Social modulation of pain: A mediation model with shared reality and emotion

by

Lauren Page Ross

Bachelor of Arts in Psychology, Mills College, 2014

Submitted to the Graduate Faculty of the

Dietrich School of Arts and Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2021

UNIVERSITY OF PITTSBURGH

DIETRICH SCHOOL OF ARTS AND SCIENCES

This dissertation was presented

by

Lauren Page Ross

It was defended on

December 6, 2021

and approved by

Kevin Binning, PhD, Department of Psychology

Lauren Bylsma, PhD, Department of Psychiatry

Amanda Forest, PhD, Department of Psychology

Thesis Advisor/Dissertation Director: Karina Schumann, PhD, Department of Psychology

Copyright © by Lauren Page Ross

2021

Social modulation of pain: A mediation model with shared reality and emotion

Lauren Page Ross, PhD

University of Pittsburgh, 2021

Physical pain is a ubiquitous human experience with complexities spanning from physical to psychological domains. Though pain has historically been thought of as a physical and sensory process, the modern definition of pain now includes cognitive, social and emotional factors (Craig, 2002; iasp-pain.org/terminology; Williams & Craig, 2016), indicating growing appreciation of the impact of broader psychological context on people's pain experiences. Support for this distinction comes from literatures exploring the many constructs proposed to moderate or mediate pain experience through psychological channels. In the pain literature social contact, which can include interactions with others, the mere presence of another person, or even the perceived presence of another person, often predicts reduced perceptions of acute experimental pain. However, this association is not always present and, at times, social contact enhances perceived pain (Che, Cash, Chung, Fitzgerald, & Fitzgibbon, 2018a; Che, Cash, Ng, Fitzgerald, & Fitzgibbon, 2018b; Krahé, Springer, Weinman, & Fotopoulou, 2013). The mixed influence of social contact may suggest that, in the face of pain, not all social contact is created equal. A parallel literature investigating the influence of emotion on pain perception demonstrates that modulating positive and negative emotion can more consistently predict pain outcomes, such that increasing positive emotion reduces perceived pain, while increasing negative emotion increases perceived pain (*e.g.*, Zelman, Howland, Nichols, & Cleeland, 1991). Therefore it was hypothesized that emotion modulation resulting from social contact may predict perceived pain. Shared reality, the experience of validating one's perception of reality through social contact, has been theorized to modulate emotion (Echterhoff, Higgins & Levine, 2009). Therefore the current work investigated sharing reality as a key moderator of the relationship between social contact and perceived pain. It was predicted that social contact involving shared reality would reduce perceived pain during a cold pressor task by decreasing negative emotions and increasing positive emotions. Although hypotheses were not supported in the present study, it is hoped that this work inspires future research on the effect of shared reality on emotion and pain perception that will eventually elucidate interventions for pain reduction.

Table of Contents

Preface x

1.0 Introduction 1

1.1 Social Contact and Perceived Pain: An Overview 2

2.0 Achieving Shared Reality With Others 6

3.0 Shared Reality and Emotion 9

4.0 Emotion and Perceived Pain 11

5.0 Study Aims 12

6.0 Method 13

6.1 Participants 13

6.2 Procedure 14

6.3 Measures and Materials 15

6.3.1 Positive and Negative Affect Scale (PANAS) 15

6.3.2 Cold Pressor Task 16

6.3.3 Visual Analog Scale (VAS) Pain Measures 16

6.3.4 Shared Reality Manipulation 17

6.3.5 Shared Reality Measure 18

6.3.6 Probe for Suspicion 19

7.0 Results 20

7.1 Manipulation Check on Shared Reality 20

7.2 Changes in Emotion 20

7.3 Self-Reported Pain 21

7.4 Indirect Effects Through Emotion **21**

8.0 Discussion **23**

8.1 Shared Reality and Emotion **24**

8.2 Emotion and Pain **25**

8.3 Shared Reality and Pain **26**

8.4 Limitations **28**

8.5 Conclusions **31**

Appendix A PANAS **32**

Appendix B Visual Analog Pain Scale **33**

Appendix C Shared Reality Scale **34**

Appendix D Shared Reality Manipulation **35**

Appendix E Figures **37**

Bibliography **39**

List of Tables

Table 1 36

Table 2 36

List of Figures

Figure 1 Theoretical Model **37**

Figure 2 Study Timeline **38**

Figure 3 Model Results **38**

Preface

Thank you to my advisors, colleagues, friends, family, and Dolly Parton.

1.0 Introduction

Acute physical pain is a ubiquitous human experience with complexities spanning from physical to psychological domains. Though pain has historically been thought of as a physical and sensory process, the modern definition of pain now includes cognitive, social and emotional factors (Craig, 2002; iasp-pain.org/terminology; Williams & Craig, 2016), indicating growing appreciation of the impact of broader psychological context on people's pain experiences. Further still, the modern literature is beginning to explore nociception—the process by which objective information about a noxious stimulus is encoded and transported to the brain as a separable but parallel process from the perceptual, cognitive, and emotional experience of pain (Baliki & Apkarian, 2015; Craig, 2002; Gilam, Gross, Wager, Keefe, & Mackey, 2020)—opening doors to valuable new inquiry into the psychological process of pain. Support for this distinction comes from vast literatures exploring the many constructs proposed to moderate or mediate pain experience through psychological channels that affect the experience of pain without manipulating nociceptive processes.

In the pain literature social contact, which can include interactions with others, the mere presence of another person, or even the perceived presence of another person, often predicts reduced perceptions of acute experimental pain. However, this association is not always present and, at times, social contact counterintuitively *enhances* perceived pain (Che, Cash, Chung, Fitzgerald, & Fitzgibbon, 2018a; Che, Cash, Ng, Fitzgerald, & Fitzgibbon, 2018b; Krahé, Springer, Weinman, & Fotopoulou, 2013). The mixed influence of social contact on pain may suggest that, in the face of pain, not all social contact is created equal. I propose that sharing reality with another person—the experience of validating one's perception of reality through sharing internal states about a person or event—is a key moderator of the relationship between social contact and perceived pain. Further, I propose that social contact that involves shared reality reduces perceived pain by decreasing negative emotions and increasing positive emotions. I therefore propose that perceiving oneself as sharing reality (vs. not sharing reality) with another person reduces negative emotions and increases positive emotions, leading to reduced pain perception (Figure 1). Below I review literature to support this model.

1.1 Social Contact and Perceived Pain: An Overview

Scientific interest in the effect of social contact on pain has existed for several decades and has taken many forms (for a review see Epley, 1975). However, a large portion of the psychological arm of this literature evolved as an extension of the social support literature, with many studies testing various aspects of social support on perceived pain outcomes (e.g., Che et al., 2018a; Che et al., 2018b). Common support manipulations in this tradition include relationship type (i.e., stranger, acquaintance, friend, partner, family member), social support type (perceived support such as imagining close others, hearing voices, or viewing photos of other people; and received support such as touch, verbal communication, and positive interactions/encouragement). Similarly, review papers have largely focused on direct versus buffering effects of social support on pain (Che et al., 2018a; Krahé, Springer, Weinman & Fotopoulou, 2013). However, results from recent meta-analyses indicate that these social support manipulations have limited effect on pain perception. For example, mere social presence of someone, receiving touch, and viewing images of loved ones showed no effect on perceived pain measures (Che et al., 2018a). Other variables presented an unclear picture: Verbal support showed effects on perceived pain, but only when that support came from strangers rather than loved ones (Che et al., 2018a; Che et al., 2018b). The specificity of the effect with strangers runs counter to what would be expected under social support theory, which typically emphasizes closer relationships (for a review see Taylor, 2011). A systematic review of the same literature also concluded that, overall, the only meaningful manipulations included relevant interactions with the observer—that is, interactions that were about the current moment—which reduced pain perception irrespective of relationship to the participant, whereas irrelevant interactions led to increased perceived pain (Krahé et al., 2013). Thus, recent summaries of this literature suggests that another psychological process other than mere social support is likely at work.

Another literature investigating the effect of observer empathy—defined as the sense of knowing and understanding someone's pain (Goubert, Craig, Vervoot, Morley, Sullivan et al., 2005)—on perceived pain shows mixed results. Empathy is at times tied to reductions in perceived pain. For example, overhearing empathetic comments made by experimenters reduced perceived pain compared to neutral or negative comments (Fauchon, Faillenot, Perrin, Borg, Pichot et al., 2017). However, empathy is also linked to increases in perceived pain. Children undergoing a cold pressor task reported perceiving more pain when their mothers showed empathy, compared to when mothers tried to distract them (Chambers, Craig & Bennet, 2002). In adults, greater perceived empathy from a partner predicted greater perceived pain compared to lower perceived empathy (Hurter, Paloyelis, Williams & Fotopoulou, 2014). Recent work in this area has identified the level of agreement between observer's and receiver's perceptions of the pain experience as a possible moderator of this effect. When an observer's perspective does not match the perspective of the receiver, the receiver reports greater distress (Clark, Cano, Goubert, Vlaeyen, Worm, et al., 2017) and perceived pain (Leong, Cano, Wurm, Lumley & Corley, 2015). However, when an observer’s perspective matches a receiver’s perspective, the receiver reports lower perceived pain (Leong et al., 2015). This work suggests that previously studied variables, including social support and empathy, would not fully predict perceived pain outcomes without accounting for the congruence between the support or empathy source and the pain experiencer.

