are often taken less seriously. This often includes patients who have substance abuse problems or comorbid disorders (Farin, Gramm, & Schmidt, 2013). Patients often feel stigmatized or as though they are labeled drug seeking by their doctors, and may modify their behavior accordingly (Matthias, Krebs, Bergman, Coffing, & Bair, 2014).

### 1.5 Current Scales Used in the Evaluation of Pain

This leads researchers and medical professionals back to the same subjective scales they have been using for decades. Three common scales include the Visual Analogue Scale, the Verbal Rating Scale, and the Numerical Rating Scale (Williamson & Hoggart, 2005). These scales all rely on self-report provided by the patient. While useful, these scales have definite drawbacks. They rely on language, require honesty, and are subject to interpersonal pressures. Because of this, individuals in pain may not receive adequate pain management and patients with little or no pain may abuse the system to obtain faster treatment, attention, and narcotics. The subjective measure from the patient is tempered by another subjective measure: the doctor's perception of the patient's pain. Physicians often rely on non-verbal indicators to determine patient's pain (Hill & Craig, 2002). However, subtle indicators such as facial expressions are unlikely to be correctly perceived without training. Untrained individuals perform a rate no better than chance when presented with real and posed pain (Littlewort, Bartlett, & Lee, 2007). There are also distal and proximal factors that influence perceptions of others pain, including one's own experiences with pain and gender (Ruben & Hall, 2013). While doctors may think of themselves as experts, they are not experts in the subtle differences between real and posed pain. With training, they can improve their accuracy and increase their ability to distinguish pain expressions; however, this approach has not been implemented in any systematic way. Even the more instinctual response to pain, pain empathy, is not a good marker in a medical setting as physicians and other healthcare professionals have been shown to down regulate empathy to pain (Jean Decety, Yang, & Cheng, 2010; Gleichgerrcht & Decety, 2014). While useful for avoiding cognitive distraction and avoiding burn out, this callousness may cause doctors to inadequately judge the level of pain suffered by an individual (Poole & Craig, 1992). Healthcare experts tend to underestimate the pain levels of individuals relative the individuals perception of pain, as reported through self-report (Solomon, Prkachin, & Farewell, 1997). Using expert knowledge of how much something "should hurt" is also problematic due to the individual differences in pain perception and even nociception which can make identical procedures and injuries have differences in pain perception.

**1.6 Experimental Models of Pain Analysis**

Despite its limitations, the numerical rating scale is still widely used, in part because there is no agreement on a better method. More accurate methodologies has been proposed and validated; however, the necessity of time and training has proven too much of detriment to implement these practices. These studies also tend to be small and performed in a research setting, limiting the data available for the efficacy of these proposed scales in a larger medical setting. One of the methodologies proposed and validated in several studies is that of using facial expression cues to code the "face of pain" (Galin & Thorn, 1993; Hill & Craig, 2002; L LeResche & Dworkin, 1988; Poole & Craig, 1992; Kenneth M. Prkachin, 2009; Solomon et al., 1997). These cues are analyzed through the use of manual or automatic implementation of the facial action coding system developed by Paul Ekman and Friesen (FACS).

The Facial Action Coding System and Pain

The facial action coding system is one of the most precise methodologies available for coding facial expressions that correspond to specific emotion (Ekman, 1993). Typically, the FACs system uses highly trained human coders to examine video footage of facial expressions and go through them in a frame by frame fashion. This stimuli is then coded for facial muscle movements called action units. The action units are numeric codes given to specific movements in facial muscles revealed through a variety of visual manifestations. This methodology has been extensively applied to the study of emotion (Ekman, 1993). Recently, automation of the system has been used with some success to make the methodology more accessible (Littlewort et al., 2007; Kenneth M. Prkachin, 2009). Both traditional FACs coding and automated coding have also been applied to pain facial expressions.

The results have been mostly successful, though limited in scale. The difficulty in implementation is twofold. FACs requires approximately 100 hours of training to become proficient, and the best method of using manual of automatic FACs is though video recordings that can be slowed and viewed multiple times (Galin & Thorn, 1993). Immediately, difficulty and cost in implementing this sort of methodology becomes apparent. In addition, ethical concerns regarding patient privacy and doctor-patient trust would need to be addressed before this method could have any application. Perhaps because of these limitations, research into this area has been extremely limited following the initial surge of interest and publication in the early 1990s. There is also a fundamental difference in the experimental pain paradigm, typically some variation on a cold presser test, and experienced pain in a non-research setting (Craig & Patrick, 1985; Linda LeResche, Dworkin, Wilson, & Ehrlich, 1992; K. M. Prkachin, 1992). Acutely induced pain is different in many ways from chronic or neuropathic pain, which also do not have a clear onset and duration. The expressions of common pain were explored that evoked pain in chronic back pain patients; however, even though they used patients with chronic back pain, their experimental paradigm was looking at movement induced acerbation of pain (Hill & Craig, 2002). In a similar study, patients with orofacial pain were examined during facial movements and the expressions of evoked pain were compared to baseline (L LeResche & Dworkin, 1988).

