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An experimental study of shared sensitivity to physical pain and social rejection

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Abstract

Recent evidence points to a possible overlap in the neural systems underlying the distressing experience that accompanies physical pain and social rejection (Eisenberger et al., 2003). The present study tested two hypotheses that stem from this suggested overlap, namely: (1) that baseline sensitivity to physical pain will predict sensitivity to social rejection and (2) that experiences that heighten social distress will heighten sensitivity to physical pain as well. In the current study, participants' baseline cutaneous heat pain unpleasantness thresholds were assessed prior to the completion of a task that manipulated feelings of social distress. During this task, participants played a virtual ball-tossing game, allegedly with two other individuals, in which they were either continuously included (social inclusion condition) or they were left out of the game by either never being included or by being overtly excluded (social rejection conditions). At the end of the game, three pain stimuli were delivered and participants rated the unpleasantness of each. Results indicated that greater baseline sensitivity to pain (lower pain unpleasantness thresholds) was associated with greater self-reported social distress in response to the social rejection conditions. Additionally, for those in the social rejection conditions, greater reports of social distress were associated with greater reports of pain unpleasantness to the thermal stimuli delivered at the end of the game. These results provide additional support for the hypothesis that pain distress and social distress share neurocognitive substrates. Implications for clinical populations are discussed.

Keywords: Pain sensitivity; Social exclusion; Social pain; Dorsal anterior cingulate cortex; Social rejection; Pain threshold; Pain unpleasantness

1. Introduction

Research has begun to reveal similarities in the neurocognitive processes underlying physical pain and 'social distress,' the painful feelings following social rejection or exclusion (Eisenberger and Lieberman, 2004; MacDonald and Leary, 2005). English and non-English speakers alike use physical pain words to describe experiences of social distress when complaining of "*broken* hearts" or "*hurt* feelings," implicitly indicating the phenomenological similarity between physical pain and social distress, linguistically (MacDonald and Leary, 2005). In addition, recent neuroimaging work has revealed that the dorsal anterior cingulate cortex (dACC), commonly associated with the "unpleasantness" of physical pain (Rainville et al., 1997), is also activated during the distressing experience of social rejection, and its activity correlates strongly with self-reported social distress (Eisenberger et al., 2003). Moreover, based on the

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distinction between the affective ('unpleasantness') and sensory ('intensity') components of physical pain (Price, 2000), it can be further specified that social distress activates neural regions involved in the affective component of pain (dACC); it is not clear whether social distress also activates sensory regions of the pain matrix. Thus, evidence suggests that physical pain distress and social distress share similar phenomenological and neurocognitive substrates. However, the extent to which these two processes overlap has yet to be directly assessed.

The present study tested two hypotheses that stem from this suggested overlap (Panksepp, 1998; Eisenberger and Lieberman, 2004, 2005). First, we examined whether baseline sensitivity to physical pain predicted sensitivity to social rejection. We hypothesized that individuals who were more sensitive to physical pain at baseline (e.g., lower somatic "pain unpleasantness thresholds") would also report more social distress in response to a social rejection manipulation, namely not being included or being overtly excluded from a virtual ball-tossing game. Second, we examined whether an experience that heightens social distress would heighten distress from physical pain as well. We hypothesized that individuals in the social rejection conditions would rate thermal pain stimuli, delivered during the ball-tossing game, as more unpleasant than individuals in the social inclusion condition. We also hypothesized that, for individuals in the social rejection conditions, those who reported feeling more socially distressed would report the heat stimuli, delivered during the game, to be more unpleasant.

We also explored whether these relationships varied as a function of the type of rejection episode (i.e., being non-included vs. overtly excluded), as experimental studies have shown that many different types of experiences can make people feel "left out" (Zadro et al., 2004; Leary, 2005). Previous neuroimaging data have shown that whereas overtly excluded participants (those left out of a virtual ball-tossing game when others deliberately stopped throwing the ball to them) showed neural activity in regions associated with distress (dACC) and the regulation of distress (right ventral prefrontal cortex: RVPFC), non-included participants (those who could not participate in a virtual ball-tossing game due to alleged technical difficulties) showed activity only in distress-related neural regions (dACC; Eisenberger et al., 2003). Based on these types of differences, we also examined whether non-inclusion and overt exclusion differentially affected the experience of physical pain.