Social comparisons facilitated by providing information about an upward social comparison of pain experience, compared to a downward social comparison of pain experience can reduce perceived pain and pain-related emotion related to threat. For example, participants who were to take part in a cold pressor task were first given information about prior participants. When told that prior participants tolerated the cold pressor task very well (an upward social comparison) compared to poorly (a downward social comparison), perceived pain decreased significantly (Jackson & Phillips, 2011). Similarly, reading a brief computer-generated message about the level of pain reported by prior study participants reduced perceived pain (Pulvers, Schroeder, Limas & Zhu, 2014), even when participants had already completed a cold pressor task earlier in the same study session without feedback (Wilson, Chaplin & Thorn, 1995). Finally, participants who watched a pain tolerant social model undergo a series of electric shocks showed reduced subjective stress after experiencing their own shock, as well as reduced perceived pain, compared to non-modeled controls (Craig & Prkachin, 1978).

Thus, across these three literatures, there is evidence that social contact is more effective at reducing pain perception when the social contact offers social validation, social comparison, and information about social norms. While these important factors may not always be present in a social support or empathy scenario, the construct of shared reality—an experience that can be achieved with any person in reference to a common subject in the world—is understood to be the experience of social validation, comparison, and adjusting to normative information when needed. It is therefore possible that shared reality is driving the effect of social contact on pain.

2.0 Achieving Shared Reality With Others

Social contact with others is a basic human need that we are fundamentally motivated to pursue (Baumeister & Leary, 1995; Bowlby, 1982). Our need for social contact becomes apparent in contexts of threat, where we pursue social contact as an important self-preservation strategy. In early life, we seek out social information when under threat. For example, when evaluating a loud noise, infants reference the emotional responses of a guardian and typically mirror that response (Parritz, Mangelsdorf & Gunnar, 1992). Young children first rely on parental reactions when evaluating potentially threatening objects (e.g., a rubber snake or spider; Gerull & Rapee, 2002) or act fearful and avoidant of a stranger when mothers respond anxiously to their presence (de Rosnay, Cooper, Tsigaras, & Murray, 2006). Children and teenagers respond to ambiguous situations with greater anxiety if they observe an anxious response from a parent, rather than a confident one (Moller, Majdandzic, Vriends & Bogels, 2013). Specific to pain, infants referencing their mother's mild pain or fear-related facial expression during immunization shots responded with less pain-related facial expressions of their own compared to when their mother's facial expressions were severe (Horton & Pillai Riddell, 2010). From the beginning of life, we instinctively depend on social contact during threat, particularly as a source of safety-related information.

Stanley Schachter's affiliative tendency experiments (1959) demonstrated the continued drive toward social contact during threat. Among women waiting for an electric shock as part of an experimental paradigm, Schachter (1959) found that a) given the choice, the women preferred to wait with others instead of being alone (affiliative tendency), b) higher anxiety predicted greater affiliative tendency, and c) this was only the case when the others were like themselves, in other words, enrolled in the same experiment. Further, women who waited with others like themselves reported less anxiety about the upcoming electric shock than women who did not, even when they were not allowed to communicate with the other women. The affiliative tendency predicted that people experiencing anxiety aroused by threat of pain benefited from the opportunity for affiliation with and possible social comparison to people similar to themselves. The affiliative tendency hypothesis built upon Leon Festinger's social comparison theory (Festinger, 1954), which posits that we are driven to compare ourselves to similar others for accurate self-understanding. Further testing the affiliative tendency and the need to be with similar others, a student of Schachter's probed the mechanism of social comparison to determine whether it reduced anxiety or if comparison led to "emotional homogenization," where the levels of anxiety experienced by similar individuals become more alike over time (Schachter, 1959). Schachter and Wrightsman (1959) ultimately determined that people's anxiety became homogenized, or became more like their group members over time, which suggests that seeking social contact under threat is a psychological strategy we may use to gauge and adapt our response to threat.

Another way to interpret social comparison and the affiliative tendency is through shared reality. We seek out opportunities to share our perspective with similar others to make sense of the world, to feel socially connected, and to feel secure in our knowledge of objective reality (epistemic validation; Echterhoff, Higgins, & Levine, 2009; Hardin & Higgins, 1996). Sharing reality about a common external factor (for example, a person or experience that both people can reference) changes one's sense of subjective reality into a sense of objective reality (Echterhoff, 2012; Hardin & Higgins, 1996), and can become the foundation of new relationships (Rossignac-Milon & Higgins, 2018). Thus, we make sense of the world through social contact with others, and those with whom we can share reality can become meaningful social connections.

Initial experimental evidence for shared reality came from experiments demonstrating the "saying-is-believing" effect (Higgins & Rholes, 1978). In the original experiment, a participant would read a short essay about a person and then describe the person to an audience. The essay included purposefully ambiguous evaluations, like saying the person was "independent/aloof." This could be positive (independent, self-reliant) or negative (aloof, standoffish). The participant was told that the audience would try to guess who he was describing based on the description he gave. Before communicating to the audience, the participant was casually informed that the audience either liked or disliked the person he was to describe. In response to this information, the participant tuned their message to the audience: they gave a positive description to an audience that favored the person, and a negative description to an audience that did not. Participants also tuned their memories—when asked to recall the person they had described at a later date, their recall was biased in the direction of the message they gave. This persistence of belief is attributed to the experience of sharing reality with others. When shared reality was not attained, the belief did not persist in memory.

Sharing reality is a motivated state. Given the opportunity, our motivation to share reality with others will lead us to infer the attitudes and experiences of others (and adapt our attitudes when reality is difficult to obtain). For example, when others conspicuously do not share reality, such as when visually judging the length of something and giving an obviously incorrect assessment, we will adapt our judgement to align with others even if we think it incorrect (Asch, 1951). Sharing reality with others confers a sense of security and social connection, while failure to share reality creates discomfort and agitation (Echterhoff, Higgins & Levine, 2009). I therefore hypothesize that sharing reality (vs. not sharing reality) with another person during pain will both reduce negative emotions and increase positive emotions.

3.0 Shared Reality and Emotion

The impact of shared reality on emotion is strongly implied. Sharing reality includes sharing inner states, which are composed of "feelings or beliefs" about a target referent (Higgins, Rossignac-Milon & Echteroff, 2020), and the process of sharing reality implies that we can compare our inner states to others for more information about reality, and tune our inner state to meet the perceived norms as necessary (Harden & Higgins, 1996). Shared reality in early life is proposed as a developmental precursor to self-regulation, the ability to control one's behaviors, thoughts, and emotions (Higgins, 2011; Higgins, 2019). Importantly, as noted above, failure to share reality leads to negative emotion (Asch, 1951; Echterhoff, 2010). The implications of shared reality theory are that we develop an innate ability to understand the world and connect to others by understanding, comparing, and tuning our own feelings to meet those of others. Successfully sharing reality increases a sense of security and social connection, and prevents the negative emotion associated with failure to share reality (e.g. anxiety, agitation; Echterhoff, Higgins, & Levine, 2009).

Shared reality has not been tested in the context of emotion and pain, but a speculative example can be drawn from the social comparison literature. As mentioned, the opportunity for social comparison to others, or to normative information, modulates perceived pain in experimental settings by offering information about what to expect, and how others perceived reality in a given situation (Jackson et al., 2011). Knowledge of other's attitudes toward a particular referent (in this case, a pain task) is sufficient to promote sharing reality with another person (Echterhoff, 2010), and expectations about pain can predict how pain is ultimately perceived (Hird, Charalambous, El-Deredy, Jones & Talmi, 2019). Importantly, orienting information about where one stands compared to others can adjust the direction of "tuning" towards other's attitudes: Upward social comparisons, or information about other's high tolerance to a pain task, can reduce perceived pain, and downward social comparisons, or information about low tolerance to a pain task, increase perceived pain (Jackson et al., 2011). These findings support the notion that "tuning" of one's inner state can occur during a pain task when orienting information is given. Social comparison is a specific, but important part of creating shared reality. While it is possible to share reality without changing one's inner state, social comparison literature supports the hypothesis that sharing reality can occur during pain, and can modulate the experience of pain.

