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ORIGINAL ARTICLE

Social cues influence perception of others' pain

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Abstract

Background: Accurately perceiving other people's pain is important in both daily life and healthcare settings. However, judging other's pain is inherently difficult and can be biased by various social and cultural factors. Here, we examined whether perception of others' pain and pain management recommendations are socially influenced by seeing the opinions of other raters.

Methods: In Experiment 1 ($N=50$), participants rated pictures depicting injured hands or feet of pre-selected high, medium and low intensities. Each picture was preceded by cues indicating ratings of 10 previous participants. Cues were randomized to indicate low ($\text{Social}_{\text{LOW}}$) or high ($\text{Social}_{\text{HIGH}}$) pain judgements and were not predictive of actual normative pain intensity. In Experiment 2 ($N=209$), participants viewed facial video clips of patients with chronic shoulder pain making painful movements. They estimated patients' pain intensity and provided pain management recommendations.

Results: Experiment 1 revealed that perceivers' pain estimates were significantly and substantially higher for stimuli following $\text{Social}_{\text{HIGH}}$ than $\text{Social}_{\text{LOW}}$ cues (Cohen's $d=1.26$, $p<0.001$) and paralleled by increased skin conductance responses. Experiment 2 replicated the effect of social cues on pain judgements ($d=0.58$, $p<0.001$). However, social cues did not influence post-study pain management recommendations, potentially due to memory limitations.

Conclusions: Together, these studies reveal that judgements of others' pain are robustly modulated by information about others' opinions. Future research could test the prevalence and strength of such effects in clinical settings.

Significance: The present study shows that even arbitrary opinions of other raters influence the perception of others' pain. This finding adds new insight into the growing evidence of social and cultural biases in pain estimation.

1 | INTRODUCTION

Accurate perception of others' pain and empathy for their suffering is essential for social interaction and altruistic behaviours in daily life (Toi & Batson, 1982; Zaki, 2014). Accurate perception is especially important in medical settings, where it may impact pain diagnosis and treatment strategies (Kappesser & Williams, 2010; Schäfer et al., 2016). Inaccuracies may lead to both undertreatment and overtreatment of pain. Like the general public, healthcare providers often look for correspondence between pain self-reports and other indicators—including facial expressions and behaviour—to infer how much pain a person is experiencing and what kind of response is warranted. There is a danger of discounting pain when these other indicators do not match self-reports, or when pain self-reports and behaviour are wrongly attributed to assumed personality features (e.g. 'attention-seeking') rather than to pain experience.

Such misattributions may underlie multiple forms of bias in judgement of others' pain. For instance, women's pain is often systematically underestimated by both healthcare providers (Schäfer et al., 2016; Wandner et al., 2014) and the general public, likely because women are perceived as more expressive and willing to report pain, leading to discounting of pain behaviours (e.g. facial expressions) and self-report (Schäfer et al., 2016; Zhang et al., 2021). In Schäfer et al., clinicians and medical students discounted women's pain relative to men's and judged them as more likely to be exaggerating. In Zhang et al., community participants systematically under-estimated women's pain relative to men's in two independent studies, using an ecologically relevant set of real patient videos with normed facial expressions and 'ground truth' self-reports (from the UNBC-McMaster Shoulder Pain Expression data set, Lucey et al., 2011). Across two studies, men were more likely to be prescribed medication, and women more likely to be prescribed psychotherapy. Similar biases have been reported regarding race (Hollingshead et al., 2015), age (Wandner et al., 2014) and perceivers' medical experience (Dirupo et al., 2021).

In these studies, participants likely use perceived gender, race, age and trustworthiness to establish prior beliefs (stereotypes) that serve as additional sources of evidence in making judgements when evidence is ambiguous or not completely trusted. However, the complex and multifaceted nature of such biases leaves open the question of whether judgements of others' pain (1) are inherently malleable or, rather, are stable reflections of experience and culture and (2) always reflect misattributions. To explore the degree to which perceptions of others' pain are influenced by immediate social context, we studied whether judgements of patients' pain from facial expressions and movements could be influenced by elementary social cues about other observers' pain judgements, which are devoid of prior cultural associations.