2. Methods

2.1. Subjects

Seventy-five undergraduates at the University of California, Los Angeles (54 females, average age = 20.7 years, SD = 4.4), received course credit for participating in this study. Written consent in accordance with UCLA's Institutional Review Board's approved procedures was obtained from each participant.

2.2. Procedures

All participants were run individually. Participants were told that the experimenters were interested in the impact that mild physical discomfort has on people's daily lives. To assess this, participants were told that the experimenters would first take a baseline measure of their sensitivity to an uncomfortable stimulus. Participants were shown the heat delivery device and the experimenter demonstrated what a sample stimulus might feel like on the participant's volar forearm. Participants were also familiarized with the pain unpleasantness rating scale that they would be using to make their judgments of the painfulness of the stimuli. The rating scale was a 21-box numerical descriptor scale anchored with previously quantified verbal descriptors of pain unpleasantness (Gracely et al., 1978). This scale has shown good psychometric properties and sensitivity in previous experimental pain studies (Petzke et al., 2005).

Participants were told that after their baseline pain sensitivity was assessed, they would complete a virtual ball-tossing game conducted over the Internet with two other individuals in different laboratories (Cyberball; Williams et al., 2000). It was explained that during the last 30 s of the game, they would be exposed to three mildly uncomfortable stimuli, and that after they felt each one, they should rate how unpleasant each felt using the pain rating scale.

2.2.1. Baseline pain unpleasantness threshold

To assess baseline pain unpleasantness thresholds to heat stimuli, the experimenter sat to the left of the participant and lowered a curtain that separated the experimenter from the participant. It was explained that the curtain was there so that participants could have some privacy and so that participants' pain ratings would not be influenced by what the experimenter was doing with the heat delivery device. The participant placed his/her left arm on a table so that it was on the same side of the curtain as the experimenter and so that the volar forearm was facing up. The experimenter then told the participant that a heat stimulus was going to be delivered, and after announcing this, placed a heat-delivery probe onto one of six locations (in a rectangular grid: 1 in. × 3 in.) on the participant's left volar forearm.

The heat delivery device was a controlled temperature contact heat device (Yale University Bioengineering Department), which consisted of a small handheld probe with a 1 cm^2 plastic thermode, using Peltier elements with thermistors, and a self-contained computer controlled power supply. The probe was heated using the Peltier principle (converting voltage into heat) and safeguarded against physical injury by having a maximum temperature of 51 °C. The heat delivery device was inspected by the UCLA Clinical Engineering Department and deemed to be both accurate in its temperature settings and safe for use on human participants. Stimuli consisted of 3 s phasic heat pulses starting from a baseline temperature of 32 °C.

Pain unpleasantness thresholds were individually calibrated for each participant using a double random staircase algorithm (DRS; Gracely et al., 1988). The DRS procedure allows for efficient determination of the temperature required to reliably elicit a specific rating (threshold) while minimizing bias from non-sensory cues (Gracely et al., 1988). Pain unpleasantness threshold was defined as a rating of 10 (very unpleasant) on the 21 point box scale, which ranges from 0 = neutral to 20 = unbearable. Briefly, the DRS procedure chooses each stimulus temperature based on a subject's previous responses; if the previous response is above the chosen threshold (in this case, above a rating of 10) the next stimulus for that staircase is lowered and if the rating is below the threshold the next stimulus is increased (Gracely et al., 1988). Stimuli from two staircases were presented pseudorandomly in order to mask from subjects the rating-stimulus intensity relationship within a staircase. Starting stimulus temperatures for the two staircases were 39 °C (102.2 °F) and 41 °C (105.8 °F). Stimulus temperatures on subsequent trials within a staircase were increased or decreased by increments between 1.6 °C and 0.2 °C, with smaller changes when the staircase crossed the threshold or reversed direction. Stimuli were delivered until the staircases converged on a temperature that evoked a 10 rating (for detailed protocol, see Gracely et al., 1988).