### 1.7 "The Face of Pain" is the Face of Evoked Pain

The majority of experiments seeking to use FACs to quantify pain look at an acute pain that can be easily standardized in a laboratory setting. Even when studying populations with a chronic pain condition, the patients are usually experiencing movement induced breakthrough pain while the experiment is performed. This evoked pain is a sharp spike in pain intensity that may be due to movement or other environmental change. The pain would more closely resemble acute pain than the constant feeling of chronic pain. While methodologically easier to produce, acute pain is not typically the type of pain that comes under question in medical settings. Acute pain is pain that occurs rapidly after a stimulus and is directly related to the damage or stimulus that is applied. Chronic pain is typically defined by duration, where pain lasts beyond six months (Dansie & Turk, 2013). Unlike acute pain, chronic pain can exist with no visible injury or physiological dysfunction (Dansie & Turk, 2013; Wood, 1992). Chronic pain can be inflammatory or neuropathic in nature, or a combination of the two and is caused by everything from genetic disorders to past injuries (Dansie & Turk, 2013; Hadjistavropoulos & Craig, 1994). Because chronic pain often exists in the absence of physical indicators, it is difficult to validate (Dansie & Turk, 2013). It is also more resistant to treatment with opiates, which increases the amount of medication needed to control pain (Ballantyne & LaForge, 2007; Chou et al., 2009). With these parameters in mind, it is easy to see how even professionals would have difficulty determining between a genuine patient and an individual feigning pain to support their drug habit. This is harmful in many ways: preventing true patients from receiving the medications they need, prescribing medications for drug seeking individuals lacking true pain, and affecting how physicians distribute medication.

**1.8 Complications to Facial Analysis of Pain**

In settings outside of research, pain doesn’t exist in isolation. Chronic pain may coexist with depression and anxiety. Even acute pain is often combined with other emotions such as fear or shock. There are also individuals who do not show pain. These are an exception to the rule, as most people have automatic expression of pain even when told to suppress any facial expression. However, they still represent a significant portion of the population. According to a study by there was no facial response in between 15% to 23% percent of the study participants (Kunz & Lautenbacher, 2014). There is also a temporal nature to the facial responses to acute pain studied. The intensity of the pain expression present and the specific facial features of pain shifted over the course of the various pain induction paradigms. (Hill & Craig, 2002) There is also a lack of agreement for a universal “pain face.” Different studies have identified significant AUs, but these do not all agree (Kenneth M. Prkachin, 2009). Another study found that there are four distinct subtypes of “pain expression” in different individuals (Kunz & Lautenbacher, 2014). In addition, while some studies showed differences in facial movement between real and posed pain, other experiments found posed pain to simply be an exaggeration of a real “pain face” (Galin & Thorn, 1993; Hill & Craig, 2002; Littlewort et al., 2007; Poole & Craig, 1992).

One possible solution would be to shift the focus from facial identifiers of pain to facial indicators of deception. However, this would encourage a more adversarial interaction between the doctor and patient, potentially punishing real patients unnecessarily. Deceptive individuals are also often good at masking facial signs of their deception to the point that training would be needed to observe them (Hurley & Frank, 2011). When warned of potential deception, physicians are no more accurate at discriminating between real and posed pain; however, they are less empathetic and more conservative in their estimations of another’s pain (Poole & Craig, 1992). Because the physician-patient relationship is important for positive patient outcomes, approaching pain judgement from a standpoint that emphasizes or presupposes deception would be detrimental to patients suffering from pain (Chou et al., 2009; Dansie & Turk, 2013; Farin et al., 2013).