4.0 Emotion and Perceived Pain

Direct experimental evidence demonstrates that inducing negative emotions like anger, anxiety, disgust, fear, and sadness lead to increased perceived discomfort and pain, while inducing positive emotions like happiness, humor, relief, and satisfaction can reduce perceived pain (Cornwall & Donderi, 1988; de Weid & Verbaten, 2001; Geva, Pruessner, & Defrin, 2014; Meagher, Arnau & Rhudy, 2001; Rainville, Bao & Chrétien, 2005; Weisenberg, Raz & Hener, 1998; Yoshino, Okamoto, Onoda, Yoshimura, Kunisato, et al., 2010; Zelman, Howland, Nichols, & Cleeland, 1991). The same is true of pain-adjacent experiences, for example, even when a stimulus is mildly uncomfortable (but not painful) higher levels of negative emotions like anxiety predict greater reported discomfort (Phillips, Gregory, Cullen, Cohen, Ng, et al., 2003). Similarly, greater perception of threat, which is commonly associated with other negative emotion such as fear and anxiety (Lazarus & Folkman, 1984; Folkman & Lazarus, 1988), can increase perceived pain. For example, being told that an experimenter has chosen to give the maximum painful stimulus (rather than a less painful version) increased perceived threat of a painful shock (Karos, Meulders, Goubert & Vlaeyen, 2018) and this increased threat was associated with an increase in perceived pain (Karos, Meulders, Goubert & Vlaeyen, 2019; Peeters & Vlaeyen, 2011).

Though chronic pain is a separate construct from acute, short-lived experimental pain, converging evidence in the chronic pain literature supports the relationship between emotion and pain. Specifically, the ability to regulate ones emotions is associated with better pain outcomes, whereas the experience of greater negative emotion is associated with worsened pain over time (Koechlin, Coakley, Schechter, Werner, & Kossowsky, 2018).

5.0 Study Aims

To the extent that achieving a state of shared reality with another person provides a sense of epistemic certainty, shared reality can enhance positive emotions like safety and social connection, and reduce negative emotions like anxiety and uncertainty in response to a threat. These outcomes are highly relevant to perceived pain, but shared reality has not been tested as a possible moderator of the effect of social contact on perceived pain. Further, despite the relationship between emotion and pain, there is a dearth of literature testing whether social contact reduces perceived pain by modulating emotion. I therefore tested the hypothesis that sharing reality (vs. not sharing reality) will affect emotional responses to pain, which in turn will reduce perceived pain. To test this hypothesis, I experimentally varied shared reality during an acute experimental pain experience to test the effect of this manipulation on emotion and subsequent pain perception (Figure 1). I hypothesized that shared reality (vs. no shared reality) would reduce negative and increase positive emotion in response to a cold pressor task, in turn reducing perceived pain.

6.0 Method

6.1 Participants

An a-priori power analysis conducted in g*power (Faul, Erdfelder, Buchner & Lang, 2009) determined that 126 participants were needed to achieve .80 power to detect a medium effect size. Due to slow recruitment the sample size was adjusted to meet the minimum possible sample size without being considered underpowered (Simmons, Nelson, & Simonsohn, 2018). A resulting sample of one hundred women free of contraindications to cold exposure were recruited to participate in this study. Sex and age differences in pain perception are noted in the literature but not well understood (Jackson, Iezzi, Chen, Ebnet & Eglitis, 2005; Lautenbacher, Peters, Heesen, Scheel, & Kunz, 2016; Mogil, 2020;), thus the current study recruited cisgender women under 40 years of age. The mean age of the final sample was 19.3, *SD* = 1.6, with a range from 18-24 years old. Age was not associated with pain measures, *p's* > .35.

Participants were recruited through the University of Pittsburgh undergraduate subject pool for a study of "thermal challenge and perspective." Once confirming safety for cold exposure, participants were scheduled for 15-minute study appointments with the researcher and an ostensible 2^{nd} participant (a confederate profile) to be conducted via Zoom. All appointments took place during normal business hours on eastern standard time (EST), between 9am-5pm. Participants received course credit in exchange for their time.

6.2 Procedure

Participants signed up for study appointments on SONA and were emailed a link to a consent form to sign digitally prior to any study procedures. Once they provided consent, participants were instructed to pick up a 16oz plastic cup from the psychology building, fill the cup with water to 1cm below the top rim, and freeze until solid at least 12 hours before their study appointment time. Participants then received an email link to a private zoom meeting and were told they would be placed in a small group, so they should keep their cameras off and change their zoom names to initials for their own privacy.

To create the appearance that participants were in the study with another participant, a deception occurred at the beginning of each zoom meeting. When participants signed on to the meeting, they saw two zoom profiles labeled Lab 1 and Lab 2. One of these profiles was the real experimenter, and one was fake. The real experimenter turned on their camera and asked the participant to wait briefly with their camera off while we waited for the second participant. After 30-60 seconds the experimenter remarked that the second participant was in the waiting room and then admitted the second participant (a fake profile labeled P.K.) to the zoom meeting. The experimenter then said, "thank you both for coming! We really appreciate it…" and gave a brief overview of the study tasks. At the end of the task overview the experimenter explained that the participants would need to turn their cameras on for approximately 3 minutes during the thermal challenge, so they would each be placed in separate room with an experimenter. At that time the two fake zoom profiles (Lab 2 and P.K.) were moved to a breakout room, the participant was asked to turn on their camera, and the experimental procedure began.

Once the experimenter and participant were alone, participants were sent a link (via Zoom's chat function) to complete a baseline measure of emotion on Qualtrics, and then the cold pressor task began. Participants turned on their cameras and held the frozen cup with their non-dominant hand for three minutes. During the cold pressor task participants underwent the shared reality manipulation described below, and verbally self-reported pain at the 2-minute mark of the cold pressor task. Once the cold pressor ended after 3 minutes participants verbally self-reported pain again, and accessed Qualtrics to complete the second measure of emotion and a shared reality questionnaire. At the end of the experiment participants were probed for suspicion, debriefed, assigned class credit, and thanked for their time. See Figure 2 for a timeline of study procedures.

6.3 Measures and Materials

6.3.1 Positive and Negative Affect Scale (PANAS)

Emotion was measured at the beginning and end of the experiment session using the 20-item PANAS questionnaire (Watson, Clark, & Tellegan, 1988; appendix a) asking to rate emotions relative to how they were feeling at the moment on a scale from "not at all -- 1" to "very much -- 5." The range of possible scores for each subscale was 10-50. Scores on the PANAS subscales were summed before analysis. The PANAS was administered both before and after the cold pressor task to allow for a test of the direction and magnitude of change in emotion caused by the cold pressor task. The PANAS positive and negative affect subscales were calculated and assessed separately (Crohnbachs alpha = .90, .83 respectively). Because participants completed the PANAS once before and once after the cold pressor task, the PANAS questions were presented in random order to increase validity.

6.3.2 Cold Pressor Task

Participants underwent a modified cold pressor task (referred to as a "thermal challenge" in study advertisements) that was designed to be conducted at their home. Though only recently developed, self-administered home cold pressor tasks show promise as an effective and valid pain manipulation (McIntyre et al., 2020). Each participant was required to visit Sennott Square to pick up a 16 oz. plastic solo cup marked with a "fill to here" line marked and containing instructions for filling with water and freezing. Any participant who was unable to freeze the cup for at least 12 before their study appointment was rescheduled (n = 2). Once the cold pressor task began, participants held the cup in their non-dominant hand for approximately 3 minutes. Participants were instructed to try to hold the cup for 3 minutes but to put it down at any time if necessary. All participants held the cup for the full 3 minutes.

6.3.3 Visual Analog Scale (VAS) Pain Measures

The VAS includes two commonly measured domains of pain representing distinct psychological experiences: Pain intensity, which represents the evaluation of the pain sensation itself, and pain unpleasantness, which includes the participants' response to the experience overall, including affective and physiological arousal (Price, 2000; see appendix b). Participants verbally reported perceived pain from the cold pressor task on these two dimensions using a visual analog scale from zero to ten, where zero indicated the absence of pain and ten was the greatest amount of pain. During the VAS the experimenter asked participants to rate first their pain "intensity," and were told this meant how strong the pain is, and then asked to rate pain "unpleasantness," and were told this meant how much the pain was bothering them overall. Previous work has shown that cold pressor pain reaches its peak between 1-2 minutes (Brown, Sheffield, Leary & Robinson, 2003) and that psychological factors impact the perception of pain in post-task recovery (Smith, Villatte, Ong, Butcher, Twohig, et al., 2018), so pain was measured at 2 minutes and right after the cup was put down at 3 minutes in an attempt to capture both of these effects.