2.2.2. Cyberball task

After pain unpleasantness thresholds were identified, participants played a virtual ball-tossing game called Cyberball (Williams et al., 2000). Participants were randomly assigned to one of three conditions: (1) a social inclusion condition, or one of two social rejection conditions, namely (2) non-inclusion, or (3) overt exclusion. Participants were told that they were going to be playing a virtual ball-tossing game with two other individuals in different laboratories and that they would be connected to these individuals over the Internet. In reality, there were no other individuals; participants played with a preset computer program that displayed cartoon images of the participant and the other players on a computer screen (see Fig. 1). Participants were told that once the game started, they could toss the ball to either of the two other players each time they received the ball by pressing one of two keys to throw to the person on the left or the person on the right. Whenever another player threw the ball to the participant, the participant automatically caught the ball without any response on his/her part.

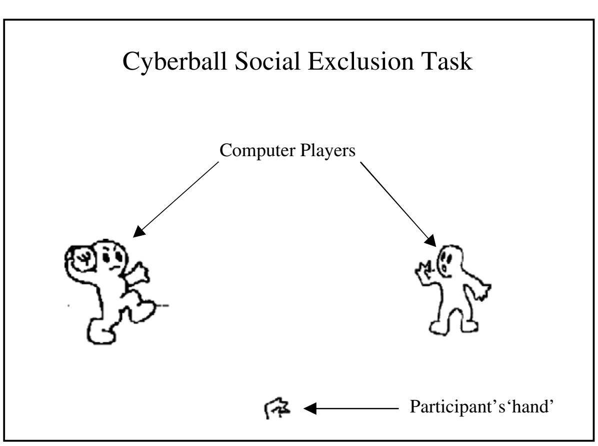

Fig. 1. Cyberball stimuli.

Each game began with a still picture of the two virtual players in the upper corners of the screen and a hand, representing the participant, in the lower-center portion of the screen. The participant's name was displayed below the hand while two other names were displayed below each of the two virtual players' animated cartoon representations. After 9 s, the cartoon player in the upper left-hand corner started the game by throwing the ball to either the other cartoon player or the participant. The participant could return the ball to one of the players by pressing one of two keys. The Cyberball program was set for 60 throws per game, with the computer players waiting 0.5–3.0 s before making a throw to heighten the sense that the participant was actually playing with other individuals.

Individuals in the inclusion condition played the interactive ball-tossing game for the entire time, which lasted approximately 2:30 min. Individuals in the non-inclusion condition were told that, due to some technical difficulties in connecting to the two other players, they could watch the other two players play, but would not actually be able to play with them. Individuals in the overt exclusion condition were included in the game for the first fifty seconds (approximately) of the game and then excluded for the duration of the game (approximately 100 s), when the two virtual players stopped throwing them the ball.

2.2.3. Final pain stimuli

During the last thirty seconds of the game, participants received three heat stimuli to their left forearm and rated the unpleasantness of each. The heat stimuli were set to the threshold temperature (at which the participant reported the pain to be very unpleasant: 10 on the Gracely scale) as well as a temperature 0.4 °C above and 0.4 °C below that target temperature. The order of the delivery of these stimuli was counterbalanced across participants. For each participant, pain unpleasantness ratings to each of the three heat stimuli were averaged to provide a measure of perceived pain unpleasantness during the Cyberball task.

2.2.4. Post-task questionnaires

Immediately after the game, participants completed a measure of self-reported social distress (Williams et al., 2000), which assessed participants' feelings of self-esteem (e.g., "I felt liked."), belongingness (e.g., "I felt rejected."), meaningfulness (e.g., "I felt invisible."), and control (e.g., "I felt powerful."). Each item asked participants to indicate the extent to which they felt these feelings during the task on a 5-point scale, with '1' indicating "not at all," '3' indicating "moderately," and '5' indicating "very much so." In line with the original cover story, they also answered questions regarding the extent to which they were distracted by the uncomfortable stimuli during the ball-tossing game. Participants also completed a measure of neuroticism (Eysenck Personality Questionnaire: EPQ; Eysenck and Eysenck, 1975), which served as a control measure to ensure that any relationships between pain and social distress assessments were not a result of their common correlation with generalized stress sensitivity or anxiety (Tang and Gibson, 2005). Following the completion of these questionnaires, participants were thoroughly debriefed and all questions were answered.