**1.9 Necessity of a Validating Patient Pain**

Lacking an objective metric to determine true pain sufferers from deceptive drug seekers or attention seeking individuals also allows a space for personal biases to come into play in a medical setting. Analysis has shown gender, racial, and socioeconomic differences in how pain patients are treated, presumably due to entrenched stereotypes of about the relative likelihood of these groups to be drug seeking or seeking attention through catastrophizing their disorder. Particularly, minorities and women are often given less aggressive treatments for their pain (Weisse, Sorum, & Dominguez, 2003). Studies have found that the gender of the physician alters how they prescribe pain medications to same gender and opposite gender patients (Weisse et al., 2003; Weisse, Sorum, Sanders, & Syat, 2001). There are also distal and proximal factors that influence one's expectations of another person's pain experience are influenced by external factors including gender, age, and race in a way that corresponds to a person's stereotypes of such groups (Wandner, Scipio, Hirsh, Torres, & Robinson, 2012).

As previously discussed, chronic pain patients are also far more likely than sufferers of acute pain or non-pain suffering individuals to have comorbid disorders such as depression and anxiety (France, 1987). These comorbid disorders have their own associated affect and facial expressions, which may mask or alter the expression of pain. There are also complications as pain and fear of pain occur simultaneously in many patients. Additionally, recent studies have found that physical and emotional pain share neural circuitry, indicating possible connections between the expression of physical pain and emotional distress, especially where both are present (Eisenberger, 2012). It's also hard to judge chronic pain as opiate abusers often also have chronic pain conditions (Ballantyne & LaForge, 2007; Chou et al., 2009).

## Vocal Analysis of Emotion and Applications to the Study of Pain Measurement

Pain is also associated with nonlinguistic vocal utterances. While vocalizations have been used as an indicator of pain in rats, little research into vocalizations has been done for humans (Levine, Feldmesser, Tecott, Gordon, & Izdebski, 1984). Again building off of the emotion literature, it also seems probably that pain induces specific vocal characteristics in addition to nonverbal utterances (Williams, 2002). The valence and arousal of emotions is revealed though patterns of frequency, pitch, and tone in speech. These connections are less understood and standardized than facial expressions; however, they also could provide insight into internal states and are less intrusive to record and measure. This is most likely due to the difficulty in isolating the elements of pitch and prosody that correspond to specific emotions (Russell, Bachorowski, &

Fernandez-Dols, 2003). The idea that pain is reflected in the voice of individuals experiencing pain is supported best by the discovery that pain empathy can be elicited in someone listening to another person in pain, though the stimuli used in this experiment included screaming and sounds of injury (Lang, Yu, Markl, Müller, & Kotchoubey, 2011). This may be useful for examining pain in particularly stoic individuals. Because chronic pain patients are good at suppressing or masking visual indicators of their pain, vocal analysis has the potential to be more revealing than visual analysis. With this in mind, commercially available vocal analysis technology, which has been validated for assessing stress, deception, and emotion, can then be applied to the analysis of vocal features of chronic pain patients.

**1.10 The Overarching Problem**

Despite the clear differences in manifestations and conceptualization of acute and chronic pain, no studies have examined how chronic pain is expressed in the face in the absence of additional evoked pain. In order to better serve patients and physicians, a better metric for measuring pain needs to be validated. The connections between experienced chronic pain, facial expression, and vocal qualities can provide a possible methodology for the detection of true pain in patients. Analysis of these elements will also determine which elements are unrelated, which can help physicians and healthcare workers know not only what to look for, but what not to look for. This may help overcome the underestimation bias and ensure patients are penalized for false assumptions on the part of healthcare workers. The novel use of vocal analysis will also begin investigation into an experimental tool for evaluating emotions that is often overlooked.

**2.0 Aims and Hypothesis**

1. Determine AUs found in chronic pain patients and while in pain but without the added element of evoked pain.

    Hypothesis: The AUs seen in the faces of chronic pain patients will correspond to emotions such as sadness and frustration. In addition, patients will exhibit few AUs

2. Compare the AUs of chronic pain patients with the AUs associated with evoked pain in the pain literature.

    Hypothesis 2. The AUs seen in chronic pain patients will not correspond significantly to the AUs in the literature

3. Use layered vocal analysis to determine unique characteristics of chronic pain patient's speech.

    Hypothesis 2. Chronic pain patients will show specific and unique vocal characteristics when discussing their pain and aspects of their lives affected by pain.

Exploratory Question: Are there unique facial or vocal cues in patients with chronic pain conditions that can be determined through FACs analysis and layered voice analysis?