Social context comes in many forms, but one of the most powerful is knowledge of others' opinions. Information about others' judgements can induce both public conformity (Asch, 1956) and influences on private judgements (Craig & Prkachin, 1978; Platow et al., 2007; Koban & Wager, 2016; Willroth et al., 2017; for reviews, see Koban et al., 2017). Powerful influences on many areas of human experience and decision-making have been reported, including effects on aesthetic preferences (Berns et al., 2010; Campbell-Meiklejohn et al., 2010; Klucharev et al., 2009; Mason et al., 2009; Zaki et al., 2011), visual perception (Berns et al., 2005; Dirupo et al., 2021), prosocial behaviours (Nook et al., 2016), responses to affective stimuli (Willroth et al., 2017) and reported pain experience (Bajcar et al., 2023; Koban & Wager, 2016; Yoshida et al., 2013). Individuals in these studies adjusted their estimation to keep consistent with perceived group norms, with moderate to large effect sizes (e.g. Koban & Wager, 2016). It can be challenging to disentangle effects on private experience from those on meta-cognitive evaluations or public communication, but at least in some cases, the types of social cues we use here can influence autonomic responses (e.g. skin conductance) and brain responses to painful events (Koban et al., 2019; Koban & Wager, 2016).

In two experimental studies, we examined how social influence could bias participants' pain estimation (Experiments 1 and 2), autonomic responses to others' pain (Experiment 1) and pain management recommendations (Experiment 2). To test the effects in different experimental settings, Experiment 1 was conducted in laboratory participants and used well-established standard stimulus materials for empathic pain (Jackson et al., 2006). Experiment 2 investigated social information effects in online participants judging naturalistic videos of actual patients with chronic shoulder pain, the UNBC-McMaster data set (Lucey et al., 2011). Tests with real patient videos may be informative because pain facial expressions are often non-stereotypical in patients with chronic pain (Vachon-Presseau et al., 2016). In both studies, high-pain and low-pain social cues were randomly assigned to videos and were thus unrelated to actual pain intensity or expression. This design allowed us to assess the direct, causal effect of social cues on perceived pain.

2 | EXPERIMENT 1

2.1 | Method

2.1.1 | Participants

Fifty healthy volunteers, recruited from the CU Boulder community and Boulder-Denver metro area, participated in the experiment (29 female, mean age = 22.3, age range 18–53 years old). The sample size was determined prior to the start of the study. All participants were screened for a history of psychiatric or neurologic problems and were free of pain conditions. The study was approved by the Institutional Review Board at the University of Colorado Boulder and conducted in accordance with the Declaration of Helsinki of 1975, as revised in 1983. Participants provided written informed consent and were paid for their time.

2.1.2 | Materials and procedures

Target stimuli

Participants' judged the painfulness of a set of 72 pictures taken from the database of Jackson et al. (2006), which depicted injuries or potential injuries to hands or feet (see

Figure 1). These were stratified into three levels of pain intensity based on prior work, with 24 pictures in each category.

Social cues

Each target stimulus was preceded by a social cue, which consisted of a rating scale (a horizontal line) with 10 vertical lines intersecting it. Participants were instructed that each vertical line indicated a previous participant's rating of this target stimulus. In fact, the lines were computer-generated randomly based on one of two Gaussian distributions: A low-pain distribution (Social$_{LOW}$: $M=0.3$, $SD=0.15$) and a high-pain distribution (Social$_{HIGH}$: $M=0.7$, $SD=0.15$). For each participant, an equal number of Social$_{LOW}$ and Social$_{HIGH}$ cues was assigned to each normative stimulus intensity level, to create a 3×2 within-person factorial design (3 intensity levels $\times 2$ social cues). The cues were thus unrelated to the normative stimulus intensity and uninformative; differences in pain judgements between high and low cue conditions could thus be attributed to causal effects of cues. We term this effect the 'social influence' effect here.

Procedure

As shown in Figure 1, each trial started with the presentation of a social cue (presented for 3s). After a jittered 2–4s delay, a target injury stimulus was presented for 5s. After a second jittered 2.5–8.5s delay, participants were asked to rate how much pain the person was experiencing in the injury depicted ('How painful was it?'), using a horizontal visual analogue scale which remained on-screen for 4.5s. The scale ranged from 0 to 100, with anchors being *absolutely no pain* and *worst pain possible*. The inter-trial interval had a jittered duration of 4–10s. The task lasted about 30min. At the end of the experimental session, two empathy questionnaires (the Interpersonal Reactivity Index, IRI, Davis, 1980 and Basic Empathy Scale in Adults, BES-A, Carré et al., 2013) were administered. However, we do not report these correlations

