

Mildly negative social encounters reduce physical pain sensitivity

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ABSTRACT

While previous research has demonstrated a reduction in physical pain sensitivity in response to social exclusion, the manipulations employed have arguably been far removed from typical daily experience. The purpose of this study was to investigate the effects of relatively ordinary social encounters on the perception of pain. Healthy participants rated the intensity and unpleasantness of painful stimuli before and after engaging in a structured interaction with a confederate who was instructed to either be warm and friendly or indifferent. A control group was asked to perform a similar structured activity, but alone. Consistent with predictions, participants who experienced the mildly negative social exchange reported lower pain intensity and unpleasantness after the encounter relative to baseline, whereas those exposed to the positive social exchange did not evidence any change in pain ratings. These results were not mediated by changes in mood or perceived connectedness. If mildly negative social encounters can provoke an analgesic effect, it is possible that social hypoalgesia may be considerably more commonplace than previously realized. Discussion focuses on the role of stress-induced hypoalgesia, and the implications of the results for clinical assessments of pain.

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1. Introduction

It is well established that health and survival depend critically on social connections. Voluminous research has shown that social isolation heightens the risk of morbidity and mortality [38], and that perceived social support is linked to a wide range of health outcomes [34,40] including pain [29]. Given the vital role of social connections in protecting physical health and survival, damage to these connections (such as through loss, rejection, etc.) might pose a threat to physical integrity just as would physical injury. If so, the body's reaction to social injury may be similar to its reaction to physical injury, including the modulation of pain mechanisms.

First, MacDonald and Leary [25] found that multiple languages use pain and injury words to describe the feelings of rejection (e.g., "hurt", "broken hearted", "crushed"). Second, Eisenberger et al. [18] found greater activity during social exclusion from an online ball toss game, relative to inclusion, in the dorsal anterior cingulate cortex (dACC) and right ventrolateral prefrontal cortex (RVLPFC), brain regions shown to be involved in pain regulation, among other functions [2,4]. Third, exogenous opioids, well known for reducing physical pain [3], diminish indications of separation distress (social pain) in non-human primates [e.g., 32].

If social injury is processed as a safety threat, social exclusion may trigger freeze-flight-fight (FFF) responses. For example,

socially disconnecting experiences have been shown to elicit reactions known to be indicators of FFF activation such as increased cortisol concentrations [5]. Just as with FFF responses to physical threats, then, one response to exclusion may be the activation of endogenous pain modulation systems. Previous research has specifically demonstrated a reduction in pain in response to social exclusion. Ostensibly on the basis of a personality test performed earlier, some participants in a study by DeWall and Baumeister [14] were randomly assigned to receive false feedback that they would spend their lives alone (i.e., current friends would drift away and marriages would dissolve quickly). In 2 control conditions, participants were either told that they would have stable, rewarding relationships throughout life, or that they would be increasingly accident prone. Relative to participants not receiving the socially injurious feedback, future alone participants reported significantly higher pain thresholds and greater pain tolerance. Although the DeWall and Baumeister study uncovered a reliable hypoalgesic effect of social injury, the manipulation was arguably so severe that the results may not generalize to the kinds of experiences people are likely to encounter in daily life. Does socially induced hypoalgesia require such a strong shock as a future alone, or might hypoalgesia be a feature of more commonplace social interactions?

The current study investigated this question by examining pain responses following random assignment to a mildly negative social encounter (NE), or to one of two comparison conditions: a positive social encounter (PE), or a no-interaction control condition. We hypothesized that participants exposed to the mildly negative

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encounter would experience a significant reduction in post-manipulation pain, a change that would not be evidenced in the other groups.

2. Method

2.1. Participants

Forty-five participants (29 female, age range 18–30 years) were recruited from the first year psychology participant pool at the University of Toronto and from an online classifieds advertisement. Only individuals reporting no medical conditions or medication use associated with altered pain sensitivity were included in the study. Specifically, participants were asked to excuse themselves (without loss of compensation) if any of the following applied: frostbite or other past trauma to the arms or hands, lupus erythematosus, Raynaud's Syndrome, arthritis or other large or small joint disease or injury, or the consumption of alcohol, psychoactive drugs, anti-inflammatory medications, or analgesics within the prior 48 h.