Although the pain literature considers pain intensity and unpleasantness different domains of pain experience (Price, 2000), self-reported pain intensity and pain unpleasantness were highly correlated during both the first measurement, $r = .75$; $p < .001$ and second measurement, $r = .79$; $p < .001$. Thus, pain intensity and pain unpleasantness were averaged into single measures of pain measured 2 minutes into the cold pressor task (pain time 1) and pain measured at 3 minutes (immediately after the cold pressor task; pain time 2). Participants' pain ratings at time 1 ranged from 0-9, and pain ratings at time 2 ranged from 0-8.

6.3.4 Shared Reality Manipulation

To achieve shared reality with another person, four conditions must be met. The first condition is that a common inner state is achieved, such as shared attitudes and opinions, and that shared reality is not just built around a common behavior (e.g., emotional mimicry; Hatfield, Cacioppo & Rapson, 1993). Second, the common inner state must pertain to some external referent in the world, such as a person or experience. Third, achieving shared reality must be motivated by seeking social contact and epistemic validation, not simply by the desire to reach a shared reality for the sake of agreement. Finally, shared reality must be communicated, recognized, or perceived between those involved (Echterhoff, Higgins & Levine, 2009; Hardin & Higgins, 1996).

To manipulate shared reality while attempting to meet these four conditions, once the cold pressor task began participants were asked to view five words, one at a time, on the screen, and to verbally indicate whether or not the word on the screen described their experience. Several words describing sensory experiences were piloted (*n* = 10); words chosen by pilot participants as describing the experience of holding something cold approximately 50% of the time were implemented. The final list included 10 words, which were split into two randomized lists of 5 words each (appendix c). Participants were randomly assigned to see one of these two lists. After the participants had seen and rated the words, the experimenter pretended to check in with the other experimenter via the Zoom chat feature. In the shared reality condition, participants were told that they had made similar choices to the other participant: "That's interesting, you both said the same thing"; in the non-shared reality condition, participants were told, "That's interesting, you both said the opposite of each other." The average time of the verbal shared reality manipulation was less than one minute into the cold pressor task.

6.3.5 Shared Reality Measure

As a manipulation check on shared reality, participants self-reported their experience with the ostensible participant after the paradigm was finished using a 5-item shared reality scale. The scale was adapted from an existing scale (Rossignac-Milon, Bolger, Zee, Boothby, & Higgins, 2021; appendix c) and asked participants to rate the degree to which they felt as though they were thinking and feeling similarly to or dissimilarly from the other participant about the cold pressor task (Cronbach's Alpha = .84). Scores on the shared reality were summed before analysis, and participants' scores ranged from 5-25 (out of a possible 35).

6.3.6 Probe for Suspicion

To probe for suspicion about the true nature of the study participants were asked to report a) if they suspected the other participant was not actually present, and b) what they thought the study hypotheses were. Two participants reported being “unsure” whether the other participant was real, and none of the participants correctly identified the study hypotheses. Therefore, all participants were retained in the analyses reported below.

7.0 Results

7.1 Manipulation Check on Shared Reality

An independent samples t-test revealed that participants in the shared reality condition reported greater feelings of shared reality (*M* = 18.18, *SD* = 2.96) than those in the non-shared reality condition (*M* = 16.13, *SD* = 3.69; *t*(96) = 2.99, *p* = .004); see Table 1. Thus, shared reality was effectively manipulated by the word choice paradigm. However, shared reality ratings were not associated with emotion or pain ratings (see Table 2 for all correlations).

7.2 Changes in Emotion

To test the effect of shared reality on emotion over time, paired samples t-test were conducted for the PANAS positive and negative subscales comparing pre- and post-task measures. No significant changes were revealed on positive emotion from the pre-task measure (*M* = 25.17, *SD* = 7.60) to post-task (*M* = 24.47, *SD* = 8.02; *t*(96) = 1.38, *p* = .171, Cohen's *d* = .14). Negative emotion decreased significantly from pre-task (*M* = 15.7, *SD* = 5.56) to post-task (*M* = 13.36, *SD* = 4.18; *t*(96) = 5.24, *p* = <.001, Cohen's *d* = .54).

Independent-samples t-tests were then conducted to compare self-reported emotion from the PANAS negative and positive emotion subscales recorded after the cold pressor task (see Table 1). No condition differences were found in negative emotion between shared reality (*M* = 13.69, *SD* = 4.58) and non-shared reality conditions (*M* = 13.26, *SD* = 3.76; *t*(93), *p* = .617, Cohen's *d* =

.001). Similarly, no differences were found in positive emotion between shared reality (*M* = 24.4, *SD* = 8.79) and non-shared reality conditions (*M* = 24.39, *SD* = 7.32; *t*(98) = .005, *p* = .99, Cohen's *d* = .103). Taken together, these results suggest that while emotion changed over time, the shared reality condition did not contribute to reduced negative emotion or changes in positive emotion compared to non-shared reality.

7.3 Self-Reported Pain

Independent-samples t-tests were conducted to compare self-reported pain at time 1 (while still holding the cup) and time 2 (after the cup was put down) in shared reality and non-shared reality conditions (see Table 2). Unexpectedly, t-tests revealed a significant effect of condition on self-reported pain at time 1 such that participants in the shared reality condition (*M* = 5.82, *SD* = 1.63) reported greater pain than those in the non-shared reality condition (*M* = 5.03, *SD* = 1.94; *t*(98) = 2.21, *p* = .029, Cohen's *d* = .44). No differences were found in pain at time 2 between shared reality (*M* = 2.87, *SD* = 2.26) and non-shared reality conditions (*M* = 2.88, *SD* = 2.06; *t*(9) = .157, *p* = .971, Cohen's *d* = .007).

7.4 Indirect Effects Through Emotion

Although shared reality did not significantly affect positive or negative emotion and emotion was not significantly associated with pain (pain time 1: positive emotion *r* = .005, *p* = .958; negative emotion *r* = .04, *p* = .66; pain time 2: positive emotion *r* = .10, *p* = ..304; negative emotion $r = .13$, $p = .198$), as planned I investigated whether the effect of shared reality on pain at time 1 was mediated by positive or negative emotion. To do so, I used PROCESS model 4 with 10,000 bootstrapped samples (Hayes, 2017), with shared reality condition entered as the independent variable, post-task positive and negative emotion entered as simultaneous mediators, and pain at time 1 entered as the outcome. The indirect effects were not significant, indirect effect through positive emotion = < .001, 95% CI [-.0754, .0804]; indirect effect through negative emotion = .006, 95% CI [-..0358, .1488].

I then conducted the same analysis on time 2 pain. Again, no indirect effects were found, indirect effect through positive emotion = -.002, 95% CI [-.1307, .1192]; indirect effect through negative emotion = .026, 95% CI [-.0698, .2230]. Full model results are depicted in Figure 3.

8.0 Discussion

Pain is a ubiquitous human experience, but the psychology of pain is not yet fully understood. Social context can modulate perception of pain, but results in this work are mixed. The current study looked to a novel variable, shared reality, as a potential predictor of perceived pain through modulating emotion, which has been shown to influence pain perception. Inducing positive emotion can reduce pain, while inducing negative emotion can increase pain (e.g., Cornwall et al., 1988; de Weid et al., 2001; Geva, et al., 2014; Meagher et al., 2001; Rainville, et al. 2005; Weisenberg et al., 1998; Yoshino et al., 2010; Zelman et al., 1991). Shared reality has been theorized to modulate emotion by providing epistemic certainty and a sense of social connection, or positive emotion, and by mitigating the discomfort of epistemic uncertainty, or negative emotion, we can feel when reality is not shared (Echterhoff et al., 2009).

The present study did not support the model proposing mediation of the relationship between shared reality and perceived pain by changes in emotion. On path a, shared reality did not predict changes in positive or negative emotion. Though a manipulation check indicated that shared reality was successfully manipulated, means on the PANAS decreased over time, and no condition effects were found. On path b, positive and negative emotion did not predict perceived pain. There were no indirect effects of shared reality on pain perception through emotion, positive or negative. Finally, the direct effect of shared reality on pain perception was the opposite of what the study hypothesized, with condition predicting increased pain perception in those who shared reality. Below I offer speculations for why hypotheses might not have been supported.

8.1 Shared Reality and Emotion

Shared reality has been theorized to increase positive emotion by providing epistemic certainty and feelings of social connection and, by extension, decrease negative emotion aroused by epistemic uncertainty. Conversely, a lack of shared reality is thought to create discomfort and agitation increasing negative emotion (Echterhoff, Higgins, & Levine, 2009; Hardin & Higgins, 1996). Although the findings from this study are not definitive, the current pattern of results does not support the hypothesis that sharing reality modulates emotions.