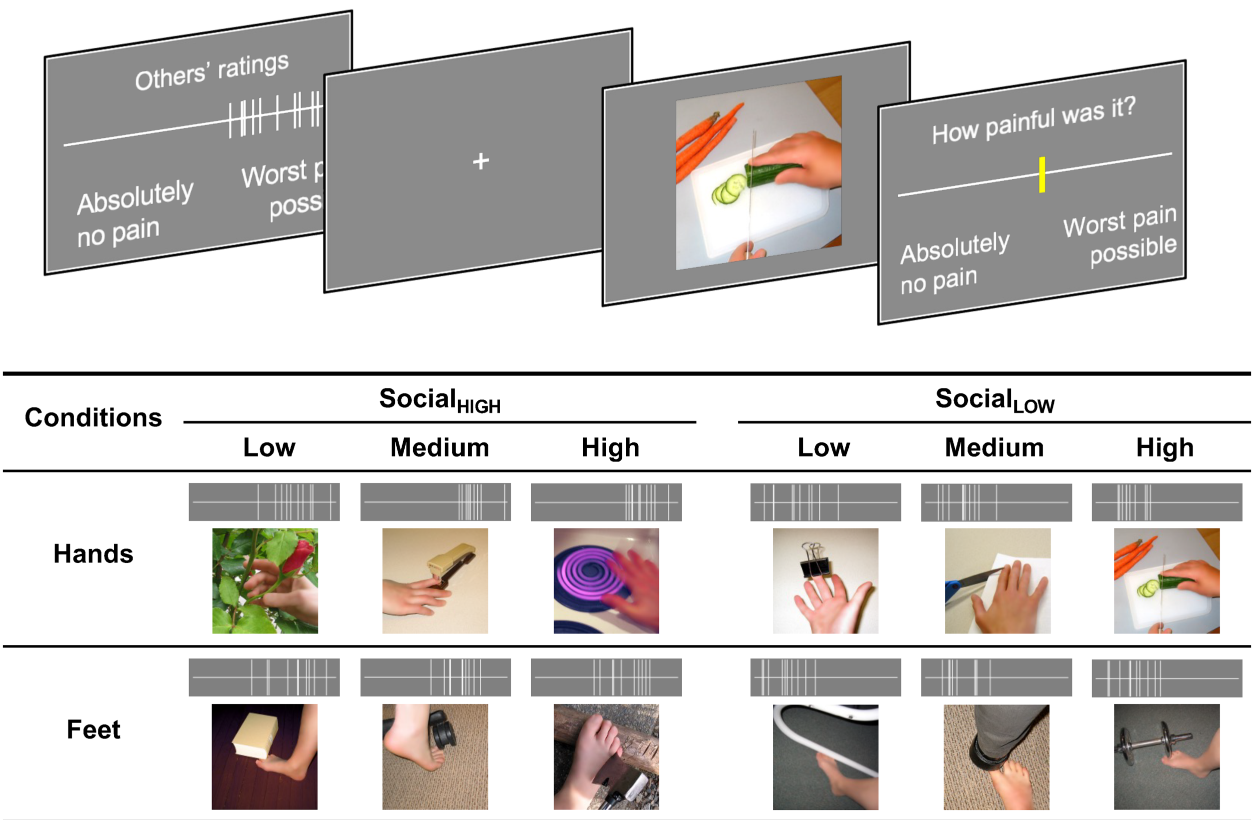

FIGURE 1 Experimental design of Experiment 1. As shown in the upper panel, each trial started with the presentation of social cues—the fictive ratings of several other persons, indicated as small vertical lines on a horizontal visual analogue scale (VAS). These social ratings could be either high (Social$_{HIGH}$) or low (Social$_{LOW}$) on average, thus indicating that other people had rated the upcoming pain picture as either intense or mild. Then participants saw a photograph displaying hands or feet in situations that are painful or about to be painful (e.g., fingers touching a hot stove, or next to a sharp knife…). The pain intensity of these pictures has been designed to be either high, medium or low. At the end of each trial, participants were asked to rate the painfulness of the situation displayed in the picture using a VAS (transformed to values from 0 to 100, anchors: 'no pain at all' to 'worst pain possible'). The lower panel shows the $2 \times 3 \times 2$ experimental design and example pictures (note that stimuli were randomly assigned to the Social$_{HIGH}$ or Social$_{LOW}$ condition).

in Study 1, as the sample size is insufficient to yield stable correlations (Schönbrodt & Perugini, 2013).

