Do You Really Want to Hurt Me?

Ostracism-Induced Physical Pain Sensitization in Real-Life Relationships

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Abstract

In humans, social and physical pain are believed to arise from common neural networks, an evolutionarily advantageous system for motivating prosocial behavior. As such, the hypothesis that social insult can sensitize physical pain perception was investigated in the context of real-life relationships. The social value ascribed to the source of virtual ostracism, the closeness of the relationship, and individual personality characteristics were expected to modulate the impact of social rejection upon physical pain reports. Romantic partners, friends, and strangers were all led to believe that their partners were excluding them from an online ball-tossing game, and pain sensitivity changes from baseline were assessed following this manipulation. Results indicated that ostracism by a relationship partner leads to an increase in cold pain tolerance, that romantic partners report more cold pain unpleasantness than friends following social rejection, and that trait sensitivity to social insult predicts physical pain sensitivity in general. The findings suggest that within the context of real-life relationships, the social rejection as an agent of influence upon pain behavior may not operate as cleanly as previously believed, and that further research in this area is definitely warranted. Results are interpreted with respect to several theories of social and physical pain behaviors, and suggestions for future studies are highlighted.
Introduction

Pain

What is Pain?

The mind is responsible for keeping itself and the body safe from harm. The psychological and physical experience of pain is the safety mechanism. Pain is a very effective warning signal, indicating that the individual is in contact with a noxious stimulus, and providing a strong, unpleasant motivation to remove oneself from the aversive situation (IASP, 1979). Even though most of us detest pain, it is a necessary and beneficial process and we often do not appreciate its uses. Why would any kind of unpleasantness or incapacitation be adaptive? Pain is effective precisely because it incapacitates, forcing our attention to the problem at hand. Pain works to warn us of currently and potentially harmful stimuli, and to motivate our actions neutralizing threats to our mental and physical health (Eisenberger & Lieberman, 2004).

Although much time and money is spent in seeking a pain-free state, it is questionable as to whether such a state is actually desirable. Individuals who cannot experience those advantages illustrate the benefits of physical pain. For example, one treatment for intractable chronic pain is cingulotomy, the partial removal of a brain structure involved in processing various aspects of pain. Animal evidence shows that monkeys and rats with ablated cingulate cortices cease producing and responding to distress vocalizations (see Eisenberger & Lieberman, 2004). Human cingulotomy patients can detect the presence of a painful stimulus but it does not distress them, and they do not remove themselves from its presence (Eisenberger & Lieberman, 2004; Price, 2000). Victims of hereditary sensory and autonomic neuropathies such as congenital insensitivity to pain must be constantly vigilant not to unknowingly injure or mutilate themselves. CIPA patients can easily die from heatstroke, unable to detect the unpleasant effects of overheating. Often these individuals will continue to function with an abscess, infected wound, or unfelt injury, and so are in double danger of worsening the injury (Schwarzkopf, Pinsk, Wiesel, Atar, & Gorzak, 2004). Some die from the effects of these injuries. Thus despite
the unpleasantness of the pain state, the possession of such a mechanism is crucial for the survival of individuals and species.

The inability to feel physical pain is a serious personal deficit, but the inability to feel psychological pain may be even worse for the individual and for society as a whole. Psychopaths feel no remorse or guilt, and perceive others as simple pawns in a chess game, not as thinking, feeling beings. This condition has been attributed to possible deficits or disconnects in the neurological pathway that processes the pain of others and relates it to pain in the self (Monk, 2008). In addition, the developmental condition of autism presents as an inability to connect with others emotionally, often causing distress and hardship in the patient and caregivers.

Humans are a social species. Displays of pain by self and other allow us, by various mechanisms, to acquire and provide help and solace, to learn from another’s experience of pain, and to remember pain-inducing and thus harmful situations to avoid. (Simon, Craig, Gosselin, Belin, & Rainville, 2008). Evolutionarily, human success has depended on the ability to be sensitive to the physical and emotional status of our conspecifics (Goubert et al., 2005; Preston & de Waal, 2002). Emotions provide a means for rapid, universally-understood communication (Ekman, 1979; Simon et al., 2008). They can also motivate the self and other to act. The negative emotional component of pain discourages repeat contact with the pain-producing stimulus. Furthermore, the organism’s current affective state can modulate its experience of physical pain (Rhudy & Meagher, 2001). Social and emotional psychological pains, then, are just as crucial as physical pain for the discrimination between health-enhancing and aversive situations and stimuli.

*Working Definition of Pain*

Even though pain is a constant of the human experience, it has proven difficult to define, quantify, and objectify for diagnostic and research purposes. Besides the existence of nearly infinite variations and gradations of somatic and psychological pain, every person has different
pain thresholds, tolerances, sensitivities, and perceptions (Berkley, 1997). These differences can be at the level of specialized peripheral nervous system receptors (nociceptors) and nerves, in spinal cord pain modulation mechanisms, or in the structure and function of the brain itself (Melzack & Wall, 1967; Sternberg, 2007; Wall, 2000). Pain is a percept, a constructed representation that is not always faithful to the intensity or unpleasantness signaled by tissue-damage induced nociceptor activation. (Basbaum & Jessell, 2000). Pain perception can be influenced by attention, social context, endocrine factors, past experience, sensitization, and a variety of other individual and environmental variables (Sternberg, 2007).

But how is physical pain to be defined? For the purposes of research and diagnosis, pain exists on two dimensions. The physical, sensory aspect of pain can be graded on intensity. However, it is the emotional, affective dimension, the unpleasantness, which distinguishes pain from any other sensation (Sternberg, 2007). The combination of these two qualities—intensity and unpleasantness—leads to the unique sensation of pain, in all degrees and forms. Cortical representation of pain unpleasantness and intensity depends on overlapping, often co-activated, yet distinct brain areas (Price, 2000; MacDonald & Leary, 2005; Singer et al., 2004). The experience of pain can be broken down into four stages, as the center of pain-processing activity moves in from the periphery to central neural structures.

*The Pain Pathway: Anatomical Substrates*

Perception is a conscious, subjective experience arising from neural activity in sensation-processing cortical areas and subcortical structures. Thus, the neural perception and behavioral consequences of pain can be generated in the brain without peripheral input. Alternatively, neural activity (or lack thereof) can dampen or eliminate pain sensation—as in situations of extreme stress or adversity (Rhudy & Meagher, 2001; Sternberg, 2007). Therefore, perceptual output many not exactly correspond to nociceptive input levels. To understand how such a modulation system may work, the entire nociceptive pathway from periphery to brain must be analyzed as a whole.
**Nociception.** Nociception is the process whereby specialized peripheral neurons detect the presence of noxious stimuli. Primary pain detection neurons have their sensory receptive projections in peripheral tissues such as muscle, skin, and blood vessels. Thin, unmyelinated, slow-conducting C-fibers project from cells that detect polymodal pain stimuli. They are responsible for the sensation of burning pain. Thinely myelinated Aδ nerves conduct thermal pain only, and give rise to pricking, more acute sensation. Both types of cell bodies reside in the dorsal root ganglion of the spinal cord. Generally speaking, intensity of stimulation of these nerve endings correlates with level of activation in primary afferent cell bodies. However, other factors in addition to level of activity determine the ultimate afferent signal of these cells to higher CNS structures (Basbaum & Jessell, 2000). Another type of sensory cell in the dorsal root ganglion has large-diameter Aβ fibers, which detect various kinds of nonpainful stimuli. (Aβ cells play an important role in pain modulation, as will be discussed later).

**Transmission.** Axons of primary afferent nociceptive nerves synapse on pain transmission neurons (PTNs) in the superficial laminae of the spinal cord dorsal gray matter. PTNs send their axons up to the brain as part of several spinoencephalic tracts. These axons of pain transmission neurons synapse on brainstem nuclei such as the thalamus, hypothalamus, and periaqueductal gray. From the thalamus, afferents project to limbic structures (areas partially responsible for the affective dimension of pain), brainstem areas responsible for autonomic arousal, and the primary somatosensory cortex. Finally, secondary somatosensory cortices send information to frontal and parietal association-integration cortices, as well as to the limbic system (Price, 2000; Sternberg, 2007). Top-down processes are at work as well, as higher-level cortices work to influence attention and future planning.

**Modulation.** Neural activity and top-down instructions also play a role in how nociceptive inputs are processed, at the level of spinal cord PTN modulation. Melzack and Wall (1965) proposed a gate-control theory of spinal cord pain modulation that has since been refined and experimentally elucidated (Basbaum & Jessell, 2000; Sternberg, 2007; Wall, 2000). The
basic premise of the gate control theory is that nonnociceptive nerve inputs as well as efferent
signals from the brain can modulate the activity of pain transmission neurons. Thus, pain
transmission is gated by central and peripheral modulation. This theory, and the research
supporting it, provides a possible framework for understanding the deviation from a 1:1 ratio of
nociceptive input to pain perception.

As well as pain transmission neurons, the dorsal horn gray matter contains local excitatory
and inhibitory interneurons that can alter the activity of PTNs at modulatory synapses. These
interneurons are activated by descending (often inhibitory) projections from the brain, as well as
by nociceptive and nonnociceptive afferents. Thus the ultimate activity level in the PTNs, which
is transmitted to the brain, is under the influence of top-down as well as bottom-up modulation.
Nonpainful stimulation of large-diameter, nonnociceptive A\textsubscript{B} fibers can actually lead to a
decrease in activity of PTNs, through the inhibitory action of interneurons receiving A\textsubscript{B} input
(Wall, 2000). As such, gently rubbing a stinging patch of skin activates large-diameter fibers,
which inhibit PTN activity and dampen ascending pain signals. Furthermore, selectively
reducing the activity in large-diameter fibers leads to a loss of specificity in the discrimination
and perception of different types of painful stimuli conducted by C-fibers (Basbaum & Jessell,
2000). Through these and other pathways, nonnociceptive afferents to modulatory input
synapses can influence the quality and intensity of pain perception.

Pain modulation is a dynamic process. Ascending pain activity activates descending
neural controls, which in turn dampen the ascending activity and the ultimate cortical activity
leading to pain perception. The influence of these descending controls is revealed by studies in
which they are eliminated. Sherrington (1906) found that severing the brain-spinal cord
connection heightened the responses of nociception-activated spinal reflexes—the first
suggestion that descending input from the brain influences peripheral pain withdrawal reflexes.
Nearly 100 years later, it was found that eliminating descending modulation from the rat brain
by lesioning the dorsolateral funiculus of the spinal cord reveals increased pain behavior.
(hyperalgesia) in response to nociceptive input, such as shocks (Meagher et al., 2000). Therefore, primary pain output from the spinal cord is constantly monitored and modulated by the brain.

Evidence for top-down modulation through descending pathways comes from studies of stress-induced analgesia and hypnosis. Stress-induced analgesic pathways are in place to inhibit pain in times of threat. These pathways make use of opioids as neurotransmitters. Opioid peptides are endogenous analgesics, ligands acting on opiate receptors in nervous system pain pathways. In response to moderate stress and autonomic arousal such as exercise, opiates are released all along the efferent pain pathway, from the hypothalamus, to the midbrain, the medulla, and finally down the spinal cord to dorsal horn PTNs. More severe stressors can lead to the activation of redundant histamine, glutamate, noradrenaline, or alternative opioid analgesic pathways (Sternberg, 2007). The ultimate effect of this modulation is to reduce activity in PTNs and correspondingly reduce the final perception and behavioral impact of pain.

Stressors can also be psychological, as in the case of male video gamers who showed decreased sensitivity to physical pain following a bout of virtual competition. Presumably, the challenge presented by competition fosters fight-response autonomic activation with corresponding endorphin release and desensitization to physical pain—in a sex-dependent manner (Sternberg, Bokat, Kass, Alboyadjian, & Gracely, 1998). If the function of the pain system is to promote survival, stress-induced analgesia is adaptive in that it relieves the body and mind from an injury’s debilitating effects (such as pain, crippled tissues, the need to rest) for the time it takes to remove oneself from a threatening situation.

There is evidence that hypnotherapy can reduce the perceived emotional unpleasantness of pain stimuli and thus inhibit the natural withdrawal behavior. However, since hypnosis-induced analgesic effects were not blocked by the opioid inhibitor naxolone, it is unlikely that the endogenous opioid system mediates this analgesic mechanism (Moret et al., 1991). However, brain and spinal cord activity can also increase sensitivity to pain. Intense tissue
damage can cause an afferent barrage of nociceptive information to the PTNs. This bout of high-frequency spinal cord input causes changes and plasticity in modulatory synapses, with the end result being hyperalgesia to stimulation of the injured site and its surroundings (Basbaum & Jessell, 2000; Sternberg, 2007).

Spinal cord modulation, although integrated and complex, is just one possible level at which pain information can be transformed and modified. The brain is remarkable in its abilities to control its own input. Evidence from analgesic acupuncture therapies, massage, placebo, and relaxation provides support for executive, cortical influence on physical and psychological pain perception (see review by Tan et al., 2007). Thus, a wide variety of physical and psychological factors can impact upon this final perception at many levels.

**Pain perception: The pain neuromatrix.** Nociceptive input to the spinal cord activates multiple ascending pathways projecting to brainstem, limbic, and cortical regions implicated in the perception of pain intensity and unpleasantness. These pathways are interconnected, may operate in parallel, and mediate different levels of processing complexity—from basic brainstem arousal to cortical associative and executive function. Activation of a diverse array of brain structures, including the periaqueductal gray, thalamus, hypothalamus, lentiform nucleus, caudate, somatosensory cortices, motor cortex, insula, anterior cingulate cortex, and frontal cortices produces the autonomic arousal, somatomotor activity, emotions, fear, distress, and appraisals associated with pain (Price, 2000). fMRI evidence suggests that perceived pain from increasingly intense cutaneous stimuli increases with the intensity and extent of activation in this “pain neuromatrix.” Graded nociceptive stimulus-response relations were observed for neural structures involved in pain sensation, motor control, attention, and affect (Coghill, Sang, Maisog, & Iadarola, 1999).

As mentioned above, pain experience is comprised of two orthogonal dimensions—sensory and affective (intensity and unpleasantness). In neurologically intact subjects, nociception leads to the activation of the entire neuromatrix—producing the unpleasant and
intense sensation that is interpreted as pain. Under neutral experimental conditions, self-reported unpleasantness increases with stimulus intensity and self-reported nociceptive intensity (Price, 2000). However, monkeys and humans with damage to the insular cortex and ACC can detect and report the sensory features of pain, but do not seem bothered by the noxious stimulus or attempt to withdraw (Berthier, Starkstein, & Leiguarda, 1988; Price, 2000; Weinstein, Kahn, & Slote, 1955). Stimulus intensity perception is preserved, but unpleasantness, that defining characteristic of pain, is no longer felt.

These results provide several important insights into the neural basis of pain perception. First, the affective and physical dimensions of pain are psychologically separate and distinct. Next, the unpleasantness of pain provides the motivation for withdrawal (consistent with the proposed evolutionary function of pain affect). Finally, the somatosensory cortices and brainstem regions likely process the sensory component of pain, while separate parts of the pain neuromatrix, the anterior cingulate cortex and insular cortex, are thought to be primarily involved with coding the affective dimension of pain perception (Price, 2000).

**Anterior Cingulate and Insular Cortices: Pain Unpleasantness in the Cortex**

PET studies of subjects undergoing hypnosis indicate that the degree of ACC and IC activity is proximate to the production of final pain perception (Tolle, Kaufmann, & Seissmeier, 1999). The ACC is also known as the limbic motor cortex, and the insula as the limbic sensory cortex (Singer et al., 2004). It is thought that pain experience is mapped onto the brain by afferents projecting through the ventromedial thalamic nucleus to the sensorimotor cortex, as well as to the posterior insula. The ipsilateral anterior insula is then activated, and the contralateral insula receives a second-order copy of the information by callosal pathways. Furthermore, afferents from the medial thalamic nucleus project to the ACC, mediating behavioral drives. The ACC has also been referred to as a "neural alarm system" (Eisenberger & Lieberman, 2004; MacDonald & Leary, 2005). This and other lesion evidence (Price, 2000) point to the ACC and IC as pivotal for coordinating the final perception of bodily threat with
attention and response priorities, as well as the generation of affective motivation and resulting behavior (Jackson, Rainville, & Decety, 2006). In sum, the ACC and insular cortex serve attentional and evaluative functions regulating pain unpleasantness (Rainville, 2002).