2.2. Setup

In order to minimize demand effects, participants were told that the study was a trial investigating the influence of two topically applied, natural food-derived substances on the perception of experimentally induced pain. They were further informed that after testing the first substance, they would need to rest before being ready to test the second substance. Participants were told that to help distract them from the first pain experience, we had pre-arranged with the university Student Union to test some methods of helping incoming students get to know each other. Thus, under the guise of a separate study, participants took turns answering a list of personal questions with someone who they thought was another participant. This "other participant" was in fact a research confederate (a trained actress with professional acting experience) who had been intensively coached to behave in one of two standardized ways: cool, standoffish and uninterested (NE) or warm, friendly and validating (PE). To create a non-social version of the interaction task, participants in the control condition were asked to think about their answers to the same personal questions in solitude.

2.3. Measures

2.3.1. Pain

A Wagner pressure algometer (Wagner Instruments, Greenwich, CT) was mounted to a stand in order to enable precise control (raising and lowering) of the device and a consistent application of pressure across trials and participants. Pain measurement involving pressure has several advantages, including precise control of stimulus intensity, immediate discontinuation upon participant discomfort or for any other reason, minimal and short-lived after-effects, and minimal anxiety compared to other methods such as electric shock. Pressure algometry has been used in research on social exclusion [14] and has been shown to provide valid and reliable measures of pain sensitivity [10].

Participants placed their hand palm-side down under the algometer so that the dorsal interosseus muscle of the proximal phalange of one finger was directly under the algometer pad. The algometer was lowered gradually at a consistent rate (5 N/s) onto the finger. The rubber pad that is pressed against the skin is soft, does not puncture the skin, and does not leave any lasting effects beyond a ring-shaped impression in the skin that disappears within an hour. Both before and after the experimental manipulation, a pain test was administered. Each pain test consisted first of the application of cream to the middle finger of either the left or right

hand (determined randomly) and then the administration of 3 pressure pain stimulus trials delivered to this same finger. Participants rested for 3 min between trials to allow pain sensitivity to recover. During application of the cream, participants were told that the cream contained a natural substance that would increase, decrease, or have no impact on pain sensitivity. After allowing about 30 s for the cream to "take effect" the pain stimulus trials began. For each pain test trial, pressure was applied with the algometer to the finger at a rate of 5 N/s. to a magnitude previously determined to be "moderately painful" during a calibration procedure (see below for details). Individuals were then immediately asked to judge both pain intensity and unpleasantness of the sensation using an 11-point numeric rating scale from 0 (not at all) to 10 (very much). Pain intensity was specified to participants as "the degree to which the sensation in your finger hurts", and pain unpleasantness was defined as the "the degree to which the sensation in your finger bothers you". Internal consistency across trials was high for both pre-manipulation pain measures, (Cronbach's alpha .91 for pain intensity and .93, for pain unpleasantness) as well as for both post-manipulation pain measures (Cronbach's alpha .90 for pain intensity and .93 for pain unpleasantness).

2.3.2. Affect

The 20-item Positive and Negative Affect Schedule (PANAS; [42]) was administered immediately before the pre-manipulation pain test and immediately before the post-manipulation pain test. The PANAS consists of 10 items describing positive affect (e.g., strong, inspired, enthusiastic) and 10 items describing negative affect (e.g., distressed, hostile, nervous). Participants indicated the degree to which they were experiencing each of the 20 emotions at the current moment on a scale from 1 (very slightly or not at all) to 5 (extremely). Scores for both positive and negative affect were computed by summing the responses to each emotion. Cronbach's alpha for pre-manipulation positive and negative affect was .87 and .78, respectively. Cronbach's alpha for post-manipulation positive and negative affect was .90 and .82, respectively.