As noted earlier, four conditions are needed to achieve shared reality: a) a common inner state, b) the common inner state pertains to some external referent in the world, such as a person or experience, c) shared reality must be motivated by seeking social contact and epistemic validation, and d) shared reality must be communicated, recognized, or perceived between those involved (Echterhoff, Higgins & Levine, 2009; Hardin & Higgins, 1996). Although the manipulation check indicated that participants felt they were sharing reality with the other person in the shared reality condition, it is possible that the motivational requirement of shared reality was not met. Indeed, the shared reality measure used (appendix c) did not include a question gauging how motivated participants were to find agreement, and it is possible that participants did not feel strongly motivated to share reality with a participant in a different zoom room that they could not see (and would never meet). Future research would benefit from the use of a paradigm that enhances motivation to share reality, as well as a measure assessing motivation to confirm that all conditions of shared reality have been met.

Another possible explanation for these results is that the shared reality manipulation in this study did not provide enough information for participants to "tune" their emotion towards their shared reality partner. Shared reality is, in part, a process of inferring the inner states of others and comparing our own experience (Echterhoff & Higgins, 2018). Experimental paradigms demonstrating social comparison processes, a key component to shared reality, typically provide orienting information about where we stand relative to others. The present study did not provide orienting information about the other participant's experience, but rather provided information that they were having a subjectively similar experience to the participant. Given the strong influence of suggestion on perceived pain in the pain literature (Wolff, Krasnegor & Farr, 1965) this study was designed to limit any suggestion about the other participant's emotion or pain experience in order to maintain internal validity of those measures. With limited information about the other participant's experience of emotion or pain, the shared reality manipulation may have simply validated whatever the participants were feeling.

An alternative possibility is that shared reality does not substantially influence or predict emotion. Limited experimental evidence on the effect of shared reality on emotion exists. The shared reality literature would therefore benefit from testing the effect of shared reality on emotion and incorporating measures of epistemic certainty and social connection—the mechanistic variables implied to influence emotion—to better understand this relationship.

8.2 Emotion and Pain

Positive and negative emotion modulate pain in experimental settings, however the current study results showed no relationship between emotion and perceived pain.

A possible reason for this null association is that the influence of emotion on pain is contingent upon an interaction between valence and arousal (Rhudy & Meagher, 2001), such that mildly negative, physiologically arousing pain procedures may not be evocative enough to modulate perceptions of pain. Given that both positive and negative emotion both unexpectedly decreased over time, irrespective of condition, it is likely that the pain paradigm was not negatively arousing enough to evoke strong emotion and consequently predict pain perception. Additional research manipulating both positive and negative emotion in addition to shared reality is needed to understand the levels or conditions under which emotions influence pain perception.

8.3 Shared Reality and Pain

Contrary to my hypothesis, sharing reality with another person about a cold-pressor task increased perceived pain at the first measurement relative to the non-shared reality condition, though the effect size was small. Further, there was no correlation between the shared reality measure and pain measures at either time. Results suggest that sharing reality in this context did not relate to pain.

One explanation for the current results may be that the experimental design limited the impact of the shared reality manipulation. Shared experiences can be "amplified," or experienced with greater salience (Boothby, Clark & Bargh, 2014), including in the context of experimental pain (Nahleen, Dornin, & Takarangi, 2019). It is possible that participants in the shared reality condition only perceived themselves to be sharing an experience, rather than sharing inner states about the experience. However, some work suggests that the amplification effect of shared experiences is moderated by "psychological distance," in other words, familiarity: In an experimental pain study, participants who saw one another before the shared experience reported greater amplification than those who had not seen the other participant (Nahleen et al., 2019).

While the present study visually cued the presence of another person with a confederate zoom profile, there was no video or photo providing the opportunity to gain familiarity. It is unclear if the shared reality manipulation actually functioned as something more like a shared experience manipulation, where the experience of the task, rather than the experience of inner states about the task, would be most impactful.

The results of this study also mirror the empathy literature, where empathy for pain can increase perceived pain (e.g., Fauchon et al. 2017; Hurter et al., 2014), though it is noted that the effect of empathy on pain is moderated by accuracy: When a participant experiences empathy that is perceived as being appropriate to the level of pain they are experiencing, perceived pain does not increase. It is when the empathy expressed is perceived to be too much or too little that perceived pain increases (Clark et al., 2017). Although the shared reality manipulation in this study provided feedback about similarity or dissimilarity of inner states (rather than another person's perception of our pain), it is possible that sharing reality with another person made the pain feel more "real" or validated, thereby enhancing pain perceptions.

It is also possible that the current pattern of results is documenting suppression of perceived pain or pain reporting in the non-shared reality condition. Early work on social factors and pain perception found that being observed by a stranger during a pain paradigm suppressed pain reports and expressions compared to people who were not observed (Kleck, Vaughan, Cartwright-Smith, Vaughan, Colby, et al., 1976). Though the experimenter was present during the cold pressor task across conditions, sharing reality with another participant may have ameliorated all or some of the effects of observation. Additionally, stressful situations can induce analgesic effects on pain under some circumstances (Yilmaz, Diers, Diener, Rance, Wessa et al., 2010), specifically when a pain paradigm follows a stress induction task. The present study did not manipulate or measure stress, but to the extent that participants found the experience to be stressful, the non-shared reality condition may have experienced a stress-induced analgesic effect. Future studies would benefit from incorporating a more complete measure of emotions that incorporates stress.

Finally, it is possible that shared reality enhances pain under certain circumstances. Despite the strength of experimental controls limiting external influences on pain perception in the present work, the current results mirror the mixed literature attempting to characterize the effect of social factors like sharing reality on pain perception. Future work is needed to fully elucidate the impact of sharing reality on perception of pain.

8.4 Limitations

The present study has a number of limitations. Perhaps most importantly, the challenges of social distancing and remote experimentation over video make it difficult to control the experimental environment. Circumstances dictate flexibility in our practices, and investigating the impact of social influence on emotion and perception is uniquely challenging among participants who are appearing on video from the comfort of their own homes. Though self-administered home cold pressor tests are effective (McIntyre et al., 2020) it is difficult to predict or interpret how the home environment may influence experimental paradigms studying social factors, given the myriad of social roles, memories, and emotions present in our homes. Further, being in our home environment may imbue a sense of safety and security. Therefore, the present study likely presents a very conservative manipulation of shared reality outside of a controlled laboratory setting.

The current study assessed only limited demographic information (age, vasculature disorders), and future work would greatly benefit from a better understanding of how individual differences in health influence the effects observed here. In particular, future research on social contact and pain should include other health indices as covariates, such as chronic pain, psychological disorders, and use of medications.

Pain decreased over time, despite evidence that the pain from a cold pressor task increases the longer the stimuli is applied (Brown et al., 2003). Though prior studies have validated the use of home cold pressor tasks (McIntyre et al., 2020) the present study is among the first to investigate social influences on cold pressor pain at home. As noted, the social and emotional environment of participant’s homes existed outside of experimental controls, and additional research is needed to determine if or how a home-based study of acute pain modulates pain outcomes. Possible experimental controls on home cold pressor tasks investigating social factors could include measures to better understand how the home environment influences such paradigms.

Additionally, the present study measured pain at 2 minutes and 3 minutes into the cold pressor task. In other words, the second pain measure was taken immediately after the participants put down the frozen cup. It is possible that the second pain measure suffered from a demand characteristic in which participants felt they were expected to report less pain since the cup was no longer in their hand. The same could be true of emotion: the PANAS was given to participants at the very beginning, and very end of the experimental paradigm. It could be the case that participants inferred that they “should” be reporting less emotion overall since the experimental procedures were complete.

Significant experimental evidence supports the impact of emotion on perceived pain, however the current study was designed to measure, not manipulate, emotion. While emotion was intentionally measured rather than manipulated to optimize measuring the effect of sharing reality on this variable, it is unclear from the current pattern of results whether the observed levels of emotion meet a possible threshold of valence and arousal necessary for influencing pain perception.

Overall, the shared reality manipulation would benefit from further refining. While the shared reality manipulation was successful per the shared reality follow-up measure, the manipulation was limited to short word lists providing no personalized information about the other participant. Further, information about sharing reality was given to the participant from the experimenter, rather than the participant. Future experiments could benefit from incorporating a live confederate, and providing more specific details about the experience as part of the shared reality manipulation.

Finally, the generalizability of the present study is limited to moderate, controlled acute pain experiences. While experimental studies of acute pain yield important insight into pain psychology, acute experimental pain is dissimilar from organic instances of pain in a number of ways. Acute pain is often unexpected, but it is not possible to administer fully unexpected pain under informed consent. It is noted that expectations about pain affect perceptions of pain (Hird et al., 2019), thus it is not possible to know how the current findings may translate to organic unexpected pain, such as a bee sting or a stubbed toe. Similarly, this research does not directly contribute to knowledge regarding chronic pain populations. Acute pain perception is a distinct psychological process from what is observed in chronic pain, for example, while upward social comparisons reduce perceived acute pain in experimental settings, it is downward social comparison that reduces measures of pain in the chronic pain literature (Taylor, Buunk & Aspinwall, 1990; Tennen, Mckee & Affleck, 2000). Additionally, the long-term nature of chronic pain involves learning about pain patterns, and responding to reminders that trigger pain (Fordyce, 1976; Lumley, Cohen, Borszsz, Cano, Radcliffe et al., 2011). Thus, the implications of these findings are limited to mainly experimental acute pain.