**General Features of the Pain Neuromatrix**

Taken together, evidence points to two general rules governing the activity of pain-processing structures in the brain. First, more intense and widespread activation of the pain neuromatrix is associated with more felt pain. And second, the pain neuromatrix consists of partially overlapping, often concurrently activated, but distinct affective and sensory networks. These two rules will become important when discussing the interplay of psychological factors and physical pain sensitivity.

Pain is crucial for survival, and thus involves an extensive neurological and somatic network to ensure it is properly, sensitively perceived and addressed. Under neutral conditions, then, a greater nociceptive input to the pain neuromatrix leads to greater activation and greater pain perception. However, various psychological and emotional manipulations that cause activity in pain neuromatrix structures can interfere in the production of a final pain perception output.

**Emotional States and Pain Sensitivity**

Emotion and pain both exist to motivate survival-promoting behaviors. As Sternberg (2007) points out with respect to pain, “In no other sensory modality is emotion a defining component of the perceptual experience.” The involvement of emotion in pain is due to overlap of the neural circuitries mediating affect and pain processing, suggesting that emotions not specifically associated with nociceptive input can influence the processing of that input (Eisenberger & Lieberman, 2004). Such an arrangement is adaptive in that the psychological state could inform and enhance physical responses and perceptions.

Emotions exist to motivate behavior. The *theory of motivational priming* suggests that prior activation of the appetitive or aversive motivational pathways, through positive- or
negative-emotion-inducing stimuli, will moderate behavioral responses to a painful stimulus. Research supporting this theory comes from human and rodent studies (see Rhudy & Meagher, 2001). A study of motivational priming in humans used positively and negatively-valenced pictures of varying arousal intensities to induce the emotional states of fear (high-negative), disgust (low-negative) and sexual excitement (positive). High-arousal positive affect reduced sensitivity to physical pain (in males only, as the females found those pictures disgusting as well as exciting), as did intense negative affect (through SIA). However, induction of mild-to-moderate states of negative affect enhanced pain sensitivity (Meagher, Arnau, & Rhudy, 2001).

Exposure to a nonnoxious but frightening stimulus, such as a loud noise, raises pain thresholds; the threat of shock produces mild anxiety and lowered pain thresholds (Rhudy & Meagher, 2001). Exposing rats to mild shock enhances pain sensitivity, while an exposure to intense shock attenuates pain (presumably by stress-induced analgesic mechanisms) (Meagher, Ferguson, & Crown, 2001).

Mild shock is a mild-negative-emotion inducing stimulus. The neural pathway activated by mild shock, presumed to be the pain affect pathway, depends on forebrain structures such as the ACC and IC, as well as the periaqueductal gray and the central nucleus of the amygdala (Rhudy & Meagher, 2001). All of these structures are part of neural pain and emotion modulation networks (MacDonald & Leary, 2005). The periaqueductal gray receives input from the hypothalamus, and sends descending modulatory signals through the rostroventral medulla to the spinal cord (Price, 2000). It is therefore positioned to dampen or heighten the output of spinal cord pain transmission neurons. The hypothalamus is also involved in autonomic arousal, and is anatomically positioned to act upon the pain pathway directly by influencing PAG activity, and indirectly through its influence on the endocrine system (Rosenzweig, Leiman, & Breedlove, 1999). Furthermore, it is likely that emotion-related amygdala activation plays a major role in the inhibition or facilitation of nociceptive signals from the spinal cord before they are even interpreted as pain (Rhudy & Meagher, 2001).
In sum, evidence supporting the motivational priming theory indicates that through emotion-induced activation of the structures from which pain's unpleasantness arises, the entire pain neuromatrix can be primed to be in a state of heightened sensitivity. This priming leads to changes in the perception of subsequent pain stimuli, and in the behavioral responses to those stimuli. What practical value does such a mechanism hold in real life? The study of the behavioral phenomenon of empathy can inform our knowledge of the adaptivity, utility, and neural bases of emotional influences on physical pain.

Social Emotions

James' (1890) (Vol. 1, p. 294) assertion that “A man has as many social selves as there are individuals who recognize him” (Vol. 1, p. 294) acknowledges that humans are exquisitely sensitive to social context. Social interactions and their consequences are paramount in the motivation of most human behavior. It stands to reason that certain emotions, as motivating agents, serve mostly if not exclusively social functions. Indeed, basic individual and social emotions are associated with the activation of distinct neural networks. (Britton et al., 1996). The sharing of social emotions can facilitate cooperation, group survival, learning, and need fulfillment by alerting the self to the experience of a conspecific (Preston & deWaal, 2002). Such emotions include empathy, jealousy, love, aggression, and even joy (Royzman & Rozin, 2006). Most relevant to the elucidation of the goals of this study are the cognitive and neurological mechanisms associated with empathy and social distress.

Empathy

The construct of empathy, like that of pain, is difficult to define and operationalize. For the purposes of this study, Ickes’ (1997) definition is appropriate: “Empathy is a complex form of psychological inference in which observation, memory, knowledge, and reasoning are combined to yield insights into the thoughts and feelings of others.” (from Jackson et al. 2005, p. 771). Theory of mind, perspective-taking, and sympathy are all similar phenomena (Batson, Eklund, Chermok, Hoyt, & Ortiz, 2007). Many animals will display distress in response to
another’s distress, including rats, monkeys, and humans (even babies). If possible, these animals will often act to terminate the other’s distress, even at personal cost. (Preston & de Waal, 2002). Chimps show emotional contagion distress responses to the observation of distressed conspecifics (Parr and Hopkins, 2000). Such an arrangement facilitates prosocial behaviors, investment in interpersonal relationships, and the ability to understand the emotions and goals of others (Jackson, Meltzoff, & Decety, 2005). From Ickes’ definition, empathy can be an extremely complex experience, involving many neural pathways and structures. However, the basic concept of empathy holds that the perception of another’s state somehow produces a similar state in the observer, allowing that observer to better understand and coordinate his behaviors with the conspecific’s needs and goals.

*Perception-action model and affect sharing.* How do we make inferences about others’ psychological states, sharing affect and its behavioral consequences? Preston and de Waal’s (2002) provides a complete, complex, and integrative mechanism by which the observer may be able to experience the state of the empathic object. According to Preston and de Waal (2002), this common-coding theory states that “attended perception of the object’s state automatically activates the subjects’ representations of the state, situation, and object, and that activation of these representations automatically primes or generates the associated neural, autonomic, and somatic responses, unless inhibited” (p. 4). This response-oriented conceptualization holds that nervous system organization facilitates quick and proper response to necessary situations, and makes possible state matching and affective resonance. Group living, the mother-infant bond, mutual alarm systems, reciprocal altruism, vicarious learning, and other forms of inclusive fitness all benefit from such an arrangement (Jackson et al, 2005; Jackson et al., 2006; Preston & de Waal, 2002). Under this model, understanding others’ emotions depends on the self actually vicariously experiencing those emotions to some degree.

A range of empirical studies detailing the link between perception and action indicates that a central nervous system network supports this phenomenon. ERP studies show that sensory
information is passed on to the response phase before perceptual analysis is complete (Hommel, 1997). Mirror neurons in the rostralmost part of the premotor area fire when perceiving the action of a conspecific, imagining that action, and performing it (Rizzolatti & Sinigaglia, 2008). These neurons provide concrete cellular evidence for shared representations. As for the emotional involvement component and affective state matching, the insular cortex is positioned to relay information from premotor areas to limbic structures such as the amygdala. The amygdala can potentiate memory consolidation in the hippocampus as well as activate brainstem autonomic structures—important for learning from empathic experiences and activating somatic response. The limbic circuit projects to the ACC and orbitofrontal cortex, which mediate the conscious perception and regulation of emotion (Preston & de Waal, 2002).

In support of the idea that observation of emotion can activate neural networks involved in feeling that emotion, neuroimaging studies show activity in emotional networks and action representation networks, as well as in the insula, while participants imitated and observed emotional facial expressions (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Decety, Chaminade, Grezes, & Meltzoff, 2002) and experienced those induced emotional states (Decety & Chaminade, 2003). These results represent examples of emotional contagion, a bottom-up process, important precursor, and frequent accompanying empathic stimulus. However, Singer et al. (2004) found that empathic neural responses were elicited simply by an arbitrary cue that a conspecific was experiencing a negative emotional state. Thus, empathic neural activity does not rely solely on visual perception of emotional expression, mirror neurons, or unconscious imitation; top-down perceptual knowledge can also induce this activity.

This theory conceptualizes empathy as literally and concretely experiencing the states of another. In fact, many of the brain structures activated through empathic induction of negative emotion and distress are part of the pain neuromatrix—the part that processes the affective, unpleasant component of pain (Price, 2000; Singer et al., 2004). As such, empathy for pain is
used to study the phenomenological and neural processes by which the pain of another can physically translate to pain in the self.

*Empathy for pain.* Of the many states, such as joy (Royzman & Rozin, 2006) that may be inferred from conspecifics through empathic processes, pain is one of the most adaptively crucial. Through the observation of and subsequent resonance with another's pain, animals can learn to associate their own pain with the presence of a physical threat and the motivation to retreat—without incurring permanent damage to the self. Animals are also motivated, by their own resonant distress, to enact helping behaviors, which relieve the pain of the other, and thus the self. As stated, these pain-motivated behaviors facilitate nurturance, prosocial activity, and reciprocal warning (Goubert et al., 2005). However, social groups must be able to differentiate between members and nonmembers. Genetic relatives are likely to be members of the same social group, and are likely to share a living environment. Therefore, closer relations are likely to share the same vulnerabilities and potential threats, making them more valuable sources of pain empathic knowledge and reciprocally beneficial recipients of empathy-motivated helping behavior. Closer conspecifics may have more similar representational schemas of the world, making for easier reciprocal mapping and transfer of representational patterns (Preston & de Waal, 2002). As such, relational and emotional proximity to conspecific, which facilitates valuing, perspective-taking, and neurological resonance, may be an important modulating factor in the nature and extent of the pain empathy response. Neuroimaging and behavioral evidence support such a view of empathy for pain.

*Neuroimaging evidence.* Empathy has been conceptualized as a sharing of representational patterns, transmitted through sensory modalities and top-down processes such as learning experience and shared knowledge (Goubert et al., 2005; Preston & de Waal, 2002). Thus, based on physiological (Levenson & Ruef, 1992) and mirror neuron evidence (Rizzolatti & Sinigaglia, 2008) researchers reasoned that such representations may be the neural processes underlying the feeling states and behaviors associated with empathy (Jackson et al., 2006;
The neurological mechanism that supports empathy for pain also mediates sensory and affective pain perception in the self—the pain neuromatrix.

Jackson et al. (2005) used fMRI scanning to investigate which components of the pain neuromatrix are active while viewing images of human body parts in physical pain. The scans showed increased activity in the “affective” components of the pain neuromatrix, the rostral ACC and anterior insula in response to pain images. Furthermore, the authors observed that levels of activity in these structures correlated with participants’ explicit ratings of how painful the images looked. Consistent with these results, Singer et al. (2004) observed increased activation in the rACC and AI (but not somatosensory areas) while participants watched a close relationship partner receive noxious stimulation. Both the anticipation of this stimulation and the actual observation activated these affect-processing regions. Participants also rated self-pain and other-pain as equally unpleasant. Seemingly, neural networks involved in the affective experience of pain can be activated simply by viewing pain in others.

In addition, contrary to Jackson et al.’s (2005) results, Singer et al. (2004) found that higher scores on self-report empathy scales correlated with stronger activity in the rACC and AI. The nature of the relationship between conspecifics (unknown stranger vs. valued partner) may play a role in this correlation. To investigate the modulating effects of social variables on empathic response, Singer et al. (2006) manipulated participants’ valuation of a fair or unfair confederate. Participants then underwent fMRI scanning while watching fair or unfair confederates receive painful stimulation. Men and women displayed activation in insular-frontal cortices and the ACC when viewing fair confederates in pain, but for men, activity in these areas was greatly reduced while viewing unfair confederates in pain. The study authors interpreted these results to mean that fair confederates are perceived to be more similar and affectively congruent to the self, and similar others’ pain maps more easily onto self representations of pain. Thus, the neural structures supporting pain unpleasantness are active (to varying degrees) during pain in self and pain in others.
Behavioral evidence and pain sensitization. What are the consequences of this mirrored activation for the individual feeling empathy for pain? Consistent with theories of motivational priming (Rhudy & Meagher, 2002), Langford et al. (2006) investigated emotional contagion in mice as an evolutionary precursor to adult-adult empathic pain sensitization. Mice in pain together displayed greater pain behavior compared to mice in pain alone, or mice in pain tested with an unafflicted conspecific. However, only cagemates displayed this heightened pain behavior. Presumably, the cagemate mice experienced both their own pain (sensory and affective) and the cagemate’s affective pain through empathic neural processes—heightening pain behavior. Echoing the Singer et al. (2006) study, the cagemates-only results suggest that previous social connection, shared world representations, or perceived similarity supports emotional contagion and enhanced pain behavior in mice. These socially-modulated results are consistent with the perception-action model of affect and somatic response priming.

Humans also display such socially-modulated empathic pain sensitization. Loggia, Mogil, and Bushnell (2008) investigated whether sensitization to physical pain in response to viewing another person in pain would be affected by empathetic emotional connections to that person. An experimental manipulation elicited participants’ sympathy for an actor experiencing pain. Participants reported greater levels of empathy, as well as more cutaneous heat pain intensity and unpleasantness while watching the actor (compared to the affectively unsympathetic group). Furthermore, sympathetic participants evidenced greater pain sensitivity than the unsympathetics, even without watching the actor receive painful stimulation. Therefore, it is not the direct observation of pain but the unpleasant emotional states related to pain empathy (presumably arising from activity in the AI and rACC) that alters pain perception.

In a different vein, Batson et al. (2007) found that manipulating participants’ emotional valuation of a fictitious individual in need influenced perspective-taking and willingness to provide helping behaviors. Valuation, then, may be the human equivalent of mouse cagemate
status—an indication of psychological similarity and facilitator of perspective-taking, prosocial behavior, empathetic emotion-sharing, and pain sensitization.

For all the reasons detailed above, perceiving pain in others increases arousal in pain affect areas/self-pain areas (Jackson et al., 2006). The observer resonates with the subject’s emotional pain, changing the observer’s own pain sensitivity. Empathy research provides examples of how neural activity related to a negative emotional state leads to changes in physical pain perception. Experiencing negative emotional states activates the same brain regions as does physical pain (Rhudy & Meagher, 2001; Singer et al., 2004; Jackson et al., 2005). The results of this research are interpreted such that inducing a negative emotional state leads to greater activation in the pain neuromatrix and its effective sensitization to future insult. Therefore, although the absolute intensity of cutaneous nociceptive stimulation may be mild, the activity elicited by that nociception will add to the activity already present in the affective areas of the neural pain matrix—leading to a final perception of more pain.

Empathy for pain is a nascent field of research and is not yet fully understood (cf. Jackson et al., 2005; Singer et al., 2004). Investigation of empathy, though, is crucial for achieving a better grasp on social and physical pain phenomena. The ability of socially-communicated pain to sensitize physical pain perception allows an individual to take advantage of pain as a danger signal at a distance. To feel the pain of another individual, especially of an individual for whom one cares (likely to be kin, and likely to share genes) would be evolutionarily advantageous as a warning mechanism against potentially dangerous stimuli and a motivator of helping behavior. Thus, the neurological overlap of social and physical pain may have arisen to support the empathic process and its benefits for evolutionary fitness.