2.3.3. Connectedness

To verify that our manipulations had the desired effect, participants completed an 8-item questionnaire assessing several components of connectedness.¹ Example items included, "How close do you feel with your partner", "How similar do you feel with your partner", and "To what degree do you feel your partner understood you?" For each item, participants responded on a scale of 1 (not at all) to 9 (very much). This scale proved to have good internal reliability with a Cronbach's alpha coefficient of .95.

2.4. Procedure

2.4.1. Step 1: Introduction and consent

After a brief wait with another individual who appeared to be a student (the confederate), the experimenter appeared and asked the participant to enter the lab. The participant read an information sheet that explained the nature of study and then provided informed consent.

2.4.2. Step 2: Calibration

Participants were shown the algometer and its function was explained. Pilot testing showed that there was considerable between-individual variation on what level of pressure was considered painful. Thus, we employed a customization procedure to determine the pressure at which each participant reported moderate pain. This procedure helps capture changes in pain sensitivity

¹ The complete questionnaire is available on request.

by reducing the potential for floor or ceiling effects. The calibration phase proceeded as follows: Participants placed the proximal phalange part of the ring finger of one of the hands (randomly selected) under the algometer probe. Participants were told that as the algometer was slowly lowered, they would begin to experience the pressure as painful but that the pressure would continue to increase. Participants were asked to state the point at which they deemed the sensation was “moderately painful”. At this point, the pressure reading on the algometer was recorded and then the pressure immediately released. This procedure was repeated for a total of 3 trials. The average pressure indicated across trials served as the stimulus intensity for the remainder of the study. Upon completion of the trials, participants rested for 3 min.

2.4.3. Step 3: Pre-manipulation pain test: Substance X cream

Participants were first asked to complete the PANAS questionnaire. Then the experimenter pointed to a jar of cream labeled “Substance X”, and indicated that this substance would be the first of the two substances to be tested. The cream was then applied and pain tested in the manner described in the pain measures section.

2.4.4. Step 4: Social manipulation

After completion of the final pre-manipulation pain test trial, participants were told the following: “You’ve now completed testing the first substance, substance X, and we would like to also test substance Y. But before proceeding it is important to rest and to do something that will help you take your mind off the pain stimulus experience in order to allow your pain sensitivity to return to baseline. Therefore, we are asking everyone to participate in another study that is currently underway. It’s short and should keep your mind off the pain stuff. There should be another participant here now. So if you’ll wait here I’ll go and see if the other participant is ready. After you’re both in the room, I’ll give you a document that will explain things in more detail. Ok?”

All participants agreed to this second experiment and engaged in a separate consent process. The experimenter left the room, closed the door, randomly assigned the participant to either the NE or PE condition,² and a few minutes later brought the confederate to the participant at which point the social experience manipulation commenced.

The social exercise was adapted from the Relationship Closeness Induction Task [37] in which two individuals take turns responding to a series of questions that gradually increase in intimacy. All participants received the same questions in the same order. The instructions for the task were as follows: “You and your partner will both receive two identical series of questions. We would like each of you to take turns answering the questions. In the process you will hopefully get to know each other. Please be as natural as possible. It may be helpful to check off each question as you finish it on the provided sheet. When you are done, one of you should come to find the experimenter.”

For participants randomly assigned to the NE condition, the confederate was instructed to act somewhat standoffishly.³ The confederate accomplished this by means of numerous verbal and non-verbal tactics. Verbal tactics included employing brief responses without being rude or abrupt. Non-verbal tactics included making very limited eye contact and using a closed body posture. For participants randomly assigned to the PE condition, the confederate was

instructed to take an interest in participants.⁴ Verbal tactics included relating participants’ responses to something in the confederate’s own life (intended to reinforce that the participants and the confederate’s life share similarities of experience), and using affirmative phrases such as “I totally agree,” “I hear you”, “Absolutely true!” where applicable. Non-verbal tactics included warm smiling, leaning forward when the participant was talking, showing genuine concern, and avoiding folded arms, hands in front of face, or other cues indicating lack of interest. Following the exchange, participants completed the manipulation checks.