## 3.0 Methods

### 3.1 Stimuli

In this experiment, 14 segments from 7 videos were manually coded using FACs. In addition, one of the video segments run through a layered vocal analysis program provided by Nemesysco. The videos were provided by a neurology clinic, and dental clinic and show real patients before and after undergoing an efficacious pain treatment. The videos are publicly available so no privacy limitations applied. The video segments were cut to include between clips ranging from 30 seconds to 100 seconds where the patients discussed their pain and how it affects their lives. While the discussion was primarily focused on describing the patient's pain, there were also related areas of discussion such as pain related limitations to activity and how pain affected the patient's personal relationships and job performance. The patients were aware that they were being recorded. There was cutting and editing of the videos so that the experimenter did not have the full, undoctored footage. Patients recorded were primarily female, with five female patients and three male patients. The patients all verbally described their pain and attested that they were currently feeling pain of some type. In the videos for back pain and TMD videos, a patient examination was performed by a specialist demonstrating limited range of motion in patients with back pain and damage to the jaw in patients suffering from TMD. The videos ranged in quality, but all had sufficient quality to determine AUs when viewed frame by frame. Additional sections ranging from 10 seconds to 20 seconds in length of the patient after pain relief were coded to provide a baseline and compare potentially habitual expressions that would occur in both conditions. These sections included some patients immediately after pain relief and some after extended pain relief.

### 3.2 Manual FACs analysis

Each video clip was analyzed by hand using the facial action coding system. The videos were coded by a trained coder. The coder was not blinded to the experimental conditions as the differences between the conditions was obvious even with blinding. The videos were analyzed twice, once for lower facial action units and then a second time for upper facial action units, blinks, and eye movement. The clips were coded frame by frame, with 25 frames per second. The number of seconds each action unit was present for was recorded and then transformed into a percentage by dividing the number of seconds the AU was present with the total time of the clip. The percentages were averaged across participants to obtain the mean percentage and standard deviation. The percentage of the time with a neutral expression was also recorded and included in the data to provide an indication of the expressiveness of individuals and of the different groups. All action units were coded for, but units only appearing for one individual for less than .5 seconds were excluded from the results.

**3.3 Vocal Analysis**

Vocal Analysis of individuals discussing their pain: As the individual describes their pain symptoms to a medical professional or interviewer, their voices will be coded for emotions using the empath emotion coding system. Nemesysco software uses layered voice analysis (LVA) to analyze nonlinguistic vocal features in any language and determine the level of stress, arousal, deception, and cognitive effort. The software uses signal processing algorithms to analyze more than 120 unique vocal parameters which are then processed into nine basic emotion categories. Each video was run through the software, which produced outputs corresponding to levels of emotions and arousal. The Sense analysis technology extracted relevant elements and produced an outcomes showing excitement, stress, contentment, truthfulness, anger, and several other cognitive and emotional outcomes.

**4.0 Results**

| Action Unit | Affiliated Movement | Chronic Pain Condition | Non-Pain Condition |
|---|---|---|---|
| 1 | Inner Brow Raiser | 0.005 | 0.338 |
| 2 | Outer Brow Raiser | 0.000 | 0.338 |
| 4 | Brow Lowerer | 0.005 | 0.000 |
| 6 | Cheek Raiser | 0.009 | 0.192 |
| 7 | Lid Tightener | 0.000 | 0.192 |
| 12 | Lip Corner Puller | 0.032 | 0.192 |
| L12 | Unilateral 12 | 0.000 | 0.000 |
| 14 | Dimpler | 0.008 | 0.000 |
| 15 | Lip Corner Depressor | 0.026 | 0.000 |
| 10 | Upper Lip Raiser | 0.000 | 0.000 |
| 16 | Lower Lip Depressor | 0.014 | 0.000 |
| 17 | Chin Raiser | 0.067 | 0.000 |
| 23 | Lip Tightener | 0.015 | 0.000 |
| 24 | Lip Presser | 0.000 | 0.000 |

Fig. 1. Chart showing percentage of time in coded sections an AU was present for patient 1.

| Action Unit | Affiliated Movement | Chronic Pain Condition | Non-Pain Condition |
|---|---|---|---|
| 1 | Inner Brow Raiser | 0.083 | 0.076 |
| 2 | Outer Brow Raiser | 0.083 | 0.076 |
| 4 | Brow Lowerer | 0.095 | 0.000 |
| 6 | Cheek Raiser | 0.007 | 0.351 |
| 7 | Lid Tightener | 0.000 | 0.000 |
| 12 | Lip Corner Puller | 0.007 | 0.351 |
| L12 | Unilateral 12 | 0.000 | 0.000 |
| 14 | Dimpler | 0.001 | 0.038 |
| 15 | Lip Corner Depressor | 0.046 | 0.000 |
| 10 | Upper Lip Raiser | 0.000 | 0.038 |
| 16 | Lower Lip Depressor | 0.000 | 0.000 |
| 17 | Chin Raiser | 0.060 | 0.000 |
| 23 | Lip Tightener | 0.007 | 0.000 |
| 24 | Lip Presser | 0.000 | 0.000 |