Overall, pain empathy studies suggest that negative emotion shared between individuals can increase pain sensitivity. As such, researchers reasoned that negative emotions in general may increase sensitivity to pain, by the same neurological mechanisms of additive activation and/or pain neuromatrix priming. As a result, one would predict that the induction of any painful
emotional state would result in pain sensitization due to activation of common neural networks. The direct emotional state of social distress is also painful, and according to several researchers also primes a pain state in the brain, with measurable psychological and behavioral consequences.

**Social Distress**

Baumeister and Leary (1995) posit that the need to belong is a fundamental motivator of human emotion, behavior, cognition, and bond formation. It has shaped human culture, and promotes survival and reproduction—reflecting the competitive disadvantage of the lone individual. Belongingness as a core goal of the human experience is acknowledged in the theorizing of influential psychologists including James, Maslow, Bowlby, and others.

Belongingness, in the view of Baumeister and Leary, is the state acquired from a caring bond with a social conspecific as well as consistent interaction with that conspecific. The state of belongingness is directly cognitively processed, has affective consequences, motivates goal-oriented behaviors, and results in ill effects when absent. It is a motivating drive system, using positive affect to signal a state of inclusion while negative affect alerts the individual to an undesirable state change—the sadness resulting from a lack of belonging (Baumeister & Leary, 1995).

Social bonds intensify emotions, and a large portion of the function of emotions may be to motivate the formation and maintenance of social bonds. Positive affect results from forming or increasing social bonds, while negative affect is associated with relationship threats and breakups. Loss of relationships, loneliness, and social exclusion are all associated with states of anxiety and depression. Introversion may be linked with depression due to introverts experiencing less belongingness.

A lack of belonging may have physiological consequences as well: loneliness is associated with a reduction in immunocompetence, while emotional and behavioral pathologies can result from a lack of appropriate care in childhood or healthy adult social connections. The
formation of social bonds actually activates the opioid systems, while the dissolution of relationships can diminish opioid production (see reviews by Baumeister & Leary, 2005; Loving, Le, & Crockett 2008). Self-esteem is strengthened through interpersonal relationships and acts as a buffer against feelings of meaninglessness (Berscheid & Peplau, 1983). Due to the crucial nature of belongingness in the human psyche, interpersonal rejection is painful, anxiety-producing, and causes extensive affective pain and loneliness.

**Ostracism**

Eisenberger and Lieberman (2004) define social pain as “the distressing experience arising from the perception of actual or potential psychological distance from close others or a social group” (p. 294). Ostracism and rejection are prevalent as social-pain inducing tactics across many species and human age groups (Williams, Cheung, & Choi, 2000). In modern social settings, the most common form of ostracism is the “silent treatment.” It is used in close relationships, friendships, and amongst coworkers (Sommer, Williams, Ciarocco, & Baumeister, 2001). Motives for ostracism may include punition, confrontation avoidance, blame avoidance, the communication of anger or disappointment, or the termination of an acquaintance (Sommer et al., 2001). Control of the social situation is augmented for the source of the ostracism, and reduced for the recipient. If the cause of the ostracism is unclear, the object may fear self-perpetrated transgressions, misdeeds, or failings. Even worse, oblivious ostracism is not explicit, but defined by the target feeling so unimportant as to warrant no notice whatsoever. Whatever the motivation or social context, ostracism can be devastating to the target’s short- and long-term feelings of control, self-worth, emotional stability, and self-esteem (Sommer et al., 2001). An ultimate explanation for such extreme reactions comes from the fact that ostracism from the group would have been fatal in the ancestral environment. Indeed, lack of human contact seems to have negative effects on physical and psychological health (Baumeister & Leary, 2005; Cacioppo et al., 2000). Therefore, some researchers suggest that we are hard-wired to be
exquisitely sensitive to the status of the self in the group (Eisenberger & Lieberman, 2004; MacDonald & Leary, 2005).

Similarly, sociometer theory holds that self-esteem is a metric of one’s worth to other individuals. Self-esteem depends on levels perceived inclusion or acceptance. Self-esteem threats cause heightened emotional pain and social distress as a warning and motivating signal that one’s social safety may be at risk and that steps should be taken to repair the deficit (Eisenberger & Lieberman, 2004; Williams, 2007). A more specific consequence of this system is reflected in the theory that individuals with low self-esteem may more readily perceive lower levels of inclusion, and are thus more vulnerable to low self-appraisal (Sommer et al., 2001). The importance of self-esteem for psychological well-being is a reflection of the importance of social security and belongingness for human survival.

Finally, the need-threat hypothesis is a working example of social monitoring. It proposes that depending on the context, length, and source of the rejection, ostracism poses potential harm to self-esteem, meaningful existence, belongingness, and/or control over one’s environment—so-called psychological basic needs (Williams, 2007b; Williams, Cheung, & Choi, 2000). These threats are all associated with some kind of emotional pain as motivation for rectifying the situation. Individuals cope with threats to these fundamental needs in different ways, from antisocial behaviors and aggression in response to control threats to increased helping behaviors and prosocial interests in response to belongingness and self-esteem threats (Williams, 2007a), as well as hopelessness, analgesia, and emotional numbness as a coping strategy to deal with chronic rejection (DeWall & Baumeister, 2006). Although coping strategies in response to rejection may vary, the initial emotional reaction is always strong and negative (DeWall & Baumeister, 2006; Williams, 2007a; Williams, 2007b; Zadro, Boland, & Richardson, 2006).

Such effects of ostracism and social rejection have been studied with success in laboratory settings. Experimental setups found to consistently induce feelings of social rejection
in the lab include the meet-and-greet paradigm, in which participants are told that strangers with whom they had a short conversation do not wish to continue the acquaintance; and the ball-tossing paradigm, wherein participants play a short game of catch with confederates from which they are mostly excluded (see Williams & Zadro, 2005).

*Cyberball.* The Cyberball program is a simple, effective, and robust laboratory task designed to investigate the effects of ostracism in a more controlled setting (and cut down on the need for confederates to mill about and/or throw balls around the lab). Williams, Cheung, and Choi (2000) created the Cyberball online ball-tossing game to manipulate levels of inclusion and exclusion between participants. In this game, participants are told they are playing an online game of ball-toss with other participants (strangers) logged in to computers elsewhere. Subjects are told to mentally visualize the game as vividly as possible. Unbeknownst to the participants, there are no “other participants.” The computer controls the opponents’ tosses. In this way, experimenters can exclude or include the participant in the game to various degrees.

This simple manipulation has consistently caused self-reported social distress, self-esteem decreases, as well as measured neural and physiological changes. Five minutes of face-to-face or Cyberball ostracism in the lab has been shown to decrease feelings of fulfillment of all four of Williams’ basic needs (Williams et al., 2000; Zadro et al. 2006), as well as greatly increase levels of self-reported social distress (Eisenberger, Lieberman, & Williams, 2003; Williams, 2007). Even if participants were financially rewarded for Cyberball exclusion and financially punished for inclusion, ostracism was still painful (van Beest & Williams, 2006). Interestingly, even the explicit knowledge of playing against a computer had no effect on heightened social distress in response to exclusion (Williams, 2007). Rejection or nonbelonging of any type seems to activate the social distress alarm system, regardless of mitigating factors.

**Neuroscience of Social Pain**

Recently, researchers have begun to investigate the neural underpinnings of rejection and social distress. Put forward by MacDonald and Leary (2005), social-pain theory posits that as
animal social structure evolved such that belonging to a social group was crucial for survival, evolution favored individuals motivated to recognize and respond quickly to signs of social exclusion. The physical pain system provided that motivating foundation—specifically, the physical pain affect system (MacDonald & Leary, 2005). Thus, physical and social pain, through the medium of the pain affect neural system, may serve the same adaptive function to motivate withdrawal from threatening situations and approach to adaptive situations. Across cultures and languages, physical pain words are used to describe states of negative affect. Personality variables such as depression, anxiety, attachment style, rejection sensitivity, introversion, and extroversion mediate physical pain sensitivity (from Loving, Le, & Crockett, 2008; MacDonald & Leary, 2005; Zadro et al., 2006). These studies, along with the work on empathy for pain, provide compelling evidence for the idea that the social and physical pain networks may overlap. Recently, studies have begun to investigate the actual neural substrates and physical consequences of social pain, specifically.

Eisenberger et al. (2003) used fMRI scanning and the Cyberball manipulation to investigate the neural activity patterns associated with feeling socially rejected. fMRI scans were performed on subjects playing Cyberball while excluded. Neurons of the dorsal ACC, as well as the anterior insular cortex, were active during exclusion. Levels of activity in the dACC correlated with self-reported distress. Interestingly, while subjects watched a game of Cyberball in which they could not participate “for technical reasons,” the degree of right ventral prefrontal cortex (RVPFC) activity correlated negatively with self-reported distress and ACC activation. These results reveal a similar pattern of neural activity for physical pain and social distress. The ACC and AI, parts of the pain affect/unpleasantness network, were active in response to ostracism. Furthermore, the RVPFC may be responsible for executive regulation of emotions, and its activity during the “rational ostracism” condition may represent inhibition of ACC-mediated automatic social pain. Eisenberger et al. (2003) concluded that based on these results, “social pain may be analogous to physical pain in neurocognitive function” (p. 292).
Building on evidence from pain empathy studies and the exacerbating effects of other-pain on pain in self (Singer et al., 2004; Loggia et al., 2008), as well as studies of affective motivational priming (Rhudy & Meagher, 2001), increasing social pain should increase physical pain sensitivity. Eisenberger, Jarcho, Lieberman, and Naliboff (2006) found that baseline sensitivity to physical pain predicted self-reported social distress after Cyberball ostracism—and that this social distress correlated positively with physical pain unpleasantness ratings in a final heat-pain threshold test. Inducing a state of social pain in participants led to increased pain sensitivity. Thus, social pain and physical pain may rely on the same physical analytic substrates, as sensitivity to social pain is associated with sensitivity to the other.

A very general illustration of the neurological linkage between sensory and intangible concepts comes from the idea that our perceptions of physical sensation can be colored by an associated mental state and vice versa. Bargh and Williams (2008) found that experiencing the sensation of physical warmth led to the formation of "warm" attributions about a fictional character's personality, as well as more prosocial helping behavior. Activation of the representational network associated with a certain concept, such as pain, cold, or warmth, then, seems to prime or make salient that concept in the processing of subsequent stimuli, such as social interactions.

In support of this reciprocal sensitivity, researchers found that chronic pain patients were more likely to have an anxious attachment style, characterized by enhanced sensitivity to social rejection (Feeney, 1999; MacDonald & Kingsbury, 2006). Furthermore, in both the clinical sample and participants from the normal population, rejection sensitivity was correlated with more suffering from, and less tolerance of physical pain. In these individuals, social and physical pain work to mutually sensitize each other. Constant perception of social rejection (in highly rejection-sensitive individuals) repeatedly activates the social pain network alarm, sensitizing the associated physical pain affect system—and leading to greater physical pain perception. In the case of chronic pain patients, constant physical pain and its affective
components sensitizes the social pain network, lowering the threshold for social pain perception and increasing anxious attachment and sensitivity to rejection (MacDonald & Kingsbury, 2006).

In sum, several lines of converging evidence support the social pain theory of neural overlap. Behavioral and neuroimaging evidence from empathy for pain indicates that another's pain can impact self-pain perception (Batson et al., 2006; Goubert et al., 2005; Jackson et al., 2005; Jackson et al., 2006; Langford et al., 2006; Loggia et al., 2008; Singer et al., 2004; Singer et al., 2006) Psychological and neurological studies find that social pain and physical pain share the same neural substrates (Eisenberger et al., 2003). Finally, social pain sensitizes the perception of physical pain (perhaps through an additive-activation mechanism in the pain neuromatrix) (Eisenberger et al., 2006; MacDonald & Kingsbury, 2006). Taken together, this evidence supports a credible argument that the neurological social pain system may be piggybacked onto the affective physical pain network for increased motivational efficacy. This common neural network can be activated, with associated perceptual and behavioral consequences, by ostracism and other social stressors. In consequence, physical pain sensitization can be used as a metric for level of social distress, and vice versa (MacDonald & Kingsbury, 2006). Social and physical pain are thus neurologically and psychologically intertwined.

Modulatory Factors?

Thus far in the literature, the social distress response to Cyberball ostracism seems relatively uniform and automatic, unchanged by personality or environmental factors (Williams, 2007; Zadro et al., 2006). But in mice and humans, empathic pain responses can change depending on context, familiarity, subject's level of need, and valuation of subject (Batson et al, 2007; Jackson et al., 2006; Langford et al., 2006; Loggia et al., 2008; Singer et al., 2006). These differences are presumably due to the fuller and richer neurological representation of a familiar or sympathetic subject, in essence, a greater "inclusion of other in self," and thus the greater emotional ties (Preston & de Waal, 2002). This arrangement would be adaptive in that the better
individuals know each other the more likely they are to share common goals, intentions, and threats. Some individuals, then, have greater importance for one’s future well-being and thus have a greater impact on psychological functioning. Therefore, when social distress situations arise in real life, they may be modulated by the ostracized individual’s relationship to the origin of the social pain. The extent to which the social pain pathway is activated (with accompanying physical pain sensitization) may correlate with how much the ostracized individual depends on the ostracizer for the satisfaction of social and emotional needs.

Relationship closeness and individual personality differences may modulate the emotional impact of an ostracism manipulation, and through mechanisms proposed by social pain theory, the intensity of the neural response and its associated physical pain sensitivity. So far in the investigation of variables that influence responses to social rejection, the initial, automatic distress reaction has been fairly resistant to manipulation. The individual variable of social anxiety influences recovery time (Zadro et al., 2006), and high self esteem seems to provide a buffer against the negative emotional effects of social rejection (Sommer et al., 2001). But overall findings indicate that the initial response to Cyberball ostracism is uniformly intense and unpleasant for all individuals and situations. The present investigation seeks to create variable conditions in which ostracism would lead to different responses in different contexts. In this study, we attempt to extend the Eisenberger et al.’s (2006) results that Cyberball ostracism by a stranger can sensitize physical pain perception. This extension is accomplished by investigating the effects of ostracism on physical pain sensitivity within the context of pre-existing social relationships. Given the physiological and psychological evidence presented above, we proposed that social and emotional valuation of a relationship partner for the maintenance of self-worth may affect the amount of social pain induced by rejection from that social partner. Investigating these mechanisms extends our knowledge of a critical component of social interaction in real-life situations and interpersonal communication.
Because being ostracized activates the same brain areas as physical pain, ostracism primes the brain for pain perception. We suspect that the extent of the priming and thus the extent of subsequent pain perception may be predicted by closeness of relationship but moderated by a variety of relational and individual factors—specifically, inclusion of other in self, relationship quality, rejection sensitivity, and attachment style.

**Modulators of Social Pain Effects**

**Relationship Type**

*Strangers.* Societal and cultural norms (as well as survival instincts) may dictate the influence of strangers’ opinions on one’s self-perceptions and affective state. Adams (2005) found that compared to West Africans, the Americans he polled viewed enmity as unnatural, aberrant, and undesirable. The West Africans, on the other hand, seemed to count enemies as a natural part of the social constellation, another type of personal relationship with no particular associated taboo. Adams hypothesized a societal difference in perception—that in Western cultures, being disliked by anyone signals a problem with one’s social competence and worth as an individual. Consistent with this hypothesis, socially rejected Americans were more personally critical of the source of rejection after a meet-and-greet paradigm than Japanese participants (see review by Williams, 2007). Americans seem to desire and derive personal validation from the acceptance and approval of everyone they meet. Denigration of the personality and judgment of a rejecting stranger may be a self-protecting mechanism of reassurance of self-worth. On the other hand, Japanese seem to value secure belonging in important relationships, and so feel no need to reassure themselves of the unimportance of a rejecting stranger.

Most research on ostracism is done in Western societies, where the opinions of strangers are valued—contributing to the consistent findings of sadness and anger in response to ostracism by strangers (Williams, 2007a, 2007b). On the other hand, sensitivity to ostracism from any source may be hardwired, a hypothesis supported by Eisenberger et al.’s (2003) neuroimaging
findings. Whatever the underlying causes, the perception of rejection by a stranger does lead to social pain.