Skin conductance

Electrodermal activity was measured at the index and middle fingers of the left hand and recorded using a BIOPAC MP150 system and Acknowledge software at 500-Hz sampling rate. Electrodermal data were low pass filtered offline with a cutoff of 5-Hz (61 dB Butterworth), down-sampled to 50 Hz, segmented from 2 s before to 8 s after stimulus onset, corrected relative to the baseline window (−2 s to stimulus onset) for each trial and averaged across all trials per condition. The mean electrodermal activity between 2 and 8 s after stimulus picture onset was used for statistical analyses.

2.1.3 | Analysis

Behavioural data (ratings on the visual analogue scales) were analysed using a multi-level general linear model (GLM), modelling variance both on the intra-individual (single trial) and group level (across participants), with planned t-contrasts for within-person effects of social cue (high vs. low), normative stimulus intensity (linear effects) and hand vs. foot stimuli. Physiological data (SCR amplitude) focused on how stimulus intensity and social cues affected responses to pain pictures. We used pairwise *t*-tests to compare the mean skin conductance amplitude between 2 and 8 s following stimulus onset following high vs. low social cues. Directional hypotheses were specified for cue and intensity effects in both models, with higher expected perceived pain and SCR for high-pain vs. low-pain cues; therefore, results are reported at $p < 0.05$ one-tailed or below, though *p*-values were substantially lower (more significant) in most cases.

2.2 | Results

2.2.1 | Behavioural results

As shown in Figure 2a, perceived pain ratings increased significantly with normative stimulus intensity level (low < medium < high), linear contrast $t(49) = 16.27$, $p < 0.001$, Cohen's $d = 2.32$, indicating that perceivers discriminated the pre-normed intensity levels, in line with previous studies (Jackson et al., 2006; Krishnan et al., 2016). Confirming our main hypothesis, pain ratings were also strongly affected by the preceding social information, with $\text{Social}_{\text{HIGH}}$ trials leading to significantly higher pain ratings than $\text{Social}_{\text{LOW}}$ trials, $t(49) = 8.83$, $p < 0.001$, Cohen's $d = 1.26$. Stimuli depicting hands versus feet were not rated significantly different from each other ($p = 0.26$).

2.2.2 | Skin conductance results

Skin conductance responses were higher for high-intensity images compared to low intensity images, $t(49) = 1.93$, $p = 0.029$, Cohen's $d = 0.27$. In line with our prediction, SCR were also significantly higher for pain stimuli preceded by high ($\text{Social}_{\text{HIGH}}$) compared to low ($\text{Social}_{\text{LOW}}$) social ratings, $t(49) = 2.58$, $p = 0.006$, Cohen's $d = 0.37$ (Figure 2b). This indicates that social ratings do not only impact self-reported pain judgements, but also physiological responses to observed pain.