3. Results

3.1. Manipulation check

Four participants who reported that they did not believe they were playing Cyberball with two other participants were excluded from further analyses (three of these individuals were in the non-inclusion condition, one was in the overt exclusion condition). An additional participant was excluded based on outlier data; specifically, this participant had pain distress ratings that were greater than 2.5 standard deviations above the mean for the social rejection conditions.

A one-way ANOVA confirmed that the different conditions of the Cyberball game led to different levels of self-reported social distress ($F(2,69) = 10.57$, $p < .001$). Post hoc analyses revealed that individuals reported greater levels of social distress in response to each of the social rejection conditions (non-inclusion: $M = 3.25$, $SD = .89$; overt exclusion: $M = 3.27$, $SD = .75$) than in response to the inclusion condition ($M = 2.49$, $SD = .45$; non-inclusion vs. inclusion: $t(44) = 3.72$, $p < .005$; overt exclusion vs. inclusion: $t(46) = 5.05$, $p < .001$). There were no differences in social distress ratings between the two social rejection conditions ($t(44) = -.06$, ns). Thus, individuals who were either not included or who were overtly excluded were significantly more socially distressed by the Cyberball game than individuals who were included.

3.2. Does baseline sensitivity to physical pain predict sensitivity to social rejection?

To assess whether baseline physical pain sensitivity predicted sensitivity to social rejection, we computed correlations between baseline pain unpleasantness thresholds and social distress ratings assessed after playing Cyberball. Because both of the social rejection conditions (non-inclusion and overt exclusion) resulted in similar increases in self-reported social distress, we first collapsed across the two social rejection groups in the initial set of analyses and then analyzed them separately in the following set. We hypothesized that individuals with lower pain unpleasantness thresholds at baseline (e.g., greater sensitivity to pain) would report greater social distress in response to social rejection than those with higher pain unpleasantness thresholds at baseline (e.g., lesser sensitivity to pain).

Results indicated that baseline pain unpleasantness thresholds were negatively correlated with social distress ratings in the social rejection conditions ($r(46) = -.35$, $p < .05$; see Fig. 2a), but not in the inclusion condition ($r(24) = .03$, ns; see Fig. 2b). These correlations were marginally significantly different from one another (Fisher $Z = 1.49$ $p = .07$). Moreover, a two-way ANOVA revealed a significant interaction between condition (inclusion vs. rejection) and baseline pain unpleasantness thresholds (high vs. low) in predicting social distress ratings ($F(3,69) = 3.85$, $p = .05$). Thus, individuals who were more sensitive to physical pain at baseline (e.g., lower pain unpleasantness thresholds) were also more sensitive to social rejection, as indicated by greater social distress ratings following non-inclusion and overt exclusion, but not following inclusion. In addition, the relationship between baseline pain unpleasantness thresholds and social distress ratings remained significant after controlling for neuroticism ($r(43) = -.37$, $p < .05$), suggesting that this relationship cannot be explained by a general tendency to experience anxiety and thus report higher levels of both types of negative experiences.