8.5 Conclusions

The present study tested the effect of shared reality on emotion and perceived pain, as well as whether shared reality influenced perceived pain via emotion. Although hypotheses were not supported, the results of this study reflect the complexity of the effect of social contact on perceived pain. Social contact appears beneficial to perceived pain at times, but the field has yet to determine when and why these benefits occur. Shared reality remains a likely candidate in future studies that address the numerous limitations of this work, as the experience of sharing reality encompasses validation and social norm information, both of which are shown to reduce perceived pain under specific circumstances. Although hypotheses were not supported in the present study, it is hoped that this work inspires future research on the effect of shared reality on emotion and pain perception that will eventually elucidate interventions for pain reduction.

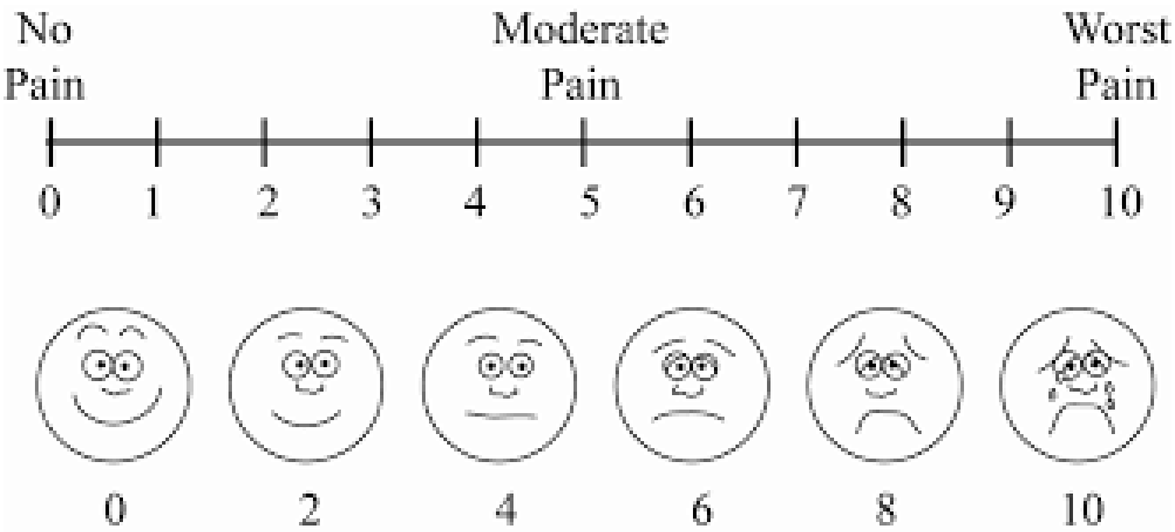
Appendix A PANAS

The Ohio State University

Positive and Negative Affect Schedule (PANAS-SF)

Indicate the extent you have felt this way over the past week.		Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
PANAS 1	Interested	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 2	Distressed	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 3	Excited	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 4	Upset	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 5	Strong	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 6	Guilty	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 7	Scared	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 8	Hostile	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 9	Enthusiastic	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 10	Proud	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 11	Irritable	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 12	Alert	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 13	Ashamed	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 14	Inspired	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 15	Nervous	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 16	Determined	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 17	Attentive	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 18	Jittery	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 19	Active	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PANAS 20	Afraid	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Appendix B Visual Analog Pain Scale



Appendix C Shared Reality Scale

Please rate your agreement with the following statements about you and your partner based on the thermal challenge that you completed at the same time.

(1- Strongly Disagree, 7 – Strongly Agree)

Please rate your agreement with the following statements (1=Strongly Disagree, 7=Strongly Agree)

I think that my partner and I are on the same wavelength with regard to the thermal challenge

My partner feels the same way about the thermal challenge as I do.

My partner agrees with my point of view of the thermal challenge.

My partner and I see the thermal challenge in the same way.

My partner agrees with my perception of the thermal challenge.

Appendix D Shared Reality Manipulation

List A

Blurry

Slippery

Prickly

Bristly

Sparkling

List B

Glistening

Silky

Biting

Shiny

Smooth

Table 1 Correlations

	1	2	3	4	5	6
1. Panas positive affect 1	---					
2. Panas negative affect 1	.254*	---				
3. Panas positive affect 2	.806**	.284**	---			
4. Panas negative affect 2	0.166	.682**	.214*	---		
5. Pain time 1	0.067	-0.095	0.005	0.045	---	
6. Pain time 2	0.104	0.054	0.105	0.133	.462**	---
7. Shared Reality	0.178	-0.057	0.138	-0.083	0.1	0.119

* indicates $p < .05$

** indicates $p < .01$

Table 2 Descriptive Statistics

	Shared Reality	*Non-Shared Reality*
	M(SD)	***M(SD)***
1. PANAS positive affect 1	25.6 (7.9)	24.71 (7.2)
2. PANAS negative affect 1	15.56 (5.8)	15.72 (5.21)
3. PANAS positive affect 2	24.4 (8.79)	24.39 (7.32)
4. PANAS negative affect 2	35.00 (13.69)	13.26 (3.76)
5. Pain time 1	5.81 (1.62)	5.02 (1.94)
6. Pain time 2	2.87 (2.26)	2.89 (2.06)
7. Shared Reality	18.18 (2.96)	16.13 (3.69)

Appendix E Figures

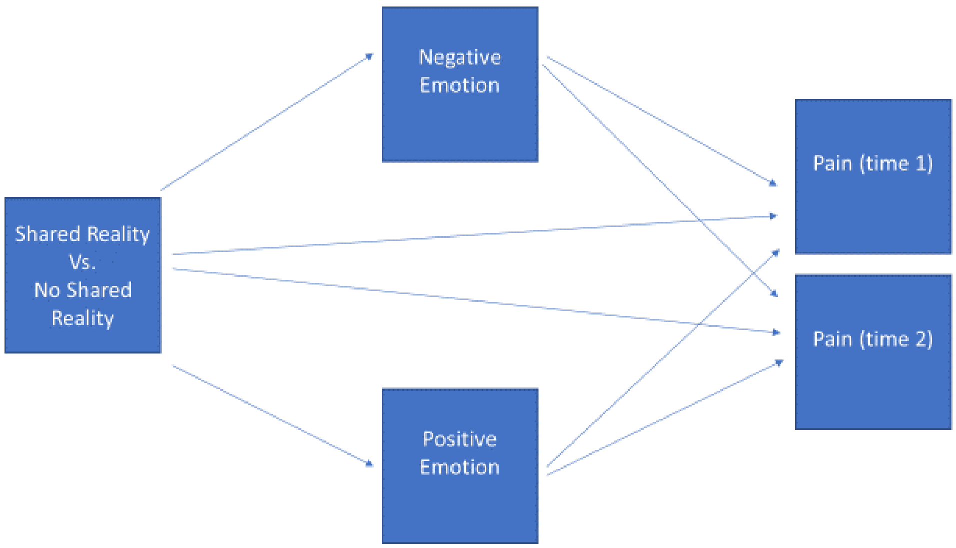
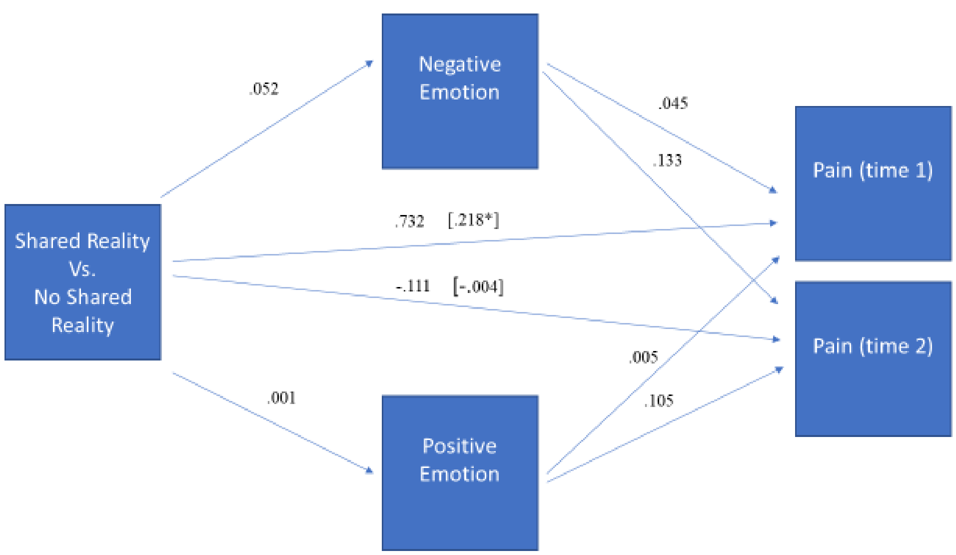


Figure 1 Theoretical Model

Setup for Shared Reality Manipulation *Participant is asked to wait for "other participant"*	***Pre-task Measure of Emotion (PANAS)** *Qualtrics*	**Cold pressor (3 min)**	**Pain Measure (VAS)** *Verbal reporting*	**Post-task Measure of Emotion** *Qualtrics*	**Shared Reality Measure, Debrief** *Qualtrics*
		Shared Reality Manipulation (Word Task), Pain measure (VAS) *Verbal reporting*			

* Fake second participant and second experimenter profiles were moved to a breakout room before the measures begin.