2.4.5. Step 5: Post-manipulation measures and debriefing

The PANAS was again administered, and a cream from another jar, labeled “Substance Y” was applied to the middle finger of the hand opposite to the one used for the pre-manipulation pain test. Pain measurement proceeded identically to Step 3. Upon completion of the pain trials, participants received a funnel debriefing that probed for suspicions regarding the cover story and manipulations. Immediately afterwards, participants received a full account of the study, had questions/concerns addressed, and then were thanked and dismissed.

3. Results

Responses to the funnel debriefing questions were reviewed. All but one participant believed the cover story about the study investigating the effects of different natural substances on the perception of pain. To avoid the possibility of biased pain reports, this participant’s data were omitted from analyses described here.⁵

3.1. Manipulation check

To verify that the social manipulation had its desired effect, the average connectedness score reported by participants in the NE group was compared to the average connectedness score reported by those in the PE group. An independent samples *t*-test revealed that the mean connectedness score was significantly lower for the NE group (4.38, range 2.13–7.13, SD 1.40) than the mean connectedness score for the PE group (7.38, range 6.00–8.88, SD .82), $t(28) = -7.31$, $p < .001$, Cohen’s $d = -2.76$. Thus the mildly negative social encounter with the confederate led to significantly lower connectedness ratings than did the positive social encounter, confirming that the social manipulation achieved its aim.⁶

3.2. Effects of manipulations on pain intensity and unpleasantness

To examine the influence of experimental condition on each dependent measure, a 2×3 analysis of variance (ANOVA) including one within-participants variable (time: before and after manipulation) and one between-participants variable (group: NE, PE, control) was conducted on both pain intensity and pain unpleasantness. For pain intensity, no main effect emerged for time, $F(1, 42) = .44$, $p = .51$, $\eta_p^2 = .01$ nor for group, $F(2, 42) = 2.28$,

⁴ We realized that some participants assigned to the PE group may feel disappointed upon learning that the social exchange that they enjoyed was not “real”. For this reason, we specifically chose a confederate who genuinely loves to meet and talk to new people and for whom showing an interest in another and quickly establishing rapport comes naturally and is genuine. In fact it was the case that for the NE condition the confederate had to *restrain* her natural inclination towards warmth and friendliness rather than forcing warmth and friendliness in the PE condition.

⁵ During debriefing four participants indicated some suspicion regarding the social encounter. None of the results differed when analyses were repeated with their data omitted so all analyses reported here include their data.

⁶ No connectedness scores were obtained for the control group since they did not encounter a social experience.

² Random assignment to the two experimental groups was achieved by means of a coin flip. At the conclusion of initial data collection, a control group was run in order to be certain the results could be attributed to the negative social interaction. Control participants were, therefore, run separately at a later time.

³ Verbal and non-verbal methods of communicating both standoffishness and acceptance were guided by suggestions in a book by Nierenberg and Calero [31].

$p = .12$, $\eta_p^2 = .10$. The interaction between time and group was significant, $F(2, 42) = 5.13$, $p = .01$, $\eta_p^2 = .20$ (see Table 1), indicating that the difference in pain intensity ratings between pre- and post-manipulation measures depended on the group to which participants had been assigned.

A simple effects analysis revealed that those in the NE condition showed a significant decrease in pain intensity from pre- to post-manipulation, $t(42) = -2.92$, $p = .006$, Cohen's $d = -.93$. No difference across time was found for those in the PE group, $t(42) = .67$, $p = .51$, $d = .17$, nor for those in the control group, $t(42) = 1.23$, $p = .23$, $d = .29$. Thus, a decrease in pain intensity occurred only for participants randomly assigned to the NE group (see Table 1). To ensure that pain intensity ratings did not differ across groups before the manipulation, a one-way ANOVA on pain intensity scores was conducted. This analysis revealed no significant differences between groups for pre-manipulation pain intensity scores, $F(2, 44) = 1.39$, $p = .26$.