Friendship. Platonic friendships, though nonsexual, can be psychologically intimate. According to Baumeister and Leary (1995), belongingness needs are satisfied by frequent interaction with a caringly-bonded conspecific. Within a friendship, mutual trust, disclosure, and confidence afford opportunities for the satisfaction of belongingness needs. In older, childless adults, having a confidante buffers depression resulting from the death of a spouse (Baumeister & Leary, 1995). The real health benefits of friendship are evidenced by a longitudinal study of older adults showed that controlling for environmental, economic, and lifestyle factors, having a network of good friends was even more predictive of longevity than having close relationships with family (Giles, Glonek, Luszcz, & Andrews, 2005). The authors hypothesized that having friends and feeling cared-for may promote a variety of pro-health behaviors such as seeking appropriate medical care, cutting down on smoking and drinking, better mood and self-esteem, and better coping with loss.

Longer-term relationships and acquaintances provide a greater sense of belonging, and closer bonds are more satisfying than more superficial ones. Indeed, research on socioemotional selectivity theory holds that as time becomes limited, people focus on emotionally close social partners (family members and old friends), and disregard more peripheral acquaintances, making social interactions more predictable, positive, and meaningful (Carstensen, Issacowitz, & Charles, 1999). Thus, evidence supports the idea that when it comes to friendships and satisfaction of psychological needs, quality is more important than quantity; however in general, people seem to need a quota of attachments for a satisfactory level of social interaction, and to some extent these attachments may be interchangeable (see review by Baumeister & Leary, 1995).

To the extent that friendships fulfill a variety of belongingness needs, they may be subject to rules of violation sensitivity. A study of adolescents examining reactions to
hypothetical hurtful situations instigated by best friends vs. acquaintances showed that being hurt by a best friend elicits more feelings of personal violation, intense negative emotions (sadness, anger, and hurt), and behavioral responses geared towards relationship preservation. The difference in emotional response to hurt from friend vs. acquaintance sources was especially salient for females (Whitesell & Harter, 1996). The restricted demographic nature of this study’s sample warrants caution in generalizability. However, these findings provide support for the idea that the extent of relational and affective devastation resulting from an interpersonal transgression may be associated with the valuation of the source of the transgression. Taken together with evidence of friendship’s beneficial effects on belongingness and social health, Whitesell and Harter’s results suggest that friendships, because they are more valued and fulfill more social needs than relationships with strangers and/or acquaintances, may hold more potential to hurt if they are violated.

**Romantic partners.** At a basic psychological level, information about romantic relationship partners is cognitively processed differently than information about other individuals (Berscheid & Peplau, 1983). Berscheid, Snyder, and Omoto (1989), in the course of developing and validating the Relationship Closeness Inventory, obtained questionnaire measure results indicating that romantic relationships are “closer” than friendships. Intimate relationships satisfy more belongingness needs and may supplant other relationships in social support and hindrance effects (Baumeister & Leary, 1995). People in close, deep relationships, then, may be less motivated to seek or form new relationships. As a result, they may stake more of their self-worth and relational valuation in that relationship. Consistent with this idea, after a divorce, the reported positive qualities of the relationship were correlated with distress over the loss of that relationship (Berman, 1988). A variety of psychological theories have been proposed to model the experience and assess the closeness of intimate relationships (Aron & Aron, 1997; Hazan and Shaver, 1987; Rusbult, Drigotas, & Verette, 1994). The findings from these various perspectives will be discussed below.
Although romantic partners seem to be generally closer than friends, who are generally closer than acquaintances, closeness and affective profile of a relationship cannot be assumed by nominal classification. Of course the quality of the relationship as well as individual differences will moderate the importance of the relationship to the individual and thus its emotional impact. Within different social networks and relational contexts, certain relationships may be more valuable to an individual and/or potentially hurtful than others. To the extent that a social bond is subjectively important to an individual, emotional responses to relationship-relevant belongingness events will vary in intensity and valence in order to motivate the maintenance of that social bond, irrespective of its objective nomenclature (Baumeister & Leary, 1995). Metrics of relationship closeness and quality provide specific support for and verification of general relationship profiles—by which hypothetical levels of ostracism-induced pain can be predicted.

Assessing Relationship Quality

Closeness and the inclusion of other in self. Social identity theory posits that our identities are structured in part by those we value, spend our time with, and associate ourselves with (Tajfel & Turner, 1979). A more specific application of this idea is self-expansion theory, or the theory of inclusion of other in self (Aron and Aron, 1997). Self-expansion theory is put forth as a possible model of individuals’ relationship-related goals and cognitions. The self-expansion model holds that self-expansion, or cognitively including another in the self, is a central human tendency and a motivating goal. It allows individuals to explore, increase self-efficacy, and experience the world through a broadened perspective. Partners can provide each other with otherwise unavailable aspects of psychological functioning. Before self-expansion, the motivation to acquire influence, knowledge, meaning, and identity through connection to another person is a selfish one. But afterwards, relationship partners are motivated to protect the interests of the self and the other, because the other’s interests are effectively also the interests of the self. Intimacy under the self-expansion model is conceptualized as reciprocally increasing self-disclosure, feeling understood, cared-for, and validated (Rusbult, Martz, & Agnew, 1998).
Through such processes, the self and other are perceived to achieve “cognitive interdependence” (Aron & Aron, 1997, p. 264), to contain some of the other’s characteristics. The implication of this overlap for each partner’s cognition and behavior are that once the self has expanded, it is motivated to resist de-expansion, as such an event would represent the loss of valuable parts of the self.

Subjective closeness, and the extent to which close relationship partners affectively and cognitively influence each other in this view, is assessed with the inclusion of other in self measure. Scores on this measure correlate with other relationship measures of satisfaction, commitment, and investment. Implicitly, people in close relationships have been found to confuse the traits of self and other, as well as episodic memories of self and friend behaviors. Increases in self-esteem, self-efficacy, and self-content domains are reported after falling in love (see review by Aron & Aron, 1997). Clearly, the formation of close relationships, whether with friends, teammates, or romantic partners, is an expansion of the self and thus associated with positive affect and the fulfillment of psychosocial goals and needs. On the other hand, Aron and Aron (1997) posit that the “degree of psychological distress (from loss) should be predictable from the degree of previously existing overlap of self and other” (p. 270).

*Interdependence and commitment.* Subjective commitment levels can also be assessed in terms of interdependence theory—the structure of interdependence between relationship partners, in terms of costs and rewards (Rusbult et al., 1994). Dependence on a relationship is experienced as feelings of commitment, reliance on the partner, need, and connection in a long-term perspective. Commitment is represented by a willingness to persist in the relationship and feelings of psychological attachment (Rusbult et al., 1998). Commitment depends on satisfaction levels (the positive and negative emotions experienced in a relationship), the perceived quality of possible alternatives to the relationship, and the resources an individual has allocated to the relationship—resources that would be lost with dissolution (echoing the inclusion of other in self/self-expansion theories).
Commitment, as a construct encompassing the aforementioned factors, serves to direct reactions to relationship situations, and motivate maintenance behaviors. The decision to remain in a relationship is strongly mediated by changes in commitment over time (see Rusbult et al., 1994). Committed individuals are invested in the well-being of their partner, and act to preserve these vested interests, such as relationship quality. For example, subjects’ private inclinations to react to partner’s potentially relationship-threatening behaviors were substantially more negative than their actual reactions (see Rusbult et al., 1994), showing restraint and accommodation in order to preserve relationship tranquility. More committed individuals have more positive affect associated with relationships, and attribute their partners’ behaviors to more positive motivations (the converse is true as well) (Rusbult et al., 1994). The investment model has been studied and found to be applicable to dating relationships, marriages, friendships, and business settings.

Ideally, both partners are strongly and equally committed with motivational tendencies towards relationship maintenance. Such tendencies include prosocial, adaptive, and constructive responses to relationship events, of which attributions for behavior are important. As assessed by the interdependence model, relationship quality directly predicts explanation patterns for events, which in turn mediates emotional responses to those events (see Rusbult et al., 1994). However, individual factors such as attachment styles and working models can predict relationship quality as well (Collins & Allard, 2001). Furthermore, relationship quality/satisfaction was found to be uncorrelated with emotional responses to attachment-relevant situations (Collins, 1996), suggesting that individual moderating factors play a major role in determining responses to both positive and negative relationship events. Overall, however, the more interdependent and committed a relationship as an entity, the more painful violation of that relationship would be for the relationship partners.

*Individual Modulators of Relationship Closeness and Social Pain Sensitivity*

*Attachment style.* Attachment styles reflect an individual’s chronically accessible working models of the worth and likely behavior of self and other (Collins & Allard, 2001;
Presumably developed through early childhood experience and shaped by subsequent interpersonal events (Hazan & Shaver, 1987), cognitive working models of self and other represent the extent to which the self is worthy of affection, and the extent to which others are likely to be affectionate and kind (Collins & Allard, 2001). Relationship schemas in general and particular are also involved in attachment style determination. Working models shape relationship outcomes by influencing patterns of cognitive, emotional, and behavioral processing and response, and providing a pre-existing framework for attending to, organizing, and understanding new relationship information. They are affect-laden structures, and centered around the fulfillment of emotional needs (Collins & Allard, 2001). Various combinations of working models result in different attachment classifications. Differences in attachment style are systematically associated with differences in emotional response patterns and emotion regulation abilities (Collins, 1996), as well as the quality of relationship experiences.

Different attachment styles lead to different relationship experiences (Hazan & Shaver, 1987). A two-dimensional attachment model divides individuals into secure and insecure categories, while a three-category model breaks down insecurity into anxious (more needy) and avoidant (more standoffish) profiles. Securely attached individuals, with positive working models of self and other, are generally happy, trusting, accepting of partners' faults, supportive, and have generally better-quality relationships (Collins, 1996). They report more relationship satisfaction and commitment and make positive attributions for partner's behaviors (Collins, 1996; Collins & Allard, 2001; Hazan & Shaver, 1987). They seem buffered, by good nature, high self-esteem, or feelings of strength and generosity in relationships, against the cycle of negative attributions, fear, and rejection sensitivity which characterizes the insecurely attached (Collins & Allard, 2001).

Conversely, insecurely attached individuals, whether anxious or avoidant, have negative working models of self and other. Anxiously attached individuals are often obsessive in relationships, worry about the stability of partners' affections, evince more self-doubts, and feel
underappreciated and misunderstood (Hazan & Shaver, 1987). These individuals have “approval-seeking” and “rejection avoiding” chronically active goals, and attentional focus is on threats to these goals. Anxious individuals make attributions for partners’ ambiguous attachment-relevant behaviors that are self-denigrating, reveal less trust and confidence in partners’ regard, and suggest that partners are purposefully rejecting (Collins & Allard, 2001). Anxiety and worry about relationships and being unloved is strongly correlated with negative emotional responses and anticipation of conflict (Collins, 1996).

Even if their relationships are going well, anxious attachment leads to fears of rejection and negative attributions. It has been proposed that anxiously-attached individuals have overactive behavioral inhibition and fight-flight-fear systems (MacDonald & Kingsbury, 2006). In the view of social pain theory, the experience of physical pain and the associated pain affect may even foster an anxious attachment style through constant augmentation of social pain sensitivity (MacDonald & Kingsbury, 2006; MacDonald & Leary, 2005). On the other hand, avoidant individuals display a fear of intimacy in relationships, negativity, suspicion, and desire to distance the self from other (Collins & Allard, 2001; Hazan & Shaver, 1987). They report feeling less negative emotion in response to potentially negative relationship situations than anxious or secure individuals, which may be a defensive mechanism (Collins, 1996).

Individuals are believed to have relatively stable, global, and self-perpetuating core attachment styles, but may display different attachment characteristics within different relationship contexts as well (Hazan & Shaver, 1987). Not every relationship will be characterized by a single attachment profile, but the majority of one’s relationships will be in his/her general style because it is the most elaborated and accessible (Collins & Allard, 2001). One’s security or anxiety in a given relationship is a function of attachment style, as well as other personal and relational characteristics. But overall, attachment-style differences in emotional responses to partner behaviors are mediated by the needs and goals perceived to be affected by those behaviors. Therefore, anxiously-attached individuals, hypervigilant for
belongingness need threats, and weighing emotional cues very heavily, will be more sensitive to rejection than individuals with secure or avoidant attachment styles (Collins & Allard, 2001).

*Rejection sensitivity.* Rejection sensitivity and the distress resulting from relationship threat has been found to be linked to anxious attachment and the behavioral inhibition system (Meyer, Olivier, & Roth, 2005). Anxious expectation of rejection in relationships predicted negative attributions for the ambiguous behavior of a partner (Downey & Feldman, 1996). Downey and Feldman (1996) conceptualize rejection-sensitive individuals as those who “anxiously expect, readily perceive, and overreact to rejection” (p. 1327). Attachment security and social anxiety measures are correlated with scores on the Rejection Sensitivity Questionnaire (Downey & Feldman, 1996). In terms of sensitivity to rejection by strangers, RSQ scores are positively correlated with increases in feelings of rejection following termination of a conversation for ambiguous reasons, as well as emotional negativity of reaction to that termination (Downey & Feldman, 1996; Study 1). Where relationships are concerned, RSQ scores are correlated with heightened concern about being rejected by partners, irrespective of partners’ actual levels of commitment. Also, rejection sensitivity is associated with less relationship satisfaction by the sensitive (due to exaggerated perceptions of partners’ dissatisfaction with, and lack of commitment to, the relationship) and by their partners (Downey & Feldman, 1996; Downey, Freitas, Michaelis, & Khouri, 1998). Stable personality traits, such as agreeableness and neuroticism, are also systematically linked to rejection sensitivity (Buckley, Winkel, & Leary, 2004). A fairly negative picture of rejection-sensitive people is painted, then; they perceive rejection in ambiguous cues, are insecure and unhappy in relationships, and respond to rejection threats or perceptions with antisocial, relationship-disruptive behaviors. For the purposes of this study, rejection sensitivity as an independent variable should be associated with greater sensitivity to social insult and pain perception (MacDonald & Kingsbury, 2006).

Summary and Goals of Study
The finding that relationship status does affect physical pain sensitivity responses to social rejection would add to the growing body of behavioral and neurobiological evidence supporting the theory that the pain neuromatrix and physical pain perception is sensitive to modulation by certain social and personal factors, in a systematic and quantifiable fashion. Furthermore, our results could extend our understanding of the influence of social factors on pain perception to include friendships and teammates, as studies so far have used only close relationship partners (Singer et al., 2004) and strangers (Eisenberger et al., 2006).

Hypotheses

Our independent variables were the Cyberball manipulation, as well as the different relationship levels. Individual and relationship variables obtained from questionnaire measures functioned as covariates, or manipulation check variables. Our dependent variables were the magnitudes of change in pain sensitivity between baseline and post-manipulation assessments. Overall, we expected females to have greater pain sensitivity than males (Berkley, 1997).

Hypothesis 1

We expected to replicate the findings of Eisenberger et al. (2006), finding a main effect for ostracism on pain sensitivity, such that for all excluded participants, Cyberball rejection would produce greater pain sensitivity compared to baseline. We expected Cyberball inclusion (receipt of the ball an equal number of times as the other three players) to produce no effect on physical pain sensitivity, and therefore expected included “control” participants to show little or no increase in pain sensitivity across testing days, compared to all excluded participants.

Hypothesis 2

To extend the previous findings, it was expected that the degree of social pain caused by Cyberball rejection by a partner and therefore the increase in pain sensitivity would be moderated by closeness of relationship—specifically, that rejection by romantic partners would cause a greater increase in pain sensitivity than rejection by friends. Therefore, we expected interaction effects of relationship type on pain sensitivity measures between baseline and test
day. Ostracism by friends would be associated with a greater increase in pain sensitivity than rejection by strangers, and ostracism by an intimate partner would be associated with the greatest measured increase in pain sensitivity across testing days.