Fig. 2. Chart showing percentage of time in coded sections an AU was present for patient 2.

| Action Unit | Affiliated Movement | Chronic Pain Condition | Non-Pain Condition |
|---|---|---|---|
| 1 | Inner Brow Raiser | 0.144 | 0.000 |
| 2 | Outer Brow Raiser | 0.073 | 0.000 |
| 4 | Brow Lowerer | 0.038 | 0.046 |
| 6 | Cheek Raiser | 0.013 | 0.115 |
| 7 | Lid Tightener | 0.000 | 0.046 |
| 12 | Lip Corner Puller | 0.015 | 0.115 |
| L12 | Unilateral 12 | 0.003 | 0.000 |
| 14 | Dimpler | 0.005 | 0.000 |
| 15 | Lip Corner Depressor | 0.000 | 0.000 |
| 10 | Upper Lip Raiser | 0.010 | 0.000 |
| 16 | Lower Lip Depressor | 0.000 | 0.000 |
| 17 | Chin Raiser | 0.000 | 0.046 |
| 23 | Lip Tightener | 0.000 | 0.015 |
| 24 | Lip Presser | 0.000 | 0.000 |

Fig. 3. Chart showing percentage of time in coded sections an AU was present for patient 3.

| Action Unit | Affiliated Movement | Chronic Pain Condition | Non-Pain Condition |
|---|---|---|---|
| 1 | Inner Brow Raiser | 0.037 | 0.182 |
| 2 | Outer Brow Raiser | 0.037 | 0.182 |
| 4 | Brow Lowerer | 0.000 | 0.000 |
| 6 | Cheek Raiser | 0.000 | 0.419 |
| 7 | Lid Tightener | 0.000 | 0.142 |
| 12 | Lip Corner Puller | 0.000 | 0.419 |
| L12 | Unilateral 12 | 0.000 | 0.000 |
| 14 | Dimpler | 0.007 | 0.000 |
| 15 | Lip Corner Depressor | 0.000 | 0.000 |
| 10 | Upper Lip Raiser | 0.000 | 0.000 |
| 16 | Lower Lip Depressor | 0.000 | 0.000 |
| 17 | Chin Raiser | 0.007 | 0.000 |
| 23 | Lip Tightener | 0.000 | 0.000 |
| 24 | Lip Presser | 0.000 | 0.000 |

Fig. 4. Chart showing percentage of time in coded sections an AU was present for patient 4.

| Action Unit | Affiliated Movement | Chronic Pain Condition | Non-Pain Condition |
|---|---|---|---|
| 1 | Inner Brow Raiser | 0.171 | 0.066 |
| 2 | Outer Brow Raiser | 0.171 | 0.066 |
| 4 | Brow Lowerer | 0.000 | 0.000 |
| 6 | Cheek Raiser | 0.000 | 0.328 |
| 7 | Lid Tightener | 0.000 | 0.000 |
| 12 | Lip Corner Puller | 0.000 | 0.361 |
| L12 | Unilateral 12 | 0.000 | 0.000 |
| 14 | Dimpler | 0.000 | 0.131 |
| 15 | Lip Corner Depressor | 0.141 | 0.000 |
| 10 | Upper Lip Raiser | 0.034 | 0.000 |
| 16 | Lower Lip Depressor | 0.034 | 0.000 |
| 17 | Chin Raiser | 0.071 | 0.000 |
| 23 | Lip Tightener | 0.000 | 0.000 |
| 24 | Lip Presser | 0.000 | 0.000 |

Fig. 5. Chart showing percentage of time in coded sections an AU was present for patient 5.

| Action Unit | Affiliated Movement | Chronic Pain Condition | Non-Pain Condition |
|---|---|---|---|
| 1 | Inner Brow Raiser | 0.089 | 0.000 |
| 2 | Outer Brow Raiser | 0.073 | 0.000 |
| 4 | Brow Lowerer | 0.027 | 0.000 |
| 6 | Cheek Raiser | 0.006 | 0.476 |
| 7 | Lid Tightener | 0.000 | 0.000 |
| 12 | Lip Corner Puller | 0.011 | 0.762 |
| L12 | Unilateral 12 | 0.001 | 0.000 |
| 14 | Dimpler | 0.004 | 0.000 |
| 15 | Lip Corner Depressor | 0.043 | 0.000 |
| 10 | Upper Lip Raiser | 0.009 | 0.000 |
| 16 | Lower Lip Depressor | 0.010 | 0.000 |
| 17 | Chin Raiser | 0.041 | 0.143 |
| 23 | Lip Tightener | 0.004 | 0.000 |
| 24 | Lip Presser | 0.000 | 0.048 |