For pain unpleasantness ratings no main effect for time, $F(1, 42) = .07$, $p = .80$, $\eta_p^2 < .01$ nor for group $F(2, 42) = 2.71$, $p = .08$, $\eta_p^2 = .11$ was found. There was however a significant interaction between time and group, $F(2, 42) = 4.77$, $p = .014$, $\eta_p^2 = .19$, indicating that, like pain intensity ratings, the difference in pain unpleasantness ratings between pre- and post-manipulation measures depended on the group to which participants had been assigned.

A simple effects analysis showed that the NE group reported a significant decrease in pain unpleasantness from pre- to post-manipulation, $t(42) = -2.62$, $p = .01$, Cohen's $d = -.95$. No difference across time was found for those in the PE group, $t(42) = 1.06$, $p = .29$, $d = .27$ nor for those in the control group, $t(42) = 1.23$, $p = .22$, $d = .28$ (see Table 1). As with pain intensity scores, a one-way ANOVA on pre-manipulation pain unpleasantness scores was conducted. This analysis revealed no significant difference between groups for pre-manipulation pain unpleasantness scores, $F(2, 44) = 1.20$, $p = .31$.

3.3. Effects of manipulations on positive affect (PA) and negative affect (NA) scores

To examine the effects of the manipulations on positive and negative affect, a 2 (time) \times 3 (group) analysis of variance (ANOVA) was conducted. For PA scores, this analysis revealed no significant main effect for time, $F(1, 39) = 2.40$, $p = .13$, $\eta_p^2 = .06$ and no significant main effect for group, $F(1, 39) = .79$, $p = .46$, $\eta_p^2 = .04$. There was, however, a significant interaction between time and group, $F(2, 39) = 6.32$, $p = .004$, $\eta_p^2 = .25$. Neither the NE, $t(39) = 8.41$,

$p = .41$, nor the PE $t(39) = .17$, $p = .87$, groups exhibited a significant change in positive affect after the social experience (see Table 2). The control group did, however, show a significant drop in PA, $t(39) = 3.87$, $p < .001$.

For NA scores, a significant main effect of time was found, $F(1, 39) = 7.00$, $p = .01$, $\eta_p^2 = .15$, with negative affect decreasing from pre- to post-manipulation. There was no significant main effect for group, $F(1, 39) = 2.67$, $p = .08$, $\eta_p^2 = .12$, nor was there a significant interaction between time and group, $F(2, 39) = .45$, $p = .64$, $\eta_p^2 = .02$ (see Table 2). These results are in keeping with the extant literature [14,15,18], showing that social exclusion manipulations do not necessarily alter general affect.

To examine whether the effects of experimental condition on pain ratings could be accounted for by changes in affect, a 2 \times 3 analysis of covariance (ANCOVA) was performed with Time as the within-participants variable and Group as the between-participants variable, with variables representing change in positive affect and negative affect from pre- to post-manipulation entered simultaneously as covariates. Change scores were computed for both positive and negative affect by subtracting post-manipulation affect scores from pre-manipulation scores. Analyses were repeated for both pain intensity and pain unpleasantness ratings. For pain intensity neither the positive, $F(1, 37) = .09$, $p = .76$, $\eta_p^2 = .002$, nor the negative, $F(1, 37) = 2.54$, $p = .12$, $\eta_p^2 = .06$, affect covariate interacted significantly with time. There were again no main effects for either time, $F(1, 37) = .22$, $p = .64$, $\eta_p^2 = .006$, or group $F(2, 37) = 1.07$, $p = .35$, $\eta_p^2 = .06$, but there remained a significant interaction between time and group, $F(2, 37) = 6.52$, $p < .01$, $\eta_p^2 = .26$. For pain unpleasantness scores, neither the positive, $F(1, 37) = .49$, $p = .49$, $\eta_p^2 = .01$, nor the negative, $F(1, 37) = 1.07$, $p = .31$, $\eta_p^2 = .03$, affect covariate interacted significantly with time. There were again no main effects for time $F(1, 37) = .33$, $p = .57$, $\eta_p^2 = .009$, or Group $F(2, 37) = 1.43$, $p = .25$, $\eta_p^2 = .07$, but there was a significant interaction between time and group, $F(2, 37) = 4.69$, $p = .02$, $\eta_p^2 = .20$. Therefore the effects of the manipulation on pain ratings could not be accounted for by changes in positive or negative affect.