**Hypothesis 3**

Evidence indicates that regardless of relationship quality, rejection sensitivity and anxious attachment style are found to correlate with negative emotional responses to attachment-relevant situations (Collins, 1996; Downey & Feldman, 1996). Anxious attachment and rejection sensitivity are characterized by over-perception of social affronts, and thus greater affective distress. Therefore, we expected rejection sensitivity and insecure attachment style, as measured by higher scores on the RSQ and ECR-S anxiety subscale to predict a greater degree of pain sensitization in response to rejection.

**Hypothesis 4**

Although higher scores on relationship closeness scales correlate with more positive attributions, trust, and generosity of interpretation for partner behaviors (Collins, 1996; Collins & Allard, 2001), the primary response to a relationship threat from a partner may be a feeling of hurt (see Rusbult et al., 1994), irrespective of the secondary, cognitively-tempered behavioral response. The closeness of the relationship may modulate this initial feeling of hurt (Whitesell & Harter, 1996). Violations of closer relationships may lead to greater social pain. Therefore, we hypothesized that higher scores on the relationship closeness and quality inventories (Commitment and IOS) would correlate with greater pain sensitivity change from baseline after ostracism.

**Methods**

**Participants**

Participants were 72 undergraduate students at a small liberal arts college, between the ages of 19 and 22 years, recruited through advertisements on the college message boards and
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This total was composed of four groups: three quasi-experimental groups of ten dyads each selected for relationship type, and one 10-person control group.

**Relationship Conditions**

Our first participant group consisted of ten pairs of opposite-sex relationship partners, twenty individuals in all. Next, we recruited ten pairs of opposite-sex strangers, in order to balance the gender distribution of the romantic couples. Our third group consisted of eleven pairs of same-sex friends (five pairs of males, six pairs of females). Romantic partners and friends self-identified as part of the screening questionnaire (see below).

Ten individuals (five males and five females) were recruited as repeated-testing controls, to ensure the validity of the ostracism manipulation by showing that pain sensitivity does not simply increase from the first testing day to the next.

In addition to the 72 experimental participants, we recruited a small set of confederates. Confederates were recruited from introductory psychology classes and received partial course credit for participation. Male to female ratios were kept equal in all experimental sessions.

**Privacy**

All data sheets, questionnaires, and computer files contained no names of subject participants. Rather, a three- or four-digit ID code was used to match data across different testing days. Thus, the results were entirely confidential.

**Screening Questionnaire**

An electronic screening questionnaire website was created in order to obtain the correct relationship dyads. Expressing interest in participating in the study, prospective participant pairs completed this online instrument, which established eligibility and garnered the information needed to place each individual in a group based on self-reported relationship status (see Appendix A). Questions included demographic measures, relationship status, assessments of conditions that may affect pain perception (see below), willingness/ability of the respondent and his/her relationship partner to participate in the study, and contact information. Due to the pain
testing involved, people with any of the following conditions were excluded: Raynaud's disease (characterized by circulatory problems in the extremities), chronic pain conditions, heart disease, chest pain, high blood pressure, arthritis, or seizures. Smoking can cause high blood pressure and increased pain sensitivity, so smokers were also excluded from participation. Furthermore, past enrollment in Social Psychology and/or current enrollment in Introductory Psychology also precluded participation. From the appropriate respondents to this questionnaire, we selected the members of our four participant groups.

Compensation

Each participant received $20.00 for participating in both testing sessions. They were paid at the end of the second day of testing. Participants could freely decide to terminate participation at any time, and would be paid the full amount even if they arrived at but did not complete the second day of testing. If participants for any reason did not return for the second testing day, they were paid $10.00. As previously stated, confederates were members of an introductory psychology class receiving partial course credit for participation. All procedures and criteria were approved by the Haverford IRB prior to recruitment and testing.

Materials

Cyberball

Cyberball (Williams, Cheung, & Choi, 2000) is a computer program developed to experimentally ostracize participants. It is ostensibly an online ball-tossing game between real participants connected over a network, but the game is actually totally individual. Participants are in fact playing with computer “friends” and the computer program controls all the tosses besides those that the participants themselves make. Thus, the experimenter can program in how much the participant receives the ball from the “other players.” Participants are told that the game is a task of “mental visualization” and to imagine as vividly as possible playing the game in real life with the online players. Should they get the ball, participants throw it to another player by clicking on his/her on-screen cartoon ball-tossing figure. Experimenters can modify
the length of the game, amount of non-inclusion, number of participants, names of participants, and participant on-screen photos. Cyberball has been shown to be an extremely effective and robust manipulation at inducing the psychological and behavioral effects of ostracism (Williams, 2007a).

This study set up a four-person Cyberball game. On the actual game screen participants see while playing, the names and photos of the four “players” (the participant, his/her partner, and the two confederates) were displayed next to each ball-tossing figure. The game lasted for a total of three minutes. In the exclusion condition, a participant was included in the game for the first minute, then the other “players” (including the participant’s “partner”) ceased throwing the ball to the participant for the rest of the game’s duration. In the inclusion control condition, the participant received the ball an equal number of times as the other “players,” throughout the 3 minutes of the game.

Pain Testing Equipment

*Medoc thermal stimulator.* Thermal threshold was determined using a Medoc thermal stimulator on the glabrous skin of the participant’s dominant arm. The stimulator is a thermode (30 mm²) connected to a computer program that controls and records its temperature and temperature change over time. The Medoc thermal stimulator device being used in this study is FDA approved and is widely used in research and clinical settings (it can be used to detect nerve injury in chronic pain patients who have altered responses to thermal stimuli).

*Cold Pressor.* The equipment used for a cold pressor test consists of a bucket of ice water at 0-4°C with a circular mesh screen enclosing the central portion of the bucket, to keep the ice itself from touching the participant.

*Gracely box scales.* Gracely Box Scales consist of 0-20 numerical ratings on the dimensions of pain unpleasantness and intensity, anchored by descriptor terms (Gracely, 1979). Participants can thus give self-report ratings of pain unpleasantness and intensity at different times throughout the duration of pain experience. This standard psychophysical scaling has been
shown to be accurate and sensitive to analgesic manipulation in a number of studies (Gracely, 1979; Gracely, 1999).

**Relationship Measures**

For the romantic and friend conditions, all relationship measures were modified from their original forms such that they instructed the participant to think of his/her experimental partner in reference to his/her responses on the questionnaires.

*Inclusion of other in self scale.* The Inclusion of Other in Self scale (IOS, Aron et al., 1992) is a pictorial instrument that assesses the subjective extent to which an individual feels cognitively overlapped with a relationship partner. Participants are asked to click and drag one of two circles representing the self and the relationship partner until the circles overlap each other to the perceived degree. The IOS produces valid results that reliably correlate with other measures of relationship closeness (Aron et al., 1992) and applies to various types of relationships.

*Investment model: Commitment facet.* The Commitment facet of the Rusbult Investment Model Scale measures relationship closeness as well (Rusbult et al., 1998). Specifically, it assesses a relationship partner’s intent to remain in the relationship as well as his/her level of psychological attachment to the partner. Participants indicate their level of agreement with statements such as “I would not feel very upset if our relationship were to end in the near future” and “I feel very attached to our relationship—very strongly linked to my partner” on an 8-point Likert-type scale ranging from 0 (do not agree at all) to 4 (agree somewhat) to 8 (agree completely). This measure also correlates well with other relationship closeness instruments, and is reliable and valid in assessing various types of relationships.

**Individual Measures**

*Rejection sensitivity questionnaire.* The Rejection Sensitivity Questionnaire (Downey & Feldman, 1996) is designed to test participants’ expectations of rejection in social situations and how intensely that rejection would influence affect, cognition, and behavior. It presents a series
of social situations for which rejection is a possible outcome (e.g. "You ask someone in class if you can borrow his/her notes"), then asks participants to indicate on 6-point Likert-type scales their degree of concern over the outcome of that situation (1 = very unconcerned, through 6 = very concerned), as well as the likelihood that the situation would end in an accepting fashion (1 = very unlikely, through 6 = very likely).

*Experiences in close relationships—short form.* The short version of the Experiences in Close Relationships form, ECR-S (Wei et al., 2007) is a measure of attachment style. Participants indicate their level of agreement on a 7-point Likert-type scale (1 = disagree strongly, 4 = neutral/mixed, 7 = agree strongly) with attachment-relevant statements (e.g. "I am nervous when partners get too close to me"). Six of these statements assess the dimension of anxiety and six assess the dimension of avoidance. Co-efficient alphas are .78 (Anxiety) and .84 (Avoidance) for the 12-item ECR-S. This measure is on the whole just as reliable and valid as the longer ECR.

*General Procedure*

Each participant came into the lab and had his/her pain tested twice: on a baseline day and again on the experimental day. The baseline session was at least 48 hours before the experimental session. Both sessions were held at roughly the same time of day to control for circadian variations in participants’ pain behavior. For the baseline session, participants came in alone; on the experimental day, each participant came to the lab together with his/her dyadic partner, or a randomly-assigned stranger partner. One female experimenter administered the baseline tests, and two female experimenters were present for the experimental test day. As stated above, thermal pain threshold and cold pain tolerance were each tested at both sessions. The order in which these tests are conducted were randomly counterbalanced at each session as well.

*Pain Testing*
**Thermal threshold.** This test is designed to assess the temperature at which a participant begins to feel heat pain. The Medoc thermal stimulator was placed on the glabrous skin of the participant's non-dominant forearm. The probe began at a neutral habituation temperature (28°C) and rose (at rate of 1.5°C/sec) until the individual reported that the stimulation was painful (usually between 41°C and 45°C for healthy participants). Once this pain threshold was reported, the device reset to the neutral temperature. The procedure was repeated five times, with the probe moved to a different spot on the forearm each time to prevent the effects of peripheral sensitization. The threshold temperatures for each trial were averaged to give a final pain threshold number for each participant. In order to practice making perceptual judgments about thermal stimuli, participants were first exposed to a “warm threshold” procedure, wherein the thermode began at 20°C and rose in temperature until the subject first detected (and reported) warmth. The computer recorded each participant’s threshold temperatures and temperature changes.

**Cold pressor.** This test measures participants’ ability to tolerate pain—duration and intensity. The test consisted of participants placing their dominant arm (up to the elbow) in the center of a mesh screen submerged in a bucket of 0-4°C ice water (ice is not in contact with subject’s arm) for a maximum of 180 seconds (or until the participant removed his or her arm). Verbal pain intensity and unpleasantness ratings on the Gracely box scales were obtained and recorded every 15 seconds until the test was terminated by the removal of the arm. For intensity and unpleasantness separately, each participant received the maximum possible score (20) for each interval following removal of the arm from the bucket (if necessary), then the ratings over all the intervals were summed. These calculations resulted in two separate scores—sum of pain unpleasantness and sum of pain intensity—for each participant, at each session. We also recorded the time the participant was able to keep his/her arm in the bucket, and used this withdrawal latency as an overall measure of pain tolerance.
The two different testing apparatus (cold-pressor bucket and Medoc thermode device) were set up in two different rooms, so that they could be administered simultaneously to the two participants.

Specific Procedure

Baseline Day

Participants came into the lab individually on the first day. They were told that this is a study of relationships, mental visualization, and pain. After signing the consent form, all participants completed the individual difference questionnaires: the ECR-S and the RSQ. The romantic partners and friends completed the relationship measures (IOS and IC) as well, with specific reference to their experimental partners. Strangers also completed these relationship questionnaires but with the instruction simply to think of their closest relationship, not anyone in particular. Controls did not fill out the relationship measures. Next, baseline heat pain threshold and baseline cold pain tolerance were assessed according to the above procedures. The order of the pain tests were randomly counterbalanced across participants. Finally, participants had a digital photograph taken to provide a standard image for use in the Cyberball game. They were then thanked and scheduled for an experimental day.

Experimental Day

Experimental groups. Experimental participants arrived at the lab together with their dyadic partners, at the same time as two gender-matched confederates. Experimenters explained to the four assembled participants that they would be playing an online sports mental visualization game with each other, to investigate the phenomenon of sports imagery training and to practice mental visualization skills before a subsequent visualization task (which did not actually occur). Both true participants were shown to separate rooms with computers on which Cyberball was installed and set up. The confederates ostensibly also went into separate rooms, but actually left the lab. The Cyberball game on each participant’s computer was set up previously with the names and photos of the participant and the three others in the group.
(partner and confederates). The games were also set to exclude the participant after 1 minute of play. Following the Cyberball game, we randomly selected one participant to receive the cold pressor test first, while at the same time the other participant was given the thermal threshold test—then switched so both participants received both tests. After administration of both pain tests, participants were independently questioned about any acquaintance with confederates/strangers and any suspicions regarding the nature of the game and the experiment as a whole. Finally, participants were brought back together, fully debriefed, compensated, thanked and dismissed.

**Controls.** Control participants were randomly scheduled together in opposite-sex pairs. Upon arrival at the lab, along with two gender-matched confederates, they were given the same instructions regarding mental visualization and game play, then shown to separate rooms with computers to play Cyberball. As in the experimental condition, the game screen displayed the correct names and photos of the four participants. However, these games were set such that the participant and the other three players received the ball an equal number of times during the 3-minute duration of play (inclusion). Following Cyberball, each pair of control participants had their pain tested by the same switch-off/counterbalanced procedure as the other groups (see above). Participants were orally questioned for suspicion and acquaintance with their Cyberball cohort. Finally, both participants were brought back together, fully debriefed, compensated, thanked and dismissed.

**Analyses**

**Hypothesis 1**

All data were analyzed using SPSS. To test Hypothesis 1 for replication of Eisenberger et al.'s (2006) results that Cyberball ostracism leads to an increase in pain sensitivity compared to inclusion, 2 (Day 1 vs. Day 2) x 2 (Control vs. Collapsed Experimental Groups) x 2 (Male vs. Female) mixed factorial ANOVAs were conducted using each pain sensitivity score obtained (thermal threshold, cold unpleasantness, cold intensity, and tolerance time) as the dependent
variable in four separate analyses. No change in pain sensitivity scores was expected in the control inclusion group, compared to the experimental ostracized groups. Thus, significant interaction effects of Session and Group were expected.

**Hypothesis 2**

To test Hypothesis 2 for the effects of the ostracism manipulation and relationship status on change in pain sensitivity from baseline, 2 (Day) x 3 (Stranger vs. Friend vs. Romantic Group) x 2 (Sex) mixed factorial ANOVAs were conducted. As for Hypothesis 1, each pain sensitivity score obtained was analyzed as a dependent measure in a separate ANOVA. Amongst the ostracized groups, greater positive changes in pain sensitivity scores were expected to be associated with closer relationships.

**Hypothesis 3**

To test for associations between rejection sensitivity, attachment style, and amount of pain sensitivity change from baseline, 2 (Day) x 4 (Control vs. Stranger vs. Friend vs. Romantic Group) x 2 (Sex) mixed factorial analyses of covariance (ANCOVAs) were performed with RSQ and ECR scores as covariates and pain sensitivity change as the dependent variables. The hypotheses would be supported by interaction effects between rejection sensitivity/anxious attachment and testing day.

**Hypothesis 4**

To test for associations between self-other overlap, commitment, and amount of pain sensitivity change from baseline, we performed two 2 (Day) x 2 (Friend vs. Relationship Group) x 2 (Sex) mixed factorial ANCOVAs for each pain test, with IOS_O and IC scores as covariates and pain test score as the dependent variable. We expected higher scores on relationship closeness and quality measures to predict greater increases in pain sensitivity from baseline to experimental day, in both the friend and romantic relationship conditions.

**Results**

*Computation of Scores*
The metrics for heat threshold at baseline and post-Cyberball were computed by averaging heat threshold in °C across the five Medoc thermal stimulation trials per test. These calculations yielded for each participant two data points in °C, a baseline heat threshold and a post-manipulation heat threshold. Time spent in the cold pressor task (in seconds) at baseline and experimental sessions represented cold pain tolerance. Reported cold pressor unpleasantness for each participant at baseline and experimental sessions was computed by summing unpleasantness ratings from each interval, including the highest possible rating (20) for all intervals after a participant removed his/her arm (if necessary). The same calculations were performed for cold pain intensity, yielding baseline and post-experimental cold pain intensity sums.