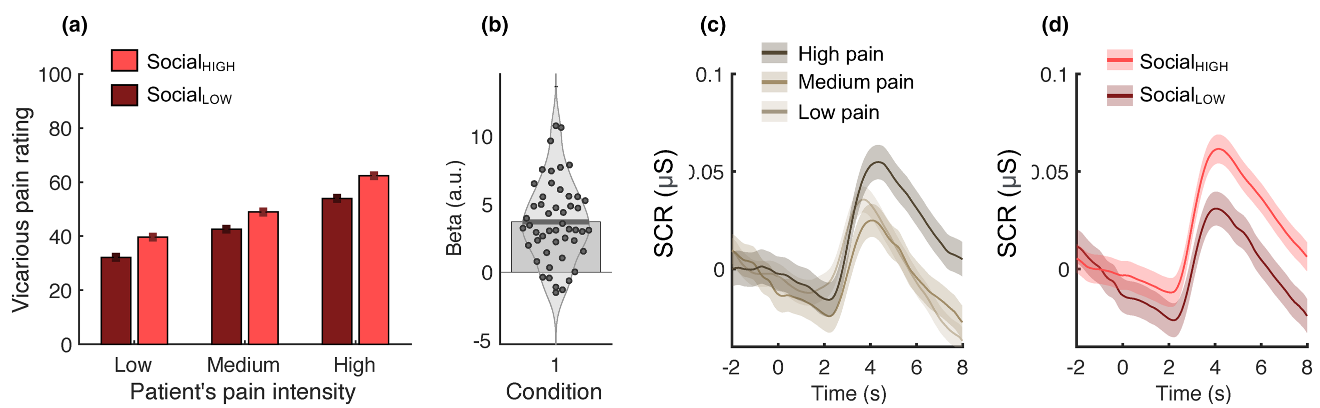

FIGURE 2 Pain ratings and skin conductance results of Experiment 1. (a) Pain ratings showed strong effects of both intensity level and social cue. Pain estimation ratings were significantly higher for pictures preceded by high ($\text{Social}_{\text{HIGH}}$) compared to low social ratings ($\text{Social}_{\text{LOW}}$ condition). Vertical bars reflect standard errors of the mean (SEM). (b) Individual social influence effects (individual beta estimates for the contrast [$\text{Social}_{\text{HIGH}} > \text{Social}_{\text{LOW}}$] are shown in a violin plot (each dot shows the beta estimate for one participant). (c and d). Skin conductance responses (mean response 2–8 s after stimulus onset, corrected for the 2 s pre-stimulus baseline) to pain pictures showed significant effects of intensity (c, high vs low intensity) and of (d) $\text{Social}_{\text{HIGH}} > \text{Social}_{\text{LOW}}$ cues. Error bands show the SEM.

3 | EXPERIMENT 2

3.1 | Methods

In Experiment 2, participants were presented with social cues (as in Experiment 1) before each of a series of brief video clips depicting facial expressions of pain evoked by shoulder movement in chronic shoulder pain patients. This allowed us to test whether we could replicate the social influence effects observed in Experiment 1 with more naturalistic pain stimuli (videos of pain patients) and in a larger participant sample, and to test whether social influence might also impact subsequent treatment recommendations.

3.1.1 | Participants

210 participants took part in the online survey. One of them was excluded because of very low ratings (>3 STD below the mean), leaving a sample of 209 participants (114 females, 93 males, 2 non-binary/other, mean age = 34.8 years, age range 19–70 years). The study was approved by the Institutional Review Board at the University of Colorado Boulder and in accordance with the Helsinki Declaration of 1975, as revised in 1983. All participants provided online informed consent, accessed the survey using Qualtrics software (Qualtrics, Provo, UT, http://www.qualtrics.com) and were paid for their time via Amazon mTurk.

3.1.2 | Materials and procedures

Stimuli

36 distinct social cues (18 each for $Social_{HIGH}$ and $Social_{LOW}$) were generated in the same way as in Experiment 1, except that the vertical lines were replaced with blue circles to match the look of the visual analogue scales on Qualtrics (see Figure 3). The target stimulus set included 36 video clips (three each for six male targets and six female targets) selected from the UNBC-McMaster Shoulder Pain Expression Archive Database (Lucey et al., 2011). The videos were captured when shoulder pain patients were performing range-of-motion tests. The database includes patients' self-reported pain in response to each movement on a 0–10 scale and ratings from a professional observer ranging from 0 to 5. Three video clips were chosen for each target, corresponding roughly to low, medium and high intensity based on the combination of patients' self-reported pain and observer ratings. Video clips were edited to 6 s duration to focus on the dynamic changes from neutral expressions before the shoulder movement to pain expressions during and immediately after the shoulder movement.

Stimuli were tested in two sets. Assignment of social cues to patient videos was randomized and counterbalanced across participants and between two stimulus sets. That is, patient videos assigned to high social cues in stimulus set 1 were assigned to low social cues in stimulus set 2. We used this approach to reduce the influence of idiosyncrasies in individual patient videos while ensuring independence of observations. Half of the participants were randomly assigned to stimulus set 1, and the other half to stimulus set 2.

Design

This experiment was carried out on the online survey platform Qualtrics. A 2 (social cue: $Social_{HIGH}$, $Social_{LOW}$) × 3 (intensity: high, medium and low) within-subject design was used, as in Experiment 1. The main dependent variable was participants' pain judgements. In addition, treatment recommendations served as additional dependent variables. Since half of the 12 patients were assigned to the $Social_{HIGH}$, the other half to the $Social_{LOW}$ condition, and only one video still for each patient was

FIGURE 3 Pain estimation task design in Experiment 2. In each trial of an online task, participants were first presented with social ratings (displayed as blue circles on a VAS), which indicated either low ($Social_{LOW}$) or high ($Social_{HIGH}$) observed pain ratings of several other people. Then participants watched a 6 s segment of a video showing a painful shoulder movement recorded in an actual pain patient. The video was auto-played and participants were self-paced for the subsequent pain estimation, using again a visual analogue scale (transformed to values between 0 and 100, anchored at 'no pain at all' to 'worst pain possible').

used for the treatment questions, the 'intensity' predictor was not tested for this secondary analysis of treatment recommendations.