Figure 2 Study Timeline



* $p = .05$.

Figure 3 Model Results

Bibliography

Asch, S. E. (1951). Effects of group pressure upon the modification and distortion of judgment. In H. Guetzkow (ed.) *Groups, leadership and men*. Pittsburgh, PA: Carnegie Press.

Balicki, M. N. & Apkarian, A. V. (2015). Nociception, pain, negative moods, and behavior selection. *Neuron*, *87*, 474-491.

Boothby, E. J., Clark, M. S., & Bargh, J. A. (2014). Shared Experiences Are Amplified. Psychological Science, 25(12), 2209–2216.

Bowlby J. (1982). Attachment and loss (Vol. 1, 2nd ed.). New York: Basic Books. (Original work published 1969).

Brown, J. L., Sheffield, D., Leary, M. R., & Robinson, M. E. (2003). Social support and experimental pain. *Psychosomatic Medicine*, *65*(2), 276-83.

Che, X., Cash, R., Chung, S., Fitzgerald, P. B., & Fitzgibbon, B. M. (2018a). Investigating the influence of social support on experimental pain and related physiological arousal: A systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews*, *92*, 437-452.

Che, X., Cash, R., Ng, S. K., Fitzgerald, P. & Fitzgibbon, B. M. (2018b). A systematic review of the processes underlying the main and buffering effect of social support on experimental pain. *Journal of Clinical Pain*, *34*, 1061-1076.

Chambers, C. T., Craig, K. D., & Bennet, S. M. (2002). The impact of maternal behavior on children's pain experiences: An experimental analysis. *Journal of Pediatric Psychology*, *27* (3), 293-301.

Clark, S. M., Cano, A., Goubert, L., Vlaeyen, J. W., Wurm, L. H., & Corley, A. M. (2017). Pain anxiety and its association with Pain congruence trajectories during the cold pressor task. *Pain*, *18* (4), 96-404.

Cornwall, A., & Donderi, D. C. (1988). The effect of experimentally induced anxiety on the experience of pressure pain. *Pain*, *35* (1), 105-113.

Craig, A. D. (2002). How do you feel? Interoception: the sense of the physiological condition of the body. *Nat. Rev. Neurosci.* 3, 655–666.

Craig, A. D. (2003). A new view of pain as a homeostatic emotion. *Trends in Neuroscience*, *26*(6), 303-307.

Craig, K. D. & Prkachin, K. M. (1978). Social modeling influences on sensory decision theory and psychophysiological indexes of pain. *Journal of Personality and Social Psychology, 36 (8),* 805–815.

Coan, J. A., Schaefer, H. S., & Davidson, R. J. (2006). Lending a hand: Social regulation of neural responses to threat. Psychological Science, 17, 1032-1039.

de Rosnay, M., Cooper, P. J., Tsigaras, N., & Murray, L. (2006). Transmission of social anxiety from mother to infant: An experimental study using a social referencing paradigm. *Behavior Research and Therapy*, *44* (8), 1165-75.

de Wied, M., & Verbaten, M. N. (2001). Affective picture processing, attention, and pain tolerance. *Pain, 90*, 163-172.

Echterhoff, G. (2010). Shared reality: Antecedents, processes, and consequences. *Social Cognition*, *28* (3), 273–276.

Echterhoff, Gerald & Higgins, E. (2018). Shared reality: Construct and mechanisms. Current Opinion in Psychology. 23. iv-vii.

Echterhoff, G., Higgins, E. T., & Levine, J. M. (2009). Shared reality: Experiencing commonality with others' inner states about the world. *Perspectives on Psychological Science, 4,* 496-521.

Edwards, R, Eccleston, C & Keogh, E. (2017). Observer influences on pain: an experimental series examining same-sex and opposite-sex friends, strangers, and romantic partners, *Pain*, *158* (5), pp. 846-855.

Eisenberger, N. I., Master, S. L., Inakagi, T. K., Taylor, S. E., Shirinyan, D., Lieberman, M. D., & Nabiloff, B. D. (2011). Attachment figures activate a safety signal-related neural region and reduce pain experience. *Proceedings of the National Academy of Science, 108*(28), 11721-11726.

Epley, S. W. (1975). Reduction of the behavioral effects of aversive stimulation by the presence of companions. *Psychological Bulletin, 81*, 271-283.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*, 1149-1160.

Fauchon, C., Faillenot, I., Perrin, A. M., Borg, C., Pichot, V., Chouchou, F., Garcia-Larrea, L. & Peyron, R. (2017), Does an observer's empathy influence my pain? Effect of perceived empathetic or unempathetic support on a pain test. *European Journal of Neuroscience, 46*, 2629-2637.

Festinger, L. (1954). A theory of social comparisons. *Human Relationships, 7,* 117-140.

Folkman, S., & Lazarus, R. S. (1988). Coping as a mediator of emotion. *Journal of Personality and Social Psychology, 54* (3), 466–475.

Fordyce, W. E. (1976). *Behavioral methods for chronic pain and illness.* Saint Louis : Mosby.

Gerull, F. C., & Rapee, R. M. (2002). Mother knows best: The effects of maternal modelling on the acquisition of fear and avoidance behaviour in toddlers. *Behaviour Research and Therapy, 40* (3), 279–287.

Geva, N., Pruessner, J., & Defrin, R. (2014). Acute psychosocial stress reduces pain modulation capabilities in healthy men. *Pain, 155*(11), 2418-2425.

Gilam, G., Gross, J. J., Wager, T. D., Keefe, F. J., & Mackey, S. C. (2020). What is the relationship between pain and emotion? Bridging constructs and communities. *Neuron, 107,* 17-21.

Goubert, L., Craig, K., Vervoort, T., Morley, S., Sullivan, M. J. L., Williams, A. C. de C., Cano, A., & Crombez G. (2005). Facing others in pain: the effects of empathy. *Pain, 118,* 285–288.

Hardin, C. D. & Higgins, E. T. (1996). Shared reality: How social verification makes the subjective objective. In Richard Sorrentino and E. Tory Higgins (Eds.) *Handbook of motivation and cognition, Vol. 3: The interpersonal context*. (pp. 28-84). New York, NY. Guilford Press.

Hatfield, E., Cacioppo, J. T., Rapson, R. L. (1993). Emotional contagion. *Current Directions in Psychological Science, 2*, 96–99.

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd edition). New York: The Guilford Press.

Hazanov, V. (2014). The effects of shared reality on emotional experience and regulation, unpublished dissertation.

Higgins, E. T. (2011). *Beyond pleasure and pain: How motivation works.* Oxford University Press, New York.

Higgins, E. T. (2019). Shared Reality: What makes us strong and tears us apart. Oxford University Press, New York.

Higgins E. T. & Rholes, W. S. (1978). “Saying is believing”: Effects of message modification on memory and liking for the person described. *Journal of Experimental Social Psychology, 14* (4), 363-378.

Hird, E. J., Charalambous, C., El-Deredy, W., Jones, A. K. P., & Talmi, D. (2019). Boundary effects of expectation in human pain perception. *Scientific Reports, 9* (1), 9443.

Horton, R. E. & Pillai Riddell, R. R. (2010). Mothers' facial expressions of pain and fear and infants' pain response during immunization. *Infant Mental Health Journal, 31,* 397-411.

Hurter, S., Paloyelis, Y., Williams, A. C. d. C., & Fotopoulou, A. (2014). Partners' empathy increases pain ratings: Effects of perceived empathy and attachment style on pain report and display. *The Journal of Pain, 15* (9), 934–944.

Jackson, T., Iezzi, T., Chen, H., Ebnet, S., & Eglitis, K. (2004). Gender, interpersonal transactions, and the perception of pain: An experimental analysis. The Journal of Pain, 6(4), 228-236.

Jackson, T. & Phillips, H. (2011). Social comparison performance standards, threat, and tolerance for experimentally-induced pain. *European Journal of Pain, 15*, 1081-1086.

Karos, K., Meulders, A., Goubert, L., & Vlaeyen, J. W. S. (2018). The influence of social threat on pain, aggression, and empathy in women. *Journal of Pain, 19,* 291-300.