**Hypothesis Testing**

*Hypothesis 1: We expect participants to report more pain following ostracism in the experimental conditions compared to the controls*

Fundamentally, this experiment was expected to replicate the common findings from a robust literature on ostracism and physical pain (Williams, 2007b). Specifically, the first hypothesis predicted that all participants’ pain sensitivity (tolerance and threshold) would increase following the social pain of Cyberball ostracism. Thus, all of the data from the pairs that received Cyberball ostracism (Romantic, Friend, and Stranger pairs) were collapsed into one group, Experimental.

Assessing heat thresholds, a 2 (Day 1 vs. Day 2) x 2 (Experimental groups vs. Control group) mixed factorial ANOVA revealed no significant interaction effects. Similarly, 2 x 2 mixed factorial ANOVAs assessing the effects of the ostracism manipulation on summed cold unpleasantness and cold intensity ratings found no Day x Group interactions. Thus, ostracism by a relationship partner did not increase heat pain sensitivity relative to controls, failing to support Hypothesis 1 for heat threshold, cold unpleasantness, and cold intensity pain metrics. F-values
and significances for all four 2 x 2 ANOVAs comparing control and experimental groups are in Table B1 (see Appendix B).

However, the cold time (tolerance) measure Day x Group interaction was significant, $F(1,69) = 7.29, p < .01$. Table B2 (see Appendix B) shows the means and standard errors of the amount of time (in seconds) that control and experimental participants endured the cold pressor task at baseline and following the manipulation. Overall, participants exposed to the ostracism manipulation showed a significant increase in pain tolerance ($t(59) = -2.08, p < .05$), spending longer in the cold after Cyberball, while participants in the control condition showed a decrease in pain tolerance that approached significance ($t(10) = 1.81, p = .10$) from the first session to the second session, spending less time in the cold after Cyberball inclusion. In other words, the control and experimental groups’ pain tolerance times were significantly different before Cyberball ($t(21) = -2.62, p < .05$) but not after, $t(69) = -.44, p = .66$ (see Figure C1, Appendix C).

The groups’ average times converged following the manipulation, in the opposite direction as expected. These results fail to support, and in fact contradict Hypothesis 1, that ostracized participants would show a decrease in pain tolerance after ostracism, relative to controls. Possible interpretations of this finding will be discussed in the following section.

Hypothesis 2: We expect that those in the romantic relationship condition will have the greatest increase in pain sensitivity compared to the other experimental groups, followed by friends and then strangers.

The second hypothesis, of particular interest in this study, was that exclusion-induced pain sensitivity would increase in proportion to the closeness of the relationship between the ostracized participants. Of the different relationship types, romantic partners would show the greatest increase in pain sensitivity after social exclusion, followed by friends and then strangers. A 2 (Day 1 vs. Day 2) x 3 (Romantic vs. Friend vs. Stranger Group) mixed factorial ANOVA with heat threshold as the dependent variable revealed no significant interaction effects. The same test using cold time as the DV was also not significant. Finally, the Day x
Group interaction for cold intensity ratings approached but did not attain statistical significance. Thus, the ostracism manipulation did not lead to any significant heat threshold, cold tolerance, or cold intensity differences between romantic partners, friends, and strangers—seeming to affect all three groups equally. F-values and significances for all of the aforementioned 2 x 2 ANOVAs comparing the three experimental groups are shown in Table B3 (see Appendix B).

However, significant differences emerged between the groups in their cold unpleasantness rating changes following ostracism, $F(2,58) = 4.44, p < .05$. As depicted in Figure C2 (see Appendix C), following the ostracism manipulation, romantic partners reported the cold to be more unpleasant, while friends and strangers found the cold to be less unpleasant. Means and standard errors for each group’s cold unpleasantness sums at each session are shown in Table B4 (see Appendix B). Scheffé’s post hoc tests of mean differences between groups revealed that romantic partners’ cold unpleasantness sums increased significantly more than friends’ following ostracism, $M_{A_F} - M_{A_R} = 24.87, SE = 8.56, p < .05$. No other between-group mean differences in cold unpleasantness rating changes were significant.

As such, Hypothesis 2 was partially supported for cold pain unpleasantness, in that romantic partners did report a greater increase in unpleasantness ratings than did friends. However, friends and strangers found the cold pressor test to be significantly less unpleasant following social rejection by a partner, contradicting our hypothesis that rejection would lead to an increase in physical pain sensitivity in these groups. The results also fail to support the part of Hypothesis 2 that predicted friends would show greater increases in pain sensitivity following rejection by a valued other, compared to strangers.

Hypothesis 3: We expect participants scoring higher on rejection sensitivity and attachment anxiety will have a greater increase in pain sensitivity following the ostracism manipulation.

RSQ (Cronbach’s $\alpha = .84$) and ECR-S (anxiety subscale Cronbach’s $\alpha = .74$—we had no predictions regarding avoidant attachment style) scores for each friend and romantic participant were calculated according to published scoring procedures and guidelines. Hypothesis 3
predicted that participants scoring higher on rejection sensitivity and attachment anxiety would be more susceptible to social insult from a valued partner, leading to greater pain sensation following ostracism as compared to those scoring lower on these variables. As such, using RSQ and ECR-S scores as covariates, two (2) 2 (Day) x 3 (Experimental Groups) mixed factorial ANCOVAs were conducted per pain test. In accordance with Hypothesis 3, we expected Day x RSQ and Day x ECR-S interaction effects. F-values for all personality variable x pain sensitivity change interactions are in Table B5 (see Appendix B).

No relationship was found between RSQ score and heat threshold change following ostracism. However, there was a main effect of RSQ, $F(1,57) = 16.25, p < .001$, such that those with higher scores on the RSQ (i.e. greater rejection sensitivity) had lower heat thresholds overall, $r = -.43$. Similarly, participants higher on ECR-S attachment anxiety did not report greater changes in heat threshold between baseline and ostracism, but higher scores on attachment anxiety did predict lower heat thresholds overall, $F(1,56) = 5.14, p < .05, r = -.28$.

Time spent in the cold pressor bucket was used as the measure of pain tolerance. A 2 (Day) x 3 (Group) mixed factorial ANCOVA with cold pressor time as the DV and RSQ score as the covariate found that rejection sensitivity did not predict change in cold pain tolerance following ostracism and that RSQ score did not predict pain tolerance overall. The same test using ECR-S anxiety score as the covariate did not support the predicted Day x ECR-S anxious interaction, but the main effect of ECR-S anxious was marginally significant, $F(1,55) = 3.10, p < .10$, such that more anxiety was related to lower cold pain tolerance in general.

A similar pattern of results was found using cold intensity sums as dependent variables. RSQ scores did not predict greater rejection-induced changes in pain intensity reports, but higher RSQ scores did correlate with higher pain intensity ratings from all participants, $F(1,57) = 4.60, p < .05; r = .23$. Likewise, attachment anxiety was unrelated to pain intensity report change, but more anxious participants did report greater cold pain intensity overall, $F(1,56) = 4.98, p < .05; r = .28$. 
Finally, an identical pattern of results was observed for cold unpleasantness ratings. The RSQ did not predict cold unpleasantness rating change, but more rejection sensitive participants reported more cold unpleasantness collapsed across testing days, $F(1,57) = 6.92, p< .05; r = .30$. By the same token, ECR-S$_{anx}$ scores did not predict more physical pain sensitivity to ostracism, but more attachment anxiety was associated with greater reported cold unpleasantness in general, $F(1,56) = 6.51, p<.05; r = .32$.

In conclusion, our data do not support Hypothesis 3, but measures of trait emotional sensitivity predict overall physical pain sensitivity in our sample, as can be seen in Table B6 (Appendix B). These data represent interesting relationships between characteristic social and physical pain perception that merit further discussion.

_Hypothesis 4: We expected that participants who report more cognitive overlap with their relationship partners would show a greater increase in pain sensitivity following ostracism; the same will be true for commitment._

Hypothesis 4 predicted that participants in relationship conditions (Romantic, Friends) reporting more IOS overlap would show a greater increase in pain sensitivity following ostracism by their partners, and the same would be true for participants who felt more committed to their partners, and thus scored higher on the Commitment Inventory (Cronbach’s $\alpha = .76$). Following the same pattern of analyses conducted for the RSQ and ECR-S$_{anx}$, two (2) 2 (Day) x 2 (Friend vs. Romantic Group) mixed factorial ANCOVAs were performed for each pain score, one using IOS$_O$ as a covariate and one using CI.

For heat threshold scores, the expected Day x IOS$_O$ interaction did not emerge, indicating that the extent of cognitive overlap with one’s partner did not influence heat pain thresholds following ostracism by that partner, supporting the null hypothesis. However, akin to the pattern that emerged in the analyses of RSQ and ECR-S$_{anx}$ scores, the main effect of IOS$_O$ was marginally significant, $F(1,38) = 3.22, p< .10$, such that more cognitive overlap with a partner was related to higher heat pain thresholds in general, $r = .11$. These data indicate that
feeling cognitively overlapped with a relationship partner is associated with greater resistance to heat pain in general, but causality cannot be established in this experimental design. The 2 (Day) x 2 (Group) mixed factorial ANCOVA with CI score as the covariate revealed no significant interaction or main effects, failing to support Hypothesis 4 and finding no further relationship between reports of closeness and heat threshold.

The same test for Day x IOS_O interaction performed on cold pressor times (in seconds) using IOS_O as the covariate was not significant, nor were any main effects found for IOS_O. In our sample, then, partner-partner cognitive overlap was not related to ostracism-induced change in cold pain tolerance. Likewise, closeness with one’s partner was not associated with any more or less cold pain tolerance following exclusion. No main effects were found in this analysis. Our results fail to support Hypothesis 4 for cold pressor tolerance.

For friends and relationship partners, cognitive overlap was unrelated to exclusion-induced change in cold pain intensity reports failing to support Hypothesis 4 for IOS_O and cold intensity. However, a main effect of IOS_O was found, $F(1,38) = 5.31, p<.05$, such that a higher degree of overlap correlated with lower cold pain intensity ratings overall, $r = -.14$. Higher levels of commitment did not predict greater changes in cold pain intensity following ostracism, nor were any main effects found for CI on intensity scores. Thus, a similar pattern of results emerged for cold pain intensity as for heat threshold—Hypothesis 4 was not supported by the data, but main effects showed an interesting mitigating effect of cognitive overlap upon pain intensity ratings overall.

Similarly, although the Day x IOS_O interaction for cold unpleasantness was not significant, the main effect of IOS_O approached significance, $F(1,38) = 3.40, p<.10$, such that more cognitive overlap related to lower pain unpleasantness ratings across the sample, $r = -.15$. No interaction effects nor main effects were found for CI on cold unpleasantness ratings. These data fail to support Hypothesis 4 for cold unpleasantness, but again main effects showed a trend
towards a reductive relationship between including one’s partner in the self-concept and pain unpleasantness ratings, as can be seen in Table B7 (Appendix B).

**Exploratory Analyses: Sex Differences**

A one-way ANOVA with sex as the fixed factor and the four pain tests as dependent variables showed that the data was consistent with the literature showing that males have greater tolerance for pain and higher pain thresholds than females, on average (Berkley, 1997). $F$ values, means, and standard deviations are reported in Table B8 (see Appendix B).

Omnibus 2 (Day) x 3 (Experimental groups) x 2 (Sex) analyses were conducted to investigate the interplay between these three factors and their effects on pain perception. The only analysis to reach significance used cold pressor time as the dependent variable, and found a Day x Group x Sex interaction, $F(2,54) = 4.28, p< .05$. Means and standard errors are reported in Table B9 (see Appendix B).

Simple main effects analyses on each sex separately showed that females’ baseline-experimental changes in cold pain tolerance did not differ significantly between groups ($F(2,29) = 1.98, p= .16, \text{ns}$) nor did males’, $F(2,25) = 3.32, p = .053$. Therefore, it may be that the present experiment’s sample size was not large enough to furnish the statistical power that would find significant simple main effects. Thus, the current data cannot reveal which sex’s between-groups differences are driving the overall interaction—whether males differ significantly between relationship conditions (although the simple main effect for males did approach significance), or whether females differ between conditions, in pain tolerance response to ostracism.

However, an interesting pattern of within-condition sex differences can be seen in Figure C3 (see Appendix C). All friends’ pain tolerances increased following ostracism. But within the relationship condition, female participants exhibited more cold pain tolerance post-manipulation, while male participants reported less tolerance for cold pain. Furthermore, male strangers’ tolerance increased and female strangers’ pain tolerance decreased following ostracism. Three 2(Day) x 2(Sex) mixed factorial ANOVAs were conducted, one for each
relationship condition, to investigate this pattern of sex differences within the groups. The male
and female friends did not significantly differ in their baseline-experimental change in pain
tolerance, $F(1,19) = .29$, $ns$. For the romantic couples, the Day x Sex interaction was only
marginally significant, $F(1,18) = 4.02$, $p = .06$, $ns$, but the general pattern in the graph suggests a
potentially interesting trend that may have reached significance in a larger study. However,
male and female strangers did differ in their pattern of pain tolerance time response to ostracism,
$F(1,17) = 6.18$, $p<.05$ (see Figure C4, Appendix C). Independent samples $t$-tests showed that in
the stranger condition, the difference between males ($M = 174.22$, $SD = 17.33$) and females ($M$
$= 70.66$, $SD = 60.32$) was even greater following ostracism ($t(17) = -5.20$, $p<.001$) than the
difference between males ($M = 151.84$, $SD = 44.59$) and females ($M = 77.56$, $SD = 55.81$) at
baseline, $t(17) = -3.18$, $p<.010$. Thus, male strangers became more tolerant, and females less
tolerant, of cold pain following Cyberball ostracism.

Discussion

Results Summary

The goal of the present experiment was to extend the investigation of social pain and
physical pain overlap into real-life relationship contexts. Pairs of friends, romantic couples, and
strangers were subjected to false Cyberball ostracism in between baseline and experimental heat
and cold pain tests (controls were included in Cyberball). In accordance with the published
literature, all experimental groups were expected to report decreases in physical pain tolerance
and threshold following social rejection, a hypothesis that was contradicted by significant
increases in cold pain tolerance time amongst the experimental groups and decreases by the non-
rejected controls. All other pain test score changes failed to reach significance.

Hypothesis 2 predicted that within the experimental groups, the romantic partners would
have the greatest increase in pain sensitivity after ostracism, followed by the friends and the
strangers. Hypothesis 2 was partially supported, such that romantic partners reported significant
increases in cold unpleasantness following social rejection—but friends’ and strangers’ pain unpleasantness ratings actually decreased.

Next, the hypothesis that post-ostracism pain increases would positively correlate with rejection sensitivity and attachment anxiety (Hypothesis 3) was also not supported by the data. However, higher scores on the RSQ and ECR_Sanx predicted significantly lower heat pain thresholds and higher cold pain intensity and unpleasantness ratings overall—suggesting a correlation between emotional and sensory pain sensitivity and perception.

In addition, Hypothesis 4, predicting (for friends and romantic partners) positive correlations between cognitive self-other overlap, relationship commitment, and pain sensitivity increase following exclusion, was not supported. Interestingly, though, main effects of IOS_O revealed that greater self-other overlap predicted lower cold pain intensity ratings overall, with the effects for lower cold pain unpleasantness and higher heat thresholds approaching significance.

Finally, simple main effects analyses of exploratory Day x Group x Sex interactions revealed that female strangers responded to ostracism with a significant decrease in cold pain tolerance, compared to stranger males’ tolerance increase. Between males and females in romantic relationships, the opposite sex pattern approached significance. Overall, despite the lack of support for most of the original hypothesis, several interesting findings have come to light which merit further discussion and perhaps experimental exploration.