3.4. Does post social-exchange connectedness predict pain intensity, pain unpleasantness?

To investigate the relationship between connectedness ratings and post-manipulation pain sensitivity, partial correlation analyses (controlling for pre-manipulation pain sensitivity) between connectedness ratings and post-manipulation pain intensity and

Table 1
Effects of experimental condition on pain intensity and unpleasantness ratings.

	NE		PE		Ctrl	
	Int	Unpl	Int	Unpl	Int	Unpl
Pre-manipulation	5.9 (1.90)	4.64 (2.38)	5.02 (1.86)	3.98 (1.88)	5.98 (1.57)	5.2 (2.33)
Post-manipulation	4.64 (1.37)	3.38 (1.69)	5.29 (1.84)	4.46 (1.97)	6.49 (1.71)	5.78 (2.14)
Change	-1.26	-1.26	0.27	0.48	0.51	0.58
<i>p</i>	0.006	0.01	0.51	0.29	0.23	0.22
<i>d</i>	-.93	-.95	.17	.27	.29	.28

Mean pain intensity and unpleasantness scores on a scale from 0 (none) to 10 (worst imaginable) both before and after the experimental manipulation across groups (with standard deviations in parentheses). Abbreviations: NE, negative exchange; PE, positive exchange; Ctrl, control group; Int, pain intensity; Unpl, pain unpleasantness. Change scores are highlighted in bold and were computed by subtracting post-manipulation pain ratings from pre-manipulation pain ratings. *P* values represent the statistical significance of the difference between pre- and post-manipulation scores. Cohen's *d* was computed using Eq. (8) from Morris and DeShon [30] in order to correct for dependence between means.

Table 2
Effects of experimental condition on positive and negative affect ratings.

	NE		PE		Ctrl	
	PA	NA	PA	NA	PA	NA
Pre-manipulation	2.60 (.65)	1.37 (.39)	2.92 (.77)	1.29 (.19)	2.86 (.61)	1.47 (.46)
Post-manipulation	2.71 (.87)	1.21 (.24)	2.94 (.88)	1.06 (.14)	2.40 (.67)	1.38 (.48)
Change	0.11	-0.16	0.02	-0.23	-0.46	-0.09
<i>p</i>	0.41	0.14	0.87	0.04	0.001	0.88
<i>d</i>	.36	-.58	.06	-1.11	-.79	-.17

Mean scores on the positive affect (PA) and negative affect (NA) measures of the PANAS questionnaire on a scale from 1 to 5 both before and after the experimental manipulation across groups (with standard deviations in parentheses). Responses are made on a scale from 1 (very slightly or not at all) to 5 (extremely). Abbreviations: NE, negative exchange; PE, positive exchange; Ctrl, control group; PA, positive affect; NA, negative affect. Change scores are highlighted in bold and were computed by subtracting post-manipulation affect ratings from pre-manipulation affect ratings. *P* values represent the statistical significance of the difference between pre- and post-manipulation scores. Cohen's *d* was computed using Eq. (8) from Morris and DeShon [30] in order to correct for dependence between means.

unpleasantness scores were performed separately for NE and PE participants. For the NE group, the partial correlation between connectedness ratings and post-manipulation pain intensity scores, controlling for pre-manipulation pain intensity scores, was $-.18$, $p = .55$. For the PE group, the partial correlation was $-.15$, $p = .61$. This analysis was repeated for pain unpleasantness scores. For the NE group, the partial correlation between connectedness ratings and post-manipulation pain unpleasantness scores, controlling for pre-manipulation pain unpleasantness scores, was $-.02$, $p = .95$. For the PE group, the partial correlation was $.25$, $p = .37$. It therefore appears that there is no relationship between self-reported feelings of connectedness and reports of pain in these data.