Karos, K., Meulders, A., Goubert, L., & Vlaeyen, J. W. S. (2019). Hide Your Pain: Social Threat Increases Pain Reports and Aggression, but Reduces Facial Pain Expression and Empathy. *Journal of Pain*, *19,* 30771-0.

Kleck, R. E., Vaughan, R. C., Cartwright-Smith, J., Vaughan, K. B., Colby, C. Z., & Lanzetta, J. T. (1976). Effects of being observed on expressive, subjective, and physiological responses to painful stimuli. *Journal of Personality and Social Psychology, 34*(6), 1211–1218.

Koechlin, H., Coakley, R., Schechter, N.,Werner, C., & Kossowsky, J. (2018). The role of emotion regulation in chronic pain: A systematic literature review. *Journal of Psychosomatic Research, 107*, 38-45.

Krahe, C., Paloyelis, Y., Condon, H., Jenkinson, P. M., Williams, S. C. R., & Fotopoulou, A. (2015). Attachment style moderates partner presence effects on pain: A laser-evoked potentials study. *Social Cognitive and Affective Neuroscience, 10,* 1030-1037.

Krahe, C., Springer, A., Weinman, J. A., & Fotopoulou, A. (2013). The social modulation of pain: others as predictive signals of salience- a systematic review. *Frontiers in Human Neuroscience,* 7, 1-19.

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual.

Lautenbacher, S., Peters, J. H., Heesen, M., Scheel, J., & Kunz, M. (2017). Age changes in pain perception: A systematic-review and meta-analysis of age effects on pain and tolerance thresholds. *Neuroscience and Biobehavioral Reviews, 75*, 104-113.

Lazarus R. S., & Folkman S. (1984). *Stress, Appraisal and Coping*. New York: Springer

Leong, L. E. M., Cano, A., Wurm, L. H., Lumley, M. A. & Corley, A. M. (2015). A perspective-taking manipulation leads to greater empathy and less pain during the cold pressor task. *Journal of Pain, 16* (11), 1176-1185

Lumley, M. A., Cohen, J. L., Borszcz, G. S., Cano, A., Radcliffe, A. M., Porter, L. S., Schubiner, H., & Keefe, F. J. (2011). Pain and emotion: a biopsychosocial review of recent research. *Journal of Clinical Psychology, 67* (9), 942-968.

McIntyre, M. H., 23andMe Research Team, Kless, A., Hein, P., Field, M., Tung, J. Y. (2020) Validity of the cold pressor test and pain sensitivity questionnaire via online self-administration. PLoS ONE 15(4): e0231697

Meagher, M. W., Arnau, R. C., & Rhudy, J. L. (2001). Pain and emotion: Effects of affective picture modulation. *Psychosomatic Medicine, 63,* 79-90.

Mogil, J .S. (2020). Qualitative sex differences in pain processing: Emerging evidence of a biased literature. *Nature Reviews Neuroscience*, *21*, 353–365.

Moller, E. L., Majdandzic, M., Vriends, N. & Bogels, S. M. (2014). Social referencing and child anxiety: The evolutionary based role of fathers' versus mothers' signals. *Journal of Child and Family Studies, 23,* 1268-1277.

Nahleen, S., Dornin, G., & Takarangi, M. K. T. (2019). When more is not merrier: shared stressful experiences amplify. Cognition & Emotion, 33(8), 1718-1725.

Parritz, R. H. (1992). "Control, social referencing, and the infant's appraisal of threat." In *Social Referencing and the Social Construction of Reality in Infancy* (p. 209). Boston, MA.

Peeters P. A., & Vlaeyen, J. W. (2011). Feeling more pain,yet showing less: the influence of social threat on pain. *Pain, 12* (12), 1255-1261.

Phillips, M. L., Gregory, L. J., Cullen, S., Cohen, S., Ng, V., Andrew, C., Giampietro, V., Bullmore, E., Zelaya, F., Amaro, E., Thompson, D. G., Hobson, A. R., Williams, S. C., Brammer, M., & Aziz, Q. (2003). The effect of negative emotional context on neural and behavioral responses to oesophageal stimulation. *Brain, 126*, 669-684.

Ploghaus, A., Narain, C., Beckman, C. F., Clare, S., Bantick, S., Wise, R., Matthews, P. M., Rawlins, J. N. P., & Tracey, I. (2001). Exacerbation of pain by anxiety is associated with activity in a hippocampal network. *Journal of Neuroscience, 21*(24), 9896-9903.

Price, D. D. (2000). Psychological and neural mechanisms of the affective dimension of pain. *Science, 288*, 1769-1772.

Price, D. D., Harkins, S. W., & Baker, C. (1987). Sensory-affective relationships among different types of clinical and experimental pain. Pain, (28) 3, 297-307.

Pulvers, K., Schroeder, J., Limas, E. F., Zhu, S.H. (2014). Computer-Delivered Social Norm Message Increases Pain Tolerance, *Annals of Behavioral Medicine*, *47*, 316–324.

Rainville, P., Bao, Q. V. H., & Chrétien, P. (2005). Pain-related emotions modulate experimental pain perception and autonomic responses. *Pain, 118* (3), 306-318.

Rhudy, J. L., Meagher, M. W. (2001). The role of emotion in pain modulation. *Current Opinion in Psychiatry, 14*(3), 241-245

Rossignac-Milon, M., Bolger, N., Zee, K. S., Boothby, E. J., & Higgins, E. T. (2021). Merged minds: Generalized shared reality in dyadic relationships. *Journal of Personality and Social Psychology, 120*(4), 882–911

Rossignac-Milon, M., & Higgins, E. T. (2018). Epistemic companions: The development of shared reality in close relationships. *Current Opinion in Psychology, 23*, 66-71.

Schachter, S. (1959). *The psychology of affiliation*. Stanford University Press.

Schmalback, B., Hennemuth, L., & Echterhoff, G. (2019). A tool for assessing the experience of shared reality: Validation of the German SR-T. *Frontiers in Psychology, 10*, 832.

Schoemann, A. M., Boulton, A. J., & Short, S. D. (2017). Determining power and sample size for simple and complex mediation models. *Social Psychological and Personality Science*, *8* (4), 379-386.

Simmons, J. P., Nelson, L. D., Simonsohn, U. (2018). False-Positive Citations. *Perspectives in Psychological Science*, *13*(2), 255-259.

Smith, B. M., Villatte, J. L., Ong, C. W., Butcher, M. G., Twohig, M. P., Levin, M. E., & Hayes, S. C. (2018). The influence of a personal values intervention on cold pressor-induced distress tolerance. *Behavior Modification, 43*(5), 688-710.

Spencer, S. J., Zanna, M. P., & Fong, G. T. (2005). Establishing a causal chain: Why experiments are often more effective than mediational analyses in examining psychological processes. *Journal of Personality and Social Psychology, 89* (6), 845–851.

Taylor, S. E. (2011). Social support: A review. In H.S. Friedman (Ed.), *Oxford Handbook of Health Psychology.* New York, NY: Oxford University Press.

Taylor, S. E., Buunk, B. P., & Aspinwall, L. G. (1990). Social Comparison, Stress, and Coping. *Personality and Social Psychology Bulletin*, *16* (1), 74–89.

Tennen, H. & Mckee, T. & Affleck, G. (2000). Social Comparison Processes in Health and Illness. In Handbook of Social Comparison, pg 443-483.

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

Weisenberg, M., Raz, T., Hener, T. (1998). The influence of film-induced mood on pain perception. *Pain. 76* (3), 365-375.

Williams, A. C. d. C., & Craig, K. D. (2016). Updating the definition of pain. *Pain, 157* (11), 2420-2423.

Wilson, J. J., Chaplin, W. F., & Thorn, B. E. (1995). The influence of different standards on the evaluation of pain: Implications for assessment and treatment. *Behavior Therapy, 26* (2), 217-239.

Wolff, B. B., Krasnegor, N. A., & Farr, R. S. (1965). Effect of suggestion upon experimental pain response parameters. *Perceptual and Motor Skills, 21*(3), 675-683.

Yilmaz, P., Diers, M., Diener, S., Rance, M., Wessa, M., & Flor, H. (2010). Brain correlates of stress-induced analgesia. *Pain, 151*(2), 522-529.

Yoshino, A., Okamoto, Y., Onoda, K., Yoshimura, S., Kunisato, Y., Demoto, Y., Okada, G., & Yamasaki, S. (2010). Sadness enhances the experience of pain via neural activation in the anterior cingulate cortex and amygdala: an fMRI study. *Neuroimage* 50, 1194–1201.

Zelman, D. C., Howland, E. W., Nichols, S. N., Cleeland, C, S. (1991). The effects of induced mood on laboratory pain. *Pain, 46*, 105-111.