*Faulty Hypotheses?*

One possible interpretation for the non-significant and inconsistent results obtained by the present experiments is that Hypothesis 1 is erroneous. However, such a situation does not seem likely, as literature from many other labs on the social pain effect is robust and conclusive (Eisenberger et al., 2006; Williams, 2007b). The inability of the present study’s manipulations to replicate the robust pain sensitization found in strangers, as well as the significant differences
obtained between experimental conditions (Hypothesis 2), seems to indicate a problem with the methodology, and not with Hypothesis 1 per se.

Further addressing the results obtained in the test of Hypothesis 1, the experimental stimuli administered to the “control” subjects seemed not to create appropriate neutral conditions and pain response. Cyberball inclusion was hypothesized not to alter participants’ perception, cognitions, emotions, or behavior in any way—evidently, this was not the case. “Control” participants, after inclusion in a game of Cyberball with strangers, actually decreased in cold pain tolerance ability (the opposite pattern of results obtained from participants in the collective “experimental” condition will be further explored below). Therefore, being included in the game may have had a sensitizing effect upon participants.

How might such sensitization come about? Conditioned anti-analgesia is a phenomenon well-documented in rodents that can be extended to humans (Johnson, 1995; Watkins et al., 1997). In situations that normally cause analgesia (such as pain testing paradigms, for example), presentation of a signal that has been conditioned to indicate the absence of forthcoming noxious stimuli will induce hyperalgesia to subsequent pain tests. This “safety signal” presumably allows subjects to relax their guard, so to speak, such that any unexpected pain input becomes especially noxious because of its unpredictability—in contrast to stress-induced analgesia. Research on behavioral control, the ability to modify a stressor by controlling one’s environment and creating a stress-free interval, supports the safety signal phenomena. Behavioral control operates in part through the activation of GABA-ergic neurons in the ventromedial prefrontal cortex. Activity in these neurons leads to inhibition of stressor-induced activation of 5-HT neurons in the caudal dorsal raphe, and a muted stress response (cited in Christianson et al., 2008). Behavioral control, as such, acts as the safety signal in this situation—and thus could be expected to enhance the experience of pain by the mechanism outlined above.

Conditioned anti-analgesia and safety signals only operate within stressful contexts that can produce analgesia. A social encounter, specifically a game of Cyberball with strangers,
could be construed as the necessary stressor, in addition to the anticipation of pain. Inclusion in the Cyberball game could give “control” participants a signal of a period of safety, and temporarily attenuate the analgesia induced by (the stressful) knowledge of forthcoming pain—even decrease tolerance of pain. In the absence of inclusion as a safety signal, as was the case in the ostracized experimental groups, stress-induced analgesic effects could operate to increase pain thresholds.

This interpretation is extremely speculative, and a more rigorous social safety signal conditioning paradigm would have to be developed to test any effects of manipulated behavioral control in social situations upon physical pain tolerance. Significant pain sensitivity changes following inclusion in a game of Cyberball, as compared to having participants sit quietly for three minutes, would confirm that Cyberball inclusion is a mediator of pain behavior—and not a true control. The present data in relation to Hypothesis 1 seems to argue for a re-evaluation of the use of inclusion as a control condition in social rejection paradigms. However, the social pain overlap hypothesis cannot be definitively refuted by the data in this study.

Other Possible Considerations

Pain Report Manipulation

Another option is that the social rejection manipulation worked to induce social pain and sensitize physical pain pathways, and the hypotheses were well-founded—but other psychological factors were in play, indirectly influencing the final outcomes. Moderated by attachment style and sensitivity, pain reports can be willfully and/or unconsciously manipulated by the participants themselves to obtain sympathy and social support (MacDonald, 2008). Amongst its many functions, pain report can serve to communicate an internal state of distress to one’s conspecifics in the hopes of soliciting a response that will ameliorate that distress. The more important one perceives the communicative function of pain to be, the more likely that person is to report a high tolerance for pain at baseline—believing this to convey a sense of toughness, stoicism, and invulnerability.
Due to the significance they ascribe to pain as a communicator, people who report high baseline invulnerability to pain are more likely to use subsequent reports to satisfy psychological needs, such as belongingness needs, in the face of a threat such as social rejection. Past literature suggests that participants change pain thresholds, not tolerances, when attempting to elicit sympathy. In the context of the present experiment, however, pain tolerance reports would be easier to manipulate. Expressions of discomfort and dramatic removal of one's arm from the cold bucket, as well as high ratings of unpleasantness and intensity, can be signals of distress. MacDonald (2008) found no gender differences in the use of pain reports for belongingness need satisfaction, although his analysis was underpowered. A larger sample, and self-report questionnaires which assess the extent to which participants believe that invulnerability to pain is an important quality to have, could help to elucidate whether participants may have manipulated their own reports to gain sympathy.

**Self-Regulation**

Furthermore, one's motivation to self-regulate, in the form of increased cold pain endurance, has been shown to increase following social rejection if the pain task is framed as indicative of future social acceptance (de Wall, Baumeister, & Vohs, 2008). These results, taken together with the idea that some individuals believe pain tolerance to be an important indicator of character, may indicate that pain reports are not the most unbiased metric of inner psychological and emotional states.

**Methodological Concerns**

Alternatively, the theory and rationale of the experiment may have been completely sound. Mechanical and methodological error, however, could decrease signal to noise ratio, prevent the proper execution of the manipulation, and lead ultimately to the results inconsistent with the hypotheses and literature. Of primary concern, community samples are always more representative than focused samples, and large universities' subject pools more closely approximate "communities" than samples at small schools. The possibility that the small sample
size in the present experiment may have contributed to the lack of conclusive results is supported by the large number of analyses that approached but did not attain significance.

**Psychological Idiosyncrasies of Sample**

Most of the literature on the social pain effect comes from studies done at large universities (see Williams, 2007b). However, the experimental samples in the present study were drawn exclusively from pools of volunteers at a small (<1200 students) liberal arts college.  

"Strangers," then, may not have been perfect strangers, as many individuals are known by reputation. A close-knit social atmosphere and an honor code emphasizing trust, respect, and concern feature prominently in the philosophy of the school. As such, many participants (in all conditions) expressed disbelief in their exclusion from Cyberball by fellow students—possibly indicating a failure of the manipulation due to sampling bias. Although few studies have looked at the impact of an honor code culture upon social judgment, the extant literature suggests that even hypothetically, participants predict that an honor code would engender less cheating (and perhaps fewer antisocial acts in general) by friends and fellow students (Engler, Landau, & Epstein, 2008). This area of study definitely merits further investigation, as honor codes are a major part of many schools’ academic and social frameworks. In sum, the self-selecting nature of the sample, composed of students who seek out a trusting academic and social atmosphere (Kaiser, 2005), may have compromised the efficacy and believability of the ostracism manipulation, thus weakening the sensitizing impact of social pain upon physical pain amongst all participants. Future Cyberball studies could avoid such issues by recruiting community samples, and excluding those individuals with prior psychology experience.

**Experimenter Error**

On the other hand, experimenter error could just as well have contributed to methodological problems. Namely, experimenters’ involuntary expressions of sympathy for participants during pain testing may have assuaged or exacerbated participants’ fears of social incompetence or the pain tests themselves, indirectly or directly affecting the results.
Ostracism and Pain Sensitivity 61

(MacDonald, 2008). More practice in administration of the pain tests, or participant self-administration of the tests, could remove this confound. Furthermore, several participants expressed confusion as to how relationships and sports imagery were included in the same experiment. Practice in dissembling may also have helped the experimenters to better convince participants of the cover story of “sports imagery,” and result in a cleaner, more effective manipulation.

Technical Error

Several unforeseen complications in participant management arose during the course of the study—often, as a result of technical error. Sometimes participant photos did not display properly in Cyberball. In several instances, Cyberball shut down before running the game to completion. Other times, Cyberball did not start upon participants’ command, or participants could not figure out how to begin the game. In the latter case, participants would often try to communicate frustration through the wall to their partners (whose games were functioning correctly), providing a clear indication that the games were not, in fact, connected. Any of these technical problems could have decreased Cyberball’s proper functioning to induce feelings of ostracism. In fact, it was in many of these cases that participants expressed the most suspicion of the game’s validity.

Furthermore, some partners talked to or touched each other while switching rooms between pain tests—attempts to reestablish trust or contact that may have changed or mitigated the impact of ostracism on pain sensitivity for both partners. Finally, practice effects and expectations have been shown to diminish the impact of pain administration in an experimental setting (Wiesenberg, 1985; Crombez, Baeyens, & Eelen, 1994). Perhaps prior experience with the pain tests led participants’ tolerances and thresholds to increase, a proposition supported by several participants’ verbal reports—that they knew what to expect and thus consciously attempted to endure the pain for a longer period of time. Despite all of these difficulties,
however, several significant and interesting positive findings emerged from the data that do merit further speculation.

**Romantic Couples and Cold Pain Unpleasantness**

Hypothesis 2 predicted that romantic couples, followed by friends, and then strangers, would show the greatest increase in pain sensitivity following Cyberball ostracism by their partners. Partially supporting this hypothesis, romantic couples showed significantly larger increases in post-Cyberball cold pain unpleasantness reports compared to friends. That cold unpleasantness was the only pain test for which a significant effect was found in this case is consistent with Eisenberger et al.'s (2006) obtaining significant relationships between pain sensitivity and social distress using heat unpleasantness ratings as a metric. Working under the social pain hypothesis, these results seem to suggest that although romantic relationships can satisfy and fulfill more social needs than other types of interpersonal connection, threats to that relationship may be more hurtful because of the greater potential for loss involved. To address this hypothesis more fully would require a more extensive study with a larger sample of romantic couples, a more convincing ostracism manipulation (perhaps face-to-face, with one partner acting as a confederate), and exploratory questionnaires regarding the impact of the manipulation upon feelings of relationship connectedness and distress.

Alternatively, romantic couples may have simply felt less stress-induced analgesia than friends, due to the closeness, trust, and importance of the romantic connection relative to a friendly relationship. Assuming the ostracism was believed, romantic partners could have been more certain in anticipating a scene of productive reconciliation and discussion, buffering them from any extremely stressful effects of the manipulation—and leading to the fairly negligible change in pain sensitivity between baseline and experimental sessions. Perhaps ostracism by friend is was so much more extreme, due to rumination and uncertainty of the friend’s true feelings, that it surpassed social pain in severity and in fact stimulated stress-induced analgesia, resulting in decreases in pain sensitivity—akin to threats to long-term social satisfaction (de
Ostracism and Pain Sensitivity (Wall and Baumeister, 2006). The Relationship Closeness Inventory (RCI; Berscheid, Snyder, & Omoto, 1989) could assess differences between relationship partners along the closeness/trust spectra, which combined with the aforementioned more stringent face-to-face manipulation could test the alternative hypothesis that ostracism by a romantic partner may be less distressing than ostracism by a friend. Consistent with this interpretation, strangers (with no prior relationship to their sources of ostracism, and therefore very little prospect of potentially hurtful future confrontation), were not significantly different from romantic partners in pain sensitivity change in response to rejection.

Finally, verbal reports from several "friend" participants indicated that they felt compelled to endure more pain the second day in sympathy because they knew their friends were undergoing the same pain testing procedure. Compared with romantic couples, more friends and strangers were suspicious of the manipulation. Suspicion of the validity of the experiment and unforeseen design complications such as these may have influenced the results in other ways, as discussed above.

*Personality and Relationship Measure Correlations with Physical Pain Perception*

*Trait Rejection Sensitivity and Physical Pain*

The results that overall pain sensitivity correlated positively with higher rejection sensitivity and attachment anxiety were unexpected, but nevertheless supported by a robust literature on physical and social pain overlap (Eisenberger et al., 2006; Loving et al., 2008). Several studies and meta-analytic reviews have found trait attachment anxiety to be associated with lower acute and chronic pain tolerances and thresholds, in normal pain-free subjects and clinical samples (Meredith, Strong, & Feeney, 2006; Porter, Davis, and Keefe, 2007). More recently, Besser and Priel's (2009) studies suggest that attachment anxiety can lead to distress, violence, excessive thoughts of rejection, covert narcissism, and negative emotionality through the medium of unstable self-esteem.
Furthermore, negative affect has been found to be associated with greater attentional focus on internal sensations, such as pain, to the detriment of other attention-demanding tasks (Stegen, Van Diest, Van de Woestijne, & Van den Bergh, 2001). Higher scores on rejection sensitivity measures positively correlate with dACC response to disapproving faces, suggesting that high rejection sensitivity is associated with greater neural pain matrix sensitivity to potentially disapproving environmental cues (Burklund, Eisenberger, & Lieberman, 2007). In addition, rejection-sensitive and anxiously-attached pain sufferers report more intense and frequent pain than their (figuratively speaking) thicker-skinned counterparts, as discussed in the introduction of this report (MacDonald and Kingsbury, 2006). Future studies could examine the moderating effects of experimentally-manipulated and trait self-esteem on social and physical pain overlap.

Cognitive Overlap Decreases Physical Pain Reports

The positive side of the physical-social pain overlap coin is illustrated by the unexpected finding that a greater degree of cognitive self-other overlap with a relationship partner provides more resilience to physical insult in general. Studies of the effect of positive affect on both pain and inclusion of other in self (IOS) may provide some insight into the mechanism behind this result. Broadened feelings of self-other overlap were found to correlate with positive emotionality, and high positive/negative emotion ratios predicted increases in feelings of self-other overlap over time (Waugh & Fredrickson, 2006). IOS scores predict marital satisfaction, and happiness in general can precede, and engender behaviors conducive to, interpersonal success (Aron, Aron, & Smollan, 1992; Lyubomirsky, King, & Diener, 2005). According to the literature, then, perceptions and reports of IOS and closeness to others are highly associated with positive emotionality. Positive affect, in turn, has been found to predict lower levels of pain in chronic patients (Zautra, Johnson, & Davis, 2005). Socioemotional positivity, then, may provide a buffer against physical pain sensitivity.
To confirm this speculative assessment of global positive affect as a moderator of the relationship between IOS scores and pain, regression path analyses could be conducted with trait positive/negative affect scores. This analysis would assess whether eliminating trait affect as a variable eliminates the IOS-pain relationship. To test causality in this phenomenon, pain sensitivity could be assessed before and after experimental priming of self-other overlap and/or positive affect. In sum, the results obtained in the present experiment augment the literature in support of shared etiology and influences on global measures of physical and social pain sensitivity.

Exploratory Analyses: Sex Differences

Another seeming anomaly in the data deserves attention. Why would stranger females’ pain tolerance decrease while stranger males’ tolerance increase following ostracism? According to Williams (2007a) and Baumeister and Leary (1995), belongingness is a universal need and so should be equally important to both sexes, and its absence should be equally painful. A recent study by Bozin and Yoder (2008) may help to elucidate the disparity in males’ and females’ pain tolerance responses to social rejection. Males have been shown to “socially loaf” on a group task following rejection, purportedly in revenge for society’s breach of faith—while females actually work harder in the same situation. The authors suggest that since society proscribes “social harmoniousness” as more important for females, stereotype threat increased the distress caused to females by strangers’ inexplicable rejection, and motivated them to work hard on a task to restore self-esteem, respect, and status. However, preemptively restoring females’ status, by framing the task as one at which women are best, reversed the pattern, such that females were free to loaf and males worked harder after ostracism (Bozin and Yoder, 2008). A similar phenomenon may have been at work with the strangers in our study. Females, struck by societal stereotype threats, could be more hurt by the social rejection than males, which manifested in relatively lower cold pain tolerance. Verbal or questionnaire measures of distress levels following ostracism, in future studies, could support or reject such a hypothesis.
On the other hand, romantic couples showed the opposite pattern of gender differences in cold pain tolerance, a trend that very nearly approached significance. Males tolerated less cold pain following Cyberball ostracism, while females' pain tolerance increased. The dynamics of jealousy within close relationships may help to explain this pattern. Jealousy is an intrinsic part of any situation where an object of value could potentially be lost. Thus, threats to the stability of a romantic relationship could induce feelings of jealousy. Women are more likely to display emotional expressions of jealousy, while men are more likely to suppress jealousy-related feelings of anger and aggression (Guerrero, Eloy, Jorgensen, & Andersen, 1993). Preliminary evidence suggests that inhibition of anger (anger-in) and suppression of verbal/physical expression of aggression can increase pain sensitivity (Burns, Quartana, & Bruehl, 2008). Research in the field of anger inhibition and pain is nascent, but perhaps the present study provides some support for sex differences in this phenomenon. Males in this study, many of who attempted to express feelings of anger by physically reaching out to, or talking to their partners between pain tests, may have been more susceptible than females to anger-in effects upon pain tolerance.