Next, we examined the correlations between baseline pain sensitivity and social distress scores in the non-inclusion and overt exclusion conditions separately. Baseline pain unpleasantness thresholds correlated significantly with social distress scores in the non-inclusion condition ($r(22) = -.42$, $p = .05$), but not in the overt exclusion condition ($r(24) = -.28$, $p = .19$), although the correlation was in the same direction. When controlling for neuroticism, the relationship between baseline pain unpleasantness thresholds and social distress scores in the non-inclusion condition remained significant ($r(19) = -.43$, $p < .05$), again showing that this relationship is not likely due to

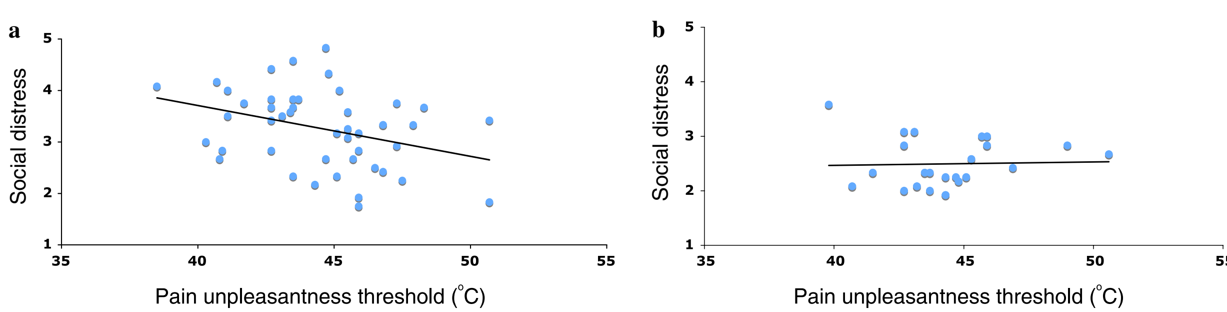

Fig. 2. Scatterplots showing the relationship between baseline pain unpleasantness thresholds and social distress ratings during: (a) the social rejection conditions (non-inclusion and overt exclusion) and (b) the social inclusion condition. Each point represents the data from a single participant.

heightened levels of trait anxiety leading to greater pain reports to both physical pain and social isolation. When controlling for neuroticism in the overt exclusion condition, the magnitude of the relationship between pain unpleasantness thresholds and social distress remained the same and there was a trend towards significance ($r(21) = -.32$, $p = .14$).

3.3. Do experiences that increase social distress potentiate pain distress as well?

To examine whether experiences that increase social distress also potentiate pain distress, we examined whether individuals in the social rejection conditions (non-inclusion and overt exclusion), compared to individuals in the inclusion condition, reported greater pain unpleasantness to the thermal stimuli delivered during the Cyberball game. We also examined whether greater social distress ratings in response to the social rejection manipulations were associated with greater pain unpleasantness ratings to the thermal stimuli delivered during Cyberball. We hypothesized that participants in the social rejection conditions, compared to those in the inclusion condition, would report more pain unpleasantness to the thermal stimuli delivered at the end of the Cyberball game and that, for those in the social rejection conditions, greater social distress scores would be associated with higher pain unpleasantness ratings.

Contrary to our first prediction, there were no significant between-group differences in thermal pain unpleasantness ratings across the inclusion ($M = 7.54$, $SD = 2.32$), non-inclusion ($M = 7.60$, $SD = 2.29$), or overt exclusion ($M = 7.91$, $SD = 2.45$) conditions. However, there was a significant correlation between social distress and pain unpleasantness ratings such that individuals who reported greater social distress in response to the social rejection manipulations reported greater pain unpleasantness to the concurrently delivered thermal stimuli ($r(46) = .30$, $p < .05$; see Fig. 3a). This relationship remained marginally significant after controlling for neuroticism ($r(43) = .27$, $p = .07$). Not surprisingly, there was no relationship between social distress and pain unpleasantness ratings within the inclusion condition ($r(24) = -.01$, ns; see Fig. 3b). Thus, increased reports of social distress, activated through non-inclusion or overt exclusion, were associated with greater pain unpleasantness ratings, a relationship that was not simply due to higher anxiety levels contributing to both higher pain and social distress ratings.

When examining the non-inclusion and overt exclusion conditions separately, greater social distress was significantly associated with greater pain unpleasantness ratings during non-inclusion ($r(22) = .43$, $p < .05$), but not during overt exclusion ($r(24) = .14$, ns). Additionally the relationship between social distress and pain unpleasantness ratings remained significant after controlling for neuroticism within the non-inclusion condition ($r(19) = .43$, $p = .05$).