4. Discussion

As predicted, participants who experienced a mildly negative social exchange reported significantly lower pain intensity and unpleasantness after the encounter relative to baseline, whereas those exposed to the positive exchange or the no-interaction control condition reported no change in pain ratings. These findings are congruous with the earlier research conducted by DeWall and Baumeister [14]. However, DeWall and Baumeister elicited a numbing effect with a strongly disquieting forecast of isolation, the hypoalgesic effect in the current study was provoked with a far more commonplace social stressor that better mimics day-to-day experience.

One potential alternative explanation for our findings is that the lower pain ratings obtained in the NE group were the result of a contrast effect. Physical pain stimuli may simply feel less painful when contrasted against the discomfort arising from a negative social experience. Two points argue against this explanation. First, if the results were due to contrast, there should be a within-cell correlation such that participants who experienced the negative social experience most strongly (i.e., reported feeling least connected) should rate the pain as least hurtful. No such relationship was found. Second, if a contrast effect was responsible for the findings, then it should follow that pain stimuli would seem especially painful immediately after a positive social experience. This did not happen.

The outcome of this study and of others such as DeWall and Baumeister's [14] raises the question as to the mechanism of social hypoalgesia. Feelings of disconnectedness and general negative affect, were ruled out by our results. First, connectedness ratings were not related to reports of pain. Second, controlling for self-reported negative affect did not alter the findings, suggesting that simply feeling bad cannot explain the results, a finding consistent with previous research [14,17,18]. Nonetheless, some studies have suggested that measures of more specific emotion variables such as shame [15], anger [11], and fear [35] may hold promise for explaining the effects of social exclusion, and thus should be included in future research.

It is also conceivable that the negative social experience elicited affective changes not directly accessible via self-report instruments. The startle reflex, in response to a sudden loud noise, has been found to be reliably modulated by underlying affective state and is commonly regarded as an objective measure of affect valence independent of self-report measures. In numerous human [20,23,24,41] and animal studies [13] the magnitude of the startle reflex (typically assessed via electromyographic recordings of muscular activity surrounding the eyes in response to a sudden burst of white noise) is potentiated under conditions of a negative emotional state and attenuated during the experience of positive affect. For example, Downey et al. [16] found that when viewing paintings depicting themes of social rejection, rejection sensitive individuals exhibited amplified eyeblink magnitude compared to their response when viewing other types of artwork. Thus measuring the

startle response before and immediately after social exclusion manipulations may reveal a mediating role for negative affect that operates by way of unconscious processes.

The results of this study are consistent with the notion that even a slight social disconnection can be stressful, in turn provoking a physiological reaction akin to that which occurs upon perception of a physical threat, one component of which is hypoalgesia [9,21,22,36,43]. The occurrence of this stress-induced hypoalgesia, wherein the perception of threat provokes a reduction in pain sensitivity, is well established in animal models and in humans [7]. Although typically linked to physical threats, to the extent that social harm is potentially as perilous to human health as physical harm, the prospect of social harm may similarly induce a hypoalgesic reaction. Research on non-human animals has indeed revealed hypoalgesic responses to a range of social stressors including social isolation [33], defeat experiences [21], and social conflict [36]. There is also empirical evidence showing effects of rejection on salivary cortisol response in humans [5]. This being the case, future studies should aim to investigate the role of physiological threat response processes in mediating the hypoalgesic effect of social disconnection by including several pre- and post-manipulation measures of autonomic nervous system activation including heart rate, blood pressure, finger temperature, skin conductance, and cortisol concentrations [e.g., [5,39]]. In addition, there is considerable evidence that the amygdala and the periaqueductal gray (PAG) are instrumental in mediating both stress- and fear-induced hypoalgesic responses [7] as well the startle reflex [1], suggesting that employing measures of startle response may not only help determine the degree to which unconscious affect mediates the social-disconnection induced hypoalgesia, but may point to the operation of the FFF response as a mediator of this effect. Indeed, if relatively ordinary, negative social experiences can provoke physiological responses typically associated with physical threat, then it is possible that, at least in some individuals, FFF responding may be occurring with greater frequency than previously realized, thereby exposing these individuals to increased allostatic load and its negative health consequences [27,28].