Procedure

The online survey opened with a consent form and an information sheet. Participants then answered questions asking about gender, age, professional experience in the domain of health care and experience of pain conditions. For the main task, each of the 36 trials started with the presentation of a social cue ($Social_{HIGH}$ or $Social_{LOW}$) for 2 s, followed by a video depicting a shoulder pain patient moving their shoulder (6 s). At the end of each trial, participants rated the patient's pain on a horizontal visual analogue scale ranging from 0 to 100 (Figure 3).

Following the main task, participants were shown one video still for each of the 12 patients, and asked to prescribe treatments, as if the participants were medical doctors. Three questions were asked for each patient: (1) 'If you were to prescribe pain medicine, what dose would you prescribe to this patient?' (with anchors at scale ends of 'minimum dose' and 'maximum dose'), (2) 'If you were to prescribe psychotherapy, how many sessions would you prescribe?' (anchored from 'minimum number of sessions' to 'maximum number of sessions') and (3) 'What do you think would help the patient more?' (forced choice between pain medicine and psychotherapy). As in Experiment 1, participants filled in the IRI and the BES-A questionnaires at the end of the survey. The whole survey took approximately 25 min to complete.

3.1.3 | Analysis

For pain estimation, the data were analysed using a multilevel GLM. Within-subject predictors were social cues ($Social_{HIGH}$ or $Social_{LOW}$) and patients' pain intensity (low, medium or high). The dependent variable was perceivers' estimates of the patients' pain. Additionally, perceivers' trait empathy and personal experience, including health care work experience (binary, yes or no) and personal pain experience (yes or no) were added in the model (effects coded with 1 and −1) as moderators to examine whether these personal characteristics affect the magnitude of the social influence effect.

We conducted additional multi-level GLMs to assess social influence on pain management recommendations and hypothetical prescriptions (dose of medicine and sessions of psychotherapy) for each patient. For the forced-choice question on which treatment would be more helpful, pain medicine vs. psychotherapy, we calculated the perceiver-wise proportion of all trials in which medicine/psychotherapy was prescribed to patients, separately for $Social_{HIGH}$ and $Social_{LOW}$ trials/patients. To test for social influence in pain management recommendations preference, we performed paired *t*-tests on the proportion prescribed medicine for $Social_{HIGH}$ vs. $Social_{LOW}$ cues. Pearson correlation coefficients were calculated to examine whether participants with more empathy showed a larger social influence effect.

3.2 | Results

3.2.1 | Social influence on pain estimation

Consistent with the findings of Experiment 1, greater patients' pain intensity led to higher pain estimations, $t(208) = 27.8$, $p < 0.001$, Cohen's $d = 1.93$. Further and in line with our main hypothesis, videos preceded by $Social_{HIGH}$ information led to significantly higher observed pain ratings than those preceded by $Social_{LOW}$ information, $t(208) = 8.33$, $p < 0.001$, Cohen's $d = 0.58$ (Figure 4).

3.2.2 | Social influence on pain management recommendations

Social cues did not influence post-task prescriptions (for dose of pain medicine, $t(208) = -0.21$, $p = 0.83$; for sessions of psychotherapy, $t(208) = 0.41$, $p = 0.68$). Paired *t*-tests on $Social_{HIGH}$ and $Social_{LOW}$ trials revealed no significant preference for psychotherapy vs. medication: $t(208) = 1.59$, $p = 0.11$, Cohen's $d = 0.11$.