Fig. 6. Chart showing percentage of time in coded sections an AU was present for patient 6.

| Action Unit | Affiliated Movement | Chronic Pain Condition | Non-Pain Condition |
|---|---|---|---|
| 1 | Inner Brow Raiser | 0.015 | 0.149 |
| 2 | Outer Brow Raiser | 0.015 | 0.149 |
| 4 | Brow Lowerer | 0.000 | 0.028 |
| 6 | Cheek Raiser | 0.028 | 0.000 |
| 7 | Lid Tightener | 0.028 | 0.000 |
| 12 | Lip Corner Puller | 0.058 | 0.019 |
| L12 | Unilateral 12 | 0.000 | 0.000 |
| 14 | Dimpler | 0.030 | 0.028 |
| 15 | Lip Corner Depressor | 0.000 | 0.000 |
| 10 | Upper Lip Raiser | 0.009 | 0.000 |
| 16 | Lower Lip Depressor | 0.000 | 0.000 |
| 17 | Chin Raiser | 0.000 | 0.000 |
| 23 | Lip Tightener | 0.009 | 0.000 |
| 24 | Lip Presser | 0.021 | 0.041 |

Fig. 7. Chart showing percentage of time in coded sections an AU was present for patient 7.

| Action Unit | Affiliated Movement | Chronic Pain Condition | Standard Deviation | Non-Pain Condition | Standard Deviation | Evoked Pain* |
|---|---|---|---|---|---|---|
| 1 | Inner Brow Raiser | 0.078 | 0.063 | 0.12 | 0.11 | 0.183 |
| 2 | Outer Brow Raiser | 0.065 | 0.057 | 0.12 | 0.11 | 0.192 |
| 4 | Brow Lowerer | 0.024 | 0.035 | 0.01 | 0.02 | 0.292 |
| 6 | Cheek Raiser | 0.009 | 0.010 | 0.27 | 0.16 | 0.233 |
| 7 | Lid Tightener | 0.004 | 0.011 | 0.05 | 0.07 | 0.142 |
| 12 | Lip Corner Puller | 0.018 | 0.021 | 0.32 | 0.23 | 0.258 |
| L12 | Unilateral 12 | 0.001 | 0.001 | 0.00 | 0.00 | 0.083 |
| 14 | Dimpler | 0.008 | 0.010 | 0.03 | 0.04 | 0.000 |
| 15 | Lip Corner Depressor | 0.037 | 0.050 | 0.00 | 0.00 | 0.000 |
| 10 | Upper Lip Raiser | 0.009 | 0.012 | 0.01 | 0.01 | 0.108 |
| 16 | Lower Lip Depressor | 0.008 | 0.013 | 0.00 | 0.00 | 0.000 |
| 17 | Chin Raiser | 0.035 | 0.032 | 0.03 | 0.05 | 0.083 |
| 23 | Lip Tightener | 0.005 | 0.006 | 0.00 | 0.01 | 0.000 |
| 24 | Lip Presser | 0.003 | 0.008 | 0.01 | 0.02 | 0.000 |

Figure 8. Averaged means and standard deviations for the pain discussion and non-pain condition across all seven patients. *Percentages from the experiments done by Craig, Hyde, & Patrick, 1991