4. Discussion

The present study investigated two hypotheses derived from the notion that pain distress and social distress rely on some of the same underlying neural substrates. Specifically, we hypothesized: (1) that baseline sensitivity to physical pain should relate to an individual's sensitivity to social rejection and (2) that experiences that heighten social distress should heighten pain distress as well. The findings from this study provided partial support for both of these hypotheses.

Participants who demonstrated greater sensitivity to physical pain at baseline (lower pain unpleasantness thresholds) reported experiencing greater social distress in response to being left out of a ball-tossing game (non-included, overtly excluded), but not in response to being included. These findings support the idea that pain distress and social distress rely on some of the same computational substrates by demonstrating that sensitivity to one type of distressing experience is directly related to sensitivity to the other. Additionally, the relationship between baseline pain sensitivity and self-reported social distress remained after controlling for neuroticism, suggesting that the overlap between these

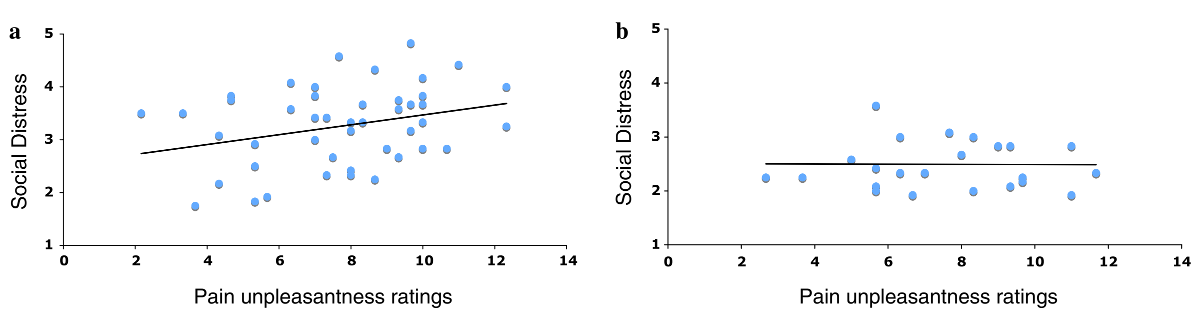

Fig. 3. Scatterplots showing the relationship between physical pain unpleasantness ratings in response to heat stimuli delivered during the Cyberball game and social distress ratings during: (a) the social rejection conditions (non-inclusion and overt exclusion) and (b) the social inclusion condition. Each point represents the data from a single participant.

two types of distressing experience is not simply a function of increased reporting of aversive events associated with neuroticism or anxiety. Instead, this relationship seems to reflect a specific shared process mediating perception of pain distress and social distress.

This study also demonstrated that individuals who reported feeling more socially distressed by being excluded or non-included reported experiencing more physical pain unpleasantness in response to heat stimuli that were delivered at the end of the Cyberball game. Although this relationship is correlational, it points to the possibility that experiences that heighten social distress can make individuals more sensitive to physical pain as well. However, it is also possible that the reverse is occurring, such that enhanced perceptions of physical pain unpleasantness led to greater retrospective reports of social distress. Regardless of the direction, these two processes seem to be moving together and possibly influencing one another. Moreover, the relationship between social distress and pain unpleasantness ratings was not present during the inclusion condition. In addition, the relationship between social distress and pain unpleasantness ratings in the social rejection conditions remained after controlling for neuroticism scores, indicating that the relationship between social distress and pain distress is not likely to be caused by generally increased perception of aversive events due to anxiety.