In the current study, the positive social encounter was not associated with any changes in pain ratings, a finding that may appear counter to prior research. For example, Brown et al. [6] had college students perform a cold pressor task with random assignment to various levels of social support. Some forms of social support were related to lower reports of pain. Master and co-workers [26] found that just looking at photos of a loved one was associated with a reduction in heat-induced pain compared to viewing pictures of strangers or objects. Why, then, did a positive interaction not reduce pain in the current study? One possibility is that, in our study, the positive social stimulus and pain test did not occur simultaneously as they did in the Brown et al. [6] and Master et al. [26] studies. Perhaps the effects of a positive encounter are more fleeting, whereas the effects of a negative exchange linger. Indeed, DeWall and Baumeister [14] found that a forecast of future belonging did not reduce later pain sensitivity. Another possibility is that the null effect in the current study's PE condition resulted because the encounter in the current study was with a stranger. The involvement of someone with whom participants had a closer relationship might have had a greater impact. Finally, in much the same way that a hungry person will more enthusiastically receive food than a satiated individual, it is possible that exchanges with strangers, of the kind that occurred in this study, might impact most those who especially crave social connection. Future studies should measure baseline levels of perceived connectedness (e.g., loneliness, social support) to assess the degree to which such individual differences moderate the effects of social manipulations on the perception of pain.

An important question left unanswered by this study is the extent to which the current findings can be generalized to individuals

who experience more chronic feelings of exclusion. That is, does chronic exposure to social disconnection threats alter the relation between social injury and pain? Participants in this study were exposed to a single negative social exchange. Perhaps repeated encounters might dampen or intensify the numbing effects of such experiences. There is evidence that prior exposure to stressful stimuli can moderate the effects of stress-induced hypoalgesia [7]. For example, in one study, rats that had experienced malnourishment from day 14 of gestation until 50 days of age exhibited significantly reduced hypoalgesia in response to restraint and forced swim stress [19]. In another study, male rats that were separated from their mothers for 180 min a day as neonates showed greater pain responses following a water avoidance stress test at 2 months of age [12]. If the reduced pain sensitivity observed in the NE group was due to stress-induced hypoalgesia, then regular exposure to even mildly negative social experiences in everyday life might alter responses to such potential threats. Future research should therefore observe the effects of repeated exposure to social exclusion threats over time on pain.

While other studies have demonstrated hypoalgesic responses to rather strong and explicit social exclusion manipulations, the current study is the first to demonstrate this effect in reaction to a mildly negative social interaction of the kind frequently encountered in everyday living. These results suggest that something as simple as the demeanor with which a clinician approaches a patient can impact patient pain reports. People suffering from chronic pain widely report that a lack of understanding by those around them, especially by those not suffering from pain, is a great source of distress [8] and they look to their physicians for understanding and guidance. Chronic pain patients may therefore be especially sensitive to signs that they are not being understood, valued, and/or supported by their physicians. Pain assessments performed by practitioners who are somewhat standoffish, aloof, distracted, or otherwise unresponsive, may result in a temporary hypoalgesia leading to underestimated patient pain, a situation that has important implications for the efficacy of treatment.

5. Conflict of interest statement

The authors have no conflicts of interest.

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