| eg# | Start Pos (Sec.) | End Pos (Sec.) | Topic | Question | Risk Value | SENSE ANALYSIS |
|---|---|---|---|---|---|---|
| 18.00 | 62.98 | 64.98 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS100) |
| 19.00 | 64.97 | 66.97 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS112) |
| 20.00 | 66.99 | 68.99 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS96) |
| 21.00 | 68.98 | 70.98 | IN PAIN | YES | 25.00 | Confusion (OZ:0/3/0 :RS102) |
| 22.00 | 70.98 | 72.98 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS109) |
| 23.00 | 72.97 | 74.97 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS103) |
| 24.00 | 74.97 | 76.97 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS101) |
| 29.00 | 84.99 | 86.99 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS101) |
| 30.00 | 86.98 | 88.98 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS106) |
| 34.00 | 94.98 | 96.98 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS107) |
| 35.00 | 96.98 | 98.98 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS105) |
| 52.00 | 164.49 | 166.49 | IN PAIN | YES | 0.00 | Embarrassment (OZ:0/1/0 :RS98) |
| 80.00 | 220.48 | 222.48 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS103) |
| 81.00 | 222.49 | 224.49 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS95) |
| 82.00 | 224.49 | 226.49 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS96) |
| 83.00 | 226.48 | 228.48 | IN PAIN | YES | 10.00 | Truth (OZ:0/2/0 :RS104) |
| 84.00 | 228.48 | 230.48 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS106) |
| 85.00 | 230.50 | 232.50 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS106) |
| 86.00 | 232.49 | 234.49 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS108) |
| 90.00 | 240.49 | 242.49 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS100) |
| 91.00 | 242.49 | 244.49 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS102) |
| 92.00 | 244.48 | 246.48 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS104) |
| 97.00 | 254.48 | 256.48 | IN PAIN | YES | 0.00 | Truth (OZ:0/1/0 :RS102) |
| 98.00 | 256.59 | 258.28 | IN PAIN | YES | 0.00 | Truth (OZ:0/0/0 :RS87) |

Fig. 9 SENSE analysis of data from patient 1 during the pain discussion condition.

| | | | | | | |
|---|---|---|---|---|---|---|
| 110.00 | 287.69 | 289.69 | AFTER TREATMENT | NO | 0.00 | High Anticipation (OZ:0/1/0 :RS124) |
| 111.00 | 289.70 | 291.70 | AFTER TREATMENT | NO | 10.00 | High Anticipation (OZ:0/2/0 :RS101) |
| 112.00 | 291.70 | 293.70 | AFTER TREATMENT | NO | 0.00 | Truth (OZ:0/0/0 :RS101) |
| 113.00 | 293.69 | 295.69 | AFTER TREATMENT | NO | 25.00 | Truth (OZ:0/3/0 :RS96) |
| 116.00 | 299.70 | 301.70 | AFTER TREATMENT | NO | 60.00 | MID RISK (OZ:3/2/0 :RS143) |
| 121.00 | 309.70 | 311.70 | AFTER TREATMENT | NO | 10.00 | Truth (OZ:0/2/0 :RS95) |
| 122.00 | 311.79 | 312.85 | AFTER TREATMENT | NO | 0.00 | Truth (OZ:0/1/0 :RS105) |
| 126.00 | 319.53 | 321.53 | AFTER TREATMENT | NO | 0.00 | Truth (OZ:0/1/0 :RS108) |
| 131.00 | 329.53 | 331.53 | AFTER TREATMENT | NO | 40.00 | Confusion (OZ:1/3/0 :RS99) |
| 134.00 | 335.52 | 337.52 | AFTER TREATMENT | NO | 0.00 | Truth (OZ:0/1/0 :RS103) |
| 142.00 | 352.06 | 354.06 | AFTER TREATMENT | NO | 0.00 | Truth (OZ:0/0/0 :RS103) |
| 147.00 | 362.06 | 364.06 | AFTER TREATMENT | NO | 0.00 | Truth (OZ:0/1/0 :RS98) |
| 148.00 | 364.05 | 366.05 | AFTER TREATMENT | NO | 0.00 | Embarrassment (OZ:0/1/0 :RS95) |
| 151.00 | 370.06 | 372.06 | AFTER TREATMENT | NO | 90.00 | Voice Manipulation (OZ:3/3/0 :RS120) |
| 152.00 | 372.05 | 374.05 | AFTER TREATMENT | NO | 70.00 | High Anticipation (OZ:2/3/0 :RS106) |

Fig. 10 SENSE layered vocal analysis of patient 1 post pain interview.