Two explanations may account for the observed trending increase in female romantic partners’ pain tolerance following ostracism. Perhaps females in relationships, compared to males, were more likely to sense that the manipulation was false. Females, on average, are better at interpretation of verbal and nonverbal social cues, and so may have been less likely to believe the validity of the manipulation given its somewhat implausible nature (Guerrero et al., 1993). This outcome would result in an ineffective manipulation and no social pain effects upon physical pain, and an increase in pain tolerance due to practice effects, as was observed in this and many of the other conditions. In anecdotal support of this interpretation, more females than males in relationships verbally reported disbelief in the validity of the Cyberball game. A more rigorous exclusion manipulation, perhaps employing male romantic partners as confederates to
personally ostracize their female companions in a face-to-face ball tossing game, could ensure the induction of social pain effects in female romantic partners.

Alternatively, the manipulation may have been effective at inducing feelings of social pain in females, and the severity of this emotional pain was so intense as to promote stress-induced analgesic effects—leading to the observed greater cold pain tolerance. More extensive self-report questionnaire measures of emotional pain following an ostracism manipulation could assess whether male and female romantic partners differ in the degree of affective pain and stress resulting from social exclusion by a partner.

Conclusions

In conclusion, the present data paints a much more complex picture of the interaction between social and physical pain than did previous studies. Not only do the magnitude and direction of physical pain responses to ostracism differ depending on the relational source of the ostracism, certain physical pain modalities seem more susceptible to social pain influence than others. These results reinforce the importance of representative samples and airtight methodology in social psychology investigation, but also provide substantial motivation for future researchers to consider many possible influences on the social pain effect, including behavioral control, safety signals, self-regulation, stress-induced analgesia, stereotype threat, and relationship closeness. Finally, the finding that greater inclusion of others in one's cognitive representation of self is associated with greater resilience to physical pain reinforces the importance of social relationships in well-being, and provides an interesting addition to the growing field of "positive psychology."
References


Pain terms: a list with definitions and notes on usage. Recommended by the IASP subcommittee on taxonomy. (1979) *Pain, 6*, 250.


Footnotes

1In the event that a confederate did not show up for an assigned session, the experimenter told the real participants that “the other pair was sick and unable to come in to the lab, but would be playing the game from their rooms over the internet, and would come in later for pain testing.” We do not believe this alteration affected the continuity or integrity of the experiment, because in post-experimental questioning, participants indicated that they were completely unaware that the confederates were not really participating.

2Although care was taken to exclude those prospective participants who may have been familiar with Cyberball, some participants were psychology majors and many had taken psychology classes—due to the eclectic academic interests of the college’s students. Experience with other facets of psychology and the nature of psychology experiments in general may have increased levels of suspicion amongst these participants and thus decreased the believability and effectiveness of the manipulation.
Appendix A

Screening Questionnaire

Web Questionnaire
Haverford College

The purpose of this questionnaire is to help determine if you are eligible to participate in a psychology study that will be conducted during the Spring semester. The study is supervised by Prof. Wendy Sternberg, working with Annelise Dickinson '09, Trina Banerji, BMC '09, and Gili Freedman '09 in the Haverford Psychology Department.

If you complete the questionnaire below, which should take only about 5 minutes, we’ll enter your name into a lottery drawing for a $20 cash prize. As long as you complete this questionnaire, your name will be entered into the lottery, even if your responses on this questionnaire make you ineligible for participating in the full study later on.

If you completed a similar questionnaire in the past, you might be wondering if it is still OK to complete this one. The answer is "yes"! Everyone is welcome to complete this questionnaire, and anyone who does so will be entered into the lottery for the $20 prize.

If your responses indicate that you are eligible for the full study, we will contact you within a couple of weeks to tell you more about what the full study involves, and to see if you might be interested in participating. The full study pays up to $20 to each person who participates. If you complete this questionnaire, it does not mean that you are committing yourself to completing the full study; you can make that decision later if it turns out that you’ve met the eligibility requirements. The ultimate purpose of the full study is to better understand how different types of visual images affect pain sensitivity (this is why your eligibility depends on certain kinds of health conditions).

We would appreciate it if you would answer the questions below as honestly as possible, but you may leave questions blank if you are uncomfortable answering them. If you choose to leave a question blank, it will not affect your entry into the lottery for the cash prizes.

Your responses will be kept confidential at all times and will not be shared with any outside parties. If you have any questions about the study, please contact Prof. Sternberg at 610-896-1237 or wsternbe@haverford.edu. If you have questions or concerns about your rights as a research participant, you may also contact Prof. Rob Scarrow (610-896-1218, rscarrow@haverford.edu). Prof. Scarrow is chair of the Haverford College IRB, which oversees the protection of research participants.

Please check this box to indicate that you have read the above instructions and that you voluntarily consent to have your responses below included in the dataset for this study.

Thank you for filling out our questionnaire!
1. Your gender:

☐ male
☐ female

2. Will you be on campus during the spring semester?

☐ yes
☐ no

3. Are you taking/planning to take Intro Psych in the Spring '09 semester?

☐ yes
☐ no

4. Have you taken (or are you planning to take in Spring '09) Social Psych?

☐ yes
☐ no

5. For this study, we are also interested in the responses of subjects that are currently in different kinds of relationships. If you wish, you can choose to participate alone or with another student (both members of the relationship would need to consent to participate). Please indicate which of the following would be your first choice for participating in the study:

☐ Participate alone

☐ Participate with my romantic partner

First and last name of romantic partner: 

☐ Participate with a friend of the same gender

First and last name of friend: 

☐ Participate with a teammate
First and last name of teammate

Note that if you identified a partner with whom you would like to participate, we will contact them to ask them if they'd like to be a part of the study. If one member of the relationship is not eligible, the other can still participate as a single individual.

6. Please indicate whether any of the following statements apply to you. We have grouped these statements together to protect your privacy. If you check “yes” at the bottom of the list, no one will be able to tell which statement you are responding to.

- I have Raynaud's disease
- I have chronic pain conditions
- I have heart disease, chest pain, high blood pressure, arthritis, or seizures.
- I smoke cigarettes.

☐ Yes, at least one of the above statements describes me.
☐ No, none of the above statements describes me.
☐ I am not sure whether any of the statements above describes me.

In the box below, you may explain your answer to the above question if you wish, but it is not necessary to do so.

In order for your name to be entered into the lottery for the cash prizes, you must enter your name and e-mail address in the boxes below. We will also use this information to contact you if your responses indicate that you are eligible for our study next semester.

Name
E-mail

PLEASE NOTE: Your responses will not be submitted to our database until you click on the “SUBMIT” button below. By clicking on the SUBMIT button, you are granting your consent for your responses to be included in our database.
Appendix B

Tables

Table B1

*Hypothesis 1: Comparing Pain Sensitivity Changes of Control Inclusion and Collapsed Experimental Groups*

<table>
<thead>
<tr>
<th>Pain Test</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Threshold(^a)</td>
<td>.46</td>
<td>$ns$</td>
</tr>
<tr>
<td>Cold Tolerance(^b)</td>
<td>7.29</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Cold Intensity(^a)</td>
<td>.004</td>
<td>$ns$</td>
</tr>
<tr>
<td>Cold Unpleasantness(^a)</td>
<td>.05</td>
<td>$ns$</td>
</tr>
</tbody>
</table>

Note. \(^a\) df = (1,70), \(^b\) df = (1,69).
Table B2

*Hypothesis 1: Mean Cold Times (in seconds) on Baseline and Experimental Days for Control and Experimental Pairs*

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SE</td>
</tr>
<tr>
<td>Control⁠⁻⁻</td>
<td>160.94†</td>
<td>17.74</td>
</tr>
<tr>
<td>Experimental</td>
<td>124.02‡</td>
<td>7.60</td>
</tr>
</tbody>
</table>

Note. ¹n = 11, ²n = 60. †Difference is significant at p = .10. ‡Difference is significant at p < .05.
### Hypothesis 2: Comparing Pain Sensitivity Changes of Romantic, Friend, and Stranger Pairs

<table>
<thead>
<tr>
<th>Pain Test</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Threshold$^a$</td>
<td>2.37</td>
<td>ns</td>
</tr>
<tr>
<td>Cold Tolerance$^b$</td>
<td>0.09</td>
<td>ns</td>
</tr>
<tr>
<td>Cold Intensity$^a$</td>
<td>2.86</td>
<td>0.10</td>
</tr>
<tr>
<td>Cold Unpleasantness$^a$</td>
<td>4.44</td>
<td>&lt; 0.05</td>
</tr>
</tbody>
</table>

Note. $^a$ df = (1, 59), $^b$ df = (1, 58)
Table B4

*Mean Cold Unpleasantness Sums on Baseline and Experimental Days for Romantic, Friend, and Stranger Pairs*

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>Experimental</th>
<th>E-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romantic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>165.05</td>
<td>168.35</td>
<td>3.30§</td>
</tr>
<tr>
<td>SE</td>
<td>13.18</td>
<td>13.49</td>
<td></td>
</tr>
<tr>
<td>Friend</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>160.43</td>
<td>138.86</td>
<td>-21.57†</td>
</tr>
<tr>
<td>SE</td>
<td>12.86</td>
<td>13.17</td>
<td></td>
</tr>
<tr>
<td>Stranger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>176.03</td>
<td>161.75</td>
<td>-14.38</td>
</tr>
<tr>
<td>SE</td>
<td>13.18</td>
<td>13.49</td>
<td></td>
</tr>
</tbody>
</table>

Note. *n = 20, ‡n = 21, §n = 20. †Mean difference significant at *p*< .05.
Table B5

*Hypotheses 3 & 4: Nonsignificant F-Values for Interaction Effects of Personality and Relationship Variables and Pain Sensitivity Changes After Cyberball Ostracism*

<table>
<thead>
<tr>
<th>Pain Test</th>
<th>RSQ</th>
<th>ECR-Sanx</th>
<th>IOS_O</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Threshold</td>
<td>1.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.69&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.45&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cold Tolerance</td>
<td>1.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.66&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.23&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.88&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cold Intensity</td>
<td>.734&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.094&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.36&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cold Unpleasantness</td>
<td>.004&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.18&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.006&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.25&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note. <sup>a</sup> df = (1,57), <sup>b</sup> df = (1,56), <sup>c</sup> df = (1,55), <sup>d</sup> df = (1,38), <sup>e</sup> df = (1,37)
Table B6

*Main Effects of RSQ and ECR-S\(_{anx}\) on Pain Sensitivity*

<table>
<thead>
<tr>
<th>Pain Test</th>
<th>RSQ</th>
<th>ECR-S(_{anx})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(F)</td>
<td>(r)</td>
</tr>
<tr>
<td>Heat Threshold</td>
<td>16.25(^a,***)</td>
<td>-.43</td>
</tr>
<tr>
<td>Cold Tolerance</td>
<td>(ns)</td>
<td>--</td>
</tr>
<tr>
<td>Cold Intensity</td>
<td>4.60(^a,**)</td>
<td>.23</td>
</tr>
<tr>
<td>Cold Unpleasantness</td>
<td>6.92(^b,**)</td>
<td>.30</td>
</tr>
</tbody>
</table>

Note. *\(p<.10\), **\(p<.05\), ***\(p<.001\). \(^a\) df = (1, 57), \(^b\) df = (1, 56), \(^c\) df = (1, 55)
Table B7

*Main Effects of IOS_O and CI Scores on Pain Sensitivity*

<table>
<thead>
<tr>
<th>Pain Test</th>
<th>IOS_O</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$</td>
<td>$r$</td>
</tr>
<tr>
<td>Heat Threshold</td>
<td>3.22</td>
<td>.11</td>
</tr>
<tr>
<td>Cold Tolerance</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Cold Intensity</td>
<td>5.31</td>
<td>-.14</td>
</tr>
<tr>
<td>Cold Unpleasantness</td>
<td>3.40</td>
<td>-.15</td>
</tr>
</tbody>
</table>

Note. *$p < .10$, **$p < .05$. $^a$ df = (1,38).
Table B8

*F-values, Means, and Standard Deviations of Overall Sex Differences in Pain Test Scores*

<table>
<thead>
<tr>
<th>Pain Test</th>
<th>F(1,69)</th>
<th>Females&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Males&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M(SD)</td>
<td>M(SD)</td>
</tr>
<tr>
<td>Heat Threshold Averages&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11.52</td>
<td>43.47(3.06)</td>
<td>45.76(2.58)</td>
</tr>
<tr>
<td>Cold Pressor Tolerance Average&lt;sup&gt;d&lt;/sup&gt;</td>
<td>18.32</td>
<td>106.11(63.90)</td>
<td>159.54(36.35)</td>
</tr>
<tr>
<td>Cold Intensity Sums Average</td>
<td>19.64</td>
<td>192.61(45.58)</td>
<td>143.24(47.51)</td>
</tr>
<tr>
<td>Cold Unpleasantness Sums Average</td>
<td>15.61</td>
<td>185.07(50.23)</td>
<td>136.59(53.15)</td>
</tr>
</tbody>
</table>

Note. <sup>a</sup>n = 37, <sup>b</sup>n = 34. <sup>c</sup>in °C. <sup>d</sup>in seconds. All p < .001.
Table B9

Means and Standard Errors for Cold Pain Tolerance Times (in seconds) at Each Session, by Experimental Group and Sex

<table>
<thead>
<tr>
<th>Session</th>
<th>Group</th>
<th>Baseline</th>
<th>Experimental</th>
<th>E-B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Romantic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Males&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>155.78</td>
<td>144.72</td>
<td>-11.06</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>16.93</td>
<td>16.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Females&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>80.25</td>
<td>94.04</td>
<td>13.79</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>16.93</td>
<td>16.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Friends</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Males&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>159.60</td>
<td>180.00</td>
<td>20.4&lt;sup&gt;‡&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>17.85</td>
<td>17.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Females&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>125.20</td>
<td>137.77</td>
<td>12.57&lt;sup&gt;‡&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>15.46</td>
<td>15.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strangers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Males&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>M</td>
<td>151.84</td>
<td>174.22</td>
<td>22.38</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>17.85</td>
<td>17.44</td>
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</tr>
<tr>
<td></td>
<td>Females&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>77.56</td>
<td>70.66</td>
<td>-6.9</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>16.93</td>
<td>16.55</td>
<td></td>
</tr>
</tbody>
</table>

Note. <sup>a</sup>n = 10, <sup>b</sup>n = 9, <sup>c</sup>n = 12. <sup>‡</sup>Mean difference significant at p< .05
Appendix C

Figure Captions

Figure C1. Experimental and Control Cold Pressor Tolerance Times (in seconds) at Baseline and Experimental Sessions

Figure C2. Experimental Groups: Cold Unpleasantness Ratings at Baseline and Experimental Sessions

Figure C3a. Experimental Groups: Female Cold Pressor Tolerance Times at Baseline and Experimental Sessions

Figure C3b. Experimental Groups: Male Cold Pressor Tolerance Times at Baseline and Experimental Sessions

Figure C4. Stranger Male and Female Cold Pressor Tolerance Times at Baseline and Experimental Sessions
Figure C4

The graph shows the time (in seconds) for both males and females across two days: Baseline and Experimental. The data indicates a trend where the time for males increases from the Baseline to the Experimental day, while the time for females remains relatively stable between the two days.

- Males: Increasing time from Baseline to Experimental day.
- Females: Stable time across Baseline and Experimental day.