It should also be noted that, although there were significant correlations between social distress and pain unpleasantness ratings within the social rejection conditions, there were no main effects of the inclusion vs. social rejection conditions on pain unpleasantness ratings. In other words, simply being put into one condition or another was not, in itself, sufficient to affect the underlying pain system in this experiment. One possible reason for this is that not all individuals who were put into the social rejection conditions (non-inclusion and overt exclusion) may have actually felt left out or rejected. For example, on a 1–5 scale of social distress, participants in the social rejection conditions reported scores that ranged from feeling very little social distress (1.75) to feeling a considerable amount of social distress (4.83). It is possible that episodes of social rejection only influence pain sensitivity to the extent that an individual experiences these episodes as upsetting or distressing, and not in the absence of feeling rejection-related distress. Future studies that use a more potent manipulation of social rejection (so that most subjects feel high levels of social distress) will be needed to more thoroughly examine the effect of social rejection on pain experience.

Based on previous work showing neural differences in response to non-inclusion vs. overt exclusion, we also investigated whether social distress in response to these two rejection manipulations related differentially to baseline pain unpleasantness thresholds and to pain perception during the Cyberball game. Within the non-inclusion condition, greater baseline sensitivity to physical pain was associated with greater social distress, and individuals who reported experiencing more social distress in response to non-inclusion also reported more pain unpleasantness during the heat stimuli delivered during the Cyberball game. However, these relationships were not found in the overt exclusion condition.

One possible explanation for the lack of a relationship between pain distress and social distress ratings in the overt exclusion condition is that there was a narrower range of social distress scores in response to the overt exclusion episode than in response to the non-inclusion episode, making a correlation less likely. Another possibility is that, because overt exclusion, but not non-inclusion, activates neural regions involved in regulating negative affect (Eisenberger et al., 2003), it is possible that individuals who were overtly excluded were regulating their responses to the rejection episode, thus reporting somewhat blunted pain and social distress responses. To the extent that pain distress and social distress rely on shared neural circuitry, regulating socially distressing experience may have the unintentional consequence of attenuating physically painful experience as well, by reducing the activity of this 'general pain distress system.' This additional regulation process, which is not typically activated during non-inclusion, may contribute added noise and variance, thus obscuring a possible correlation between pain distress and social distress during overt exclusion. Further studies are needed to clarify what is driving the different outcomes across the non-inclusion and overt exclusion conditions.

The present findings build on previous literature suggesting an overlap in the neural systems underlying pain distress and social distress and thus may have important implications for both acute pain as well chronic pain conditions. With regard to acute pain, a great deal of correlational research has shown that individuals with more social support experience less cancer pain (Zaza and Baine, 2002), are less likely to suffer from chest pain following coronary artery bypass surgery (Kulik and Mahler, 1989; King et al., 1993), report less labor pain, and are less likely to use epidural anasthesia during childbirth (Kennell et al., 1991; Chalmers et al., 1995). One possible reason for these relationships is that the perception or presence of social support, which attenuates feelings of social distress, may have similar effects on reports of physical pain. Indeed, experimental work has shown that the presence of supportive others attenuates pain perception in both animals and humans (Epley, 1974; Brown et al., 2003). Thus, social support may be an important regulator of acute feelings of physical pain.

With regard to chronic pain, individuals who are more rejection sensitive may be at a higher risk for developing certain types of chronic pain conditions. For instance, it has been shown that, compared to healthy controls, adults with chronic pain are more likely to have an anxious attachment style, characterized by a heightened sense of concern with a partner's relationship commitment (Ciechanowski et al., 2003). Although these findings are correlational, it is possible that individuals with greater interpersonal or attachment concerns may be more vulnerable to chronic pain conditions. In addition, it is also possible that social stressors may be a uniquely robust predictor of symptom exacerbation for those with certain types of chronic pain conditions, contributing directly to symptom flare-ups. Indeed, chronic social stress can adversely affect the treatment outcomes of individuals with irritable bowel syndrome, making these individuals almost completely immune to any type of treatment (Lea and Whorwell, 2004).

Finally, an overlap in the neural systems underlying pain distress and social distress also suggests alternative ways to treat and manage chronic pain conditions. For example, rather than treating pain symptoms directly, it may be possible to alleviate physical pain symptoms, in part, by treating the social stressors that may go along with them. Further studies are needed to test these hypotheses and to further explore the ways in which pain distress and social distress processes overlap or diverge.

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