## 5.0 Conclusions

### 5.1 Discussion of the Results

Due to the low number of subjects and large variance, it was impossible to achieve significant differences between the pain and non-pain condition or the chronic pain and evoked pain condition. Despite that, there are several patterns that provide a starting place for future experimentation. It is possible to qualitatively see common facial action units in the chronic pain patients. The AUs with the largest mean values, other than neutral, are inner brow raiser, outer brow raiser, chin raiser, and lip corner depressor. These do not correspond with the majority of AUs commonly associated with the “face of pain” from the literature, which focuses on brown lowering, upper lip raiser, lid lightener and cheek raiser (L LeResche & Dworkin, 1984, 1988; K. M. Prkachin, 1992; Kenneth M. Prkachin, 2009). Both chronic and evoked pain show inner and outer brow raising, as does the non-pain condition, indicating that brow raising may be a common emotion across the experimental conditions (Craig & Patrick, 1985). In addition, inner brow raiser has been associated with other types of negative affect, including sadness, fear, and surprise (Du, Tao, & Martinez, 2014). The preliminary results were consistent with the hypothesis, as chronic pain seems to have a different expression than induced pain. Perhaps more than an expression, chronic pain seems to lack a specific expression, as is seen in the high standard deviations of the action units and low percentages of any given action unit. The majority of time chronic pain patients discussed their pain, their faces were neutral and presented no action units. The may indicate a flattened affect on the part of chronic pain patients, either as a result of comorbid depressive disorders or as a result of the constant suppression of pain leading to a more global masking of affect (France, 1987). Additionally possible reasons for this reduced expressiveness in the majority of the patients may be fatigue due to poor sleep or difficulty concentrating, both problems commonly seen in pain patients and even referenced to in the videos (Wood, 1992). Lastly, it's possible that the limited results and high variability was a result of the limitation in stimuli and methodology.

**5.1 Limitations of the Experiment**

The experiment was limited in scope, and further analysis is needed to determine if the results here are universally applicable. The sample size was very small, with specific subsets of the chronic pain population. Chronic pain patients presenting different types of pain and symptoms may have different manifestation in facial expression. Because the videos were intended for educational and promotional purposes, it is also important to note that significant trimming and combining of the videos occurred even before sections of the video were selected for analysis. The subjective judgement which elements were most relevant for coding also provided a space for experimental bias. The experimental was also the coder, which may have produced unconscious bias. This bias could be corrected by using two coder who are blinded to the intent and conditions of the experiment and whose results are correlated with each other to verify inter-rater reliability. Another potential option is to use automated facial action coding software to look for facial action units. In order to feasible have a large enough sample size to find significant results, and automated system is probably the most logical option. It also is free of bias in the conditions and can be used in place of human coder when privacy is a consideration, as in patient data.

In addition to potential bias, there were systematic limitations in the method of collection. The duration of each action unit was recorded; however, any potential relevant combinations of action units were lost by simply looking at the percentage of time each action unit occurred without consideration of potential combinations. Action units can convey very different emotional responses in different combinations, so some of the subtlety and meaning of the facial expression as a whole is lost when the action units are coded and recorded individually. This may explain the why many of the action units coded seems at odds with the experimental paradigm. This may also be due to the varied nature of individual emotional expressiveness and the conversations themselves, some of which had elements that may have caused embarrassment or even brief amusement despite their central focus on pain. The variability of the conversations and emotions was also reflected in the vocal data, which showed a variety of different emotions at different times, including embarrassment and amusement. In the context of a healthcare provider putting a patient at ease and a patients feelings while discussing personal health issues, various emotions may be felt and expressed. However, these emotions are conversationally induced and should be brief in duration, a fact that was supported in the facial expression data. It is also difficult to gain a good baseline, as relief of pain is not neutral and has a lot variability. This causes vocal and facial expressions that are unconnected to pain but that may prevent the non-pain condition from being a good baseline for comparison.

Due to software usage limitations, only one participant was run through vocal analysis. Even from the limited sample, distinct differences were seen in the pain and non-pain conditions. Again, less emotional affect was seen in the chronic pain discussion. It is also verified the truthfulness of the patients description of her own pain. However, this case study does not necessarily indicate a pattern in a group of individuals. Rather than use the current SENSE technology, as was used for this patient’s data, it might make more sense to begin with a naïve learning algorithm and see if there are any unique characteristics to chronic pain patients that are separate from characteristics of comorbid emotions and posed pain.

**5.3 Future Directions**

Through limited in scale and scope, this experiment provides a place from which to run a full investigation into the facial and vocal characteristics of chronic pain using a more standardized stimuli set and much larger sample size. There are also elements that were not explored in the current research project that may provide additional insights. While it was not done in this experiment as the camera angle were not always straight on, gaze should be examined in the experimental paradigm of chronic pain. Gaze and eye movements can provide valuable lessons into a person's cognitive and emotional state. In future studies, it would be promising area to explore. In addition, blinking and partial eye closure may prove another area to explore as previous studies have associated changes in blinking frequency with pain, and concentration (K. M. Prkachin, 1992). In order to make better comparisons, a group of participants posing as chronic pain patients should be obtained as well. Lastly, the patients selected should be thoroughly interviewed prior to recording or during recording to determine comorbid disorders, current level of self-reported pain, medication usage, and expressiveness.

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