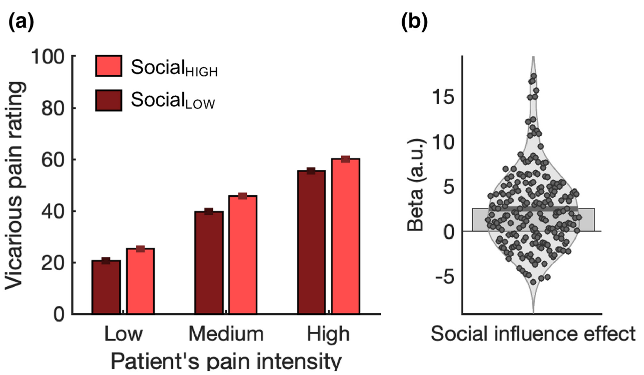

FIGURE 4 Pain estimates in Experiment 2. (a) Paralleling the effects in Experiment 1, pain estimation ratings were significantly higher for videos preceded by $Social_{HIGH}$ compared to $Social_{LOW}$ ratings. (b) The violin plot shows individual beta estimates for the social influence effect (each dot reflects the beta weight of one study participant).

3.2.3 | Individual differences in social influence on pain estimation

Individual differences in the magnitude of social influence effects were not significantly correlated with trait empathy as measured with the Empathic Concern subscale of the IRI ($r=0.10$, $p=0.08$). Perceivers with higher trait empathy showed numerically larger social influence on pain estimation, but based on the small estimated effect size here, larger sample sizes are needed to characterize relationships between self-reported empathy and task performance-based measures of observed pain.

Out of 209 perceivers, 41 reported work experience in healthcare settings and 127 reported personal persistent pain experience. However, neither perceivers' healthcare working experience, $t(208)=0.18$, $p=0.86$, nor their personal experience with pain, $t(208)=0.68$, $p=0.50$, moderated the effect of social cues on pain estimation.

4 | DISCUSSION

Being attuned to the feelings and pains of others is a prerequisite for empathic responses in social interactions. Accurately estimating patients' pain is especially important in medical settings, where it informs diagnosis and treatment approaches. It is therefore important to better understand the factors that might influence and bias pain perception. Our results show that abstract social cues about others' pain ratings strongly modulate participants' estimates of others' pain. This main finding was replicated across two different experimental settings and for different observed pain cues, including videos of actual patients suffering from shoulder pain. Study 1 further demonstrated that high (vs. low) social ratings increase autonomic (skin conductance) responses to observed pain cues, suggesting a modulation of implicit physiological responses as well as explicit judgements. The effect size for physiological modulation was small, however, compared to the large and robust effects on judgement.

The finding that pain judgements are susceptible to social influence is meaningful in several ways. In medical and healthcare settings, doctors and caregivers might underestimate or overestimate patients' pain based on social information (e.g. from peers, textbooks), which might even overrule self-reported pain ratings from the patients themselves (Dirupo et al., 2021). As a potential consequence, patients may receive inadequate or excessive treatment (Cremeans-Smith et al., 2003), especially in combination with other pain estimation biases such as those related to gender or minority status (Hadjistavropoulos et al., 2014; Hoffman et al., 2016; Losin et al., 2020; Mende-Siedlecki et al., 2021; Zhang et al., 2021). Together, such contextual biases may lead to systematic errors in patients' pain estimations in clinical settings (Dirupo et al., 2021; Kappesser et al., 2006).

The present findings build on a growing body of evidence for social influence effects on the perception of one's own pain (e.g. Craig & Prkachin, 1978; Koban & Wager, 2016; Bajcar et al., 2023; Reicherts et al., 2013; Świder & Bąbel, 2013; for a review, see Schenk et al., 2017). Of note, there may be bidirectional influences between judgements of self-pain and others' pain, as the perception of pain facial expressions can enhance the perception of one's own pain in response to noxious stimuli (i.e. pain contagion) and vice versa (Reicherts et al., 2013; see also Krueger & Clement, 1994). Future studies could test whether providing low-pain social cues, as employed here, result in altered perception of pain facial expressions, which may further result in lower pain self-reports and thus contribute to socially induced placebo effects (see Colloca & Benedetti, 2009).

Observational learning plays an especially important role in development. Children's pain responses are shaped by observing parents' verbal and nonverbal pain behaviours such as facial pain expressions in pain situations (for a review, see Goubert et al., 2011). Similarly, children's empathic responses to others' suffering could be influenced by how their parents and other role models respond to others' suffering. Social influence might thus be employed as a promising tool for enhancing empathy and altruistic behaviour. For instance, an experimental study has shown that donations to homeless shelters increased when individuals were exposed to high empathy ratings or to more generous donation behaviours of others (Nook et al., 2016). This effect, and other effects on social perceptions, may be explained as a rational (i.e. Bayesian) inference over multiple sources of information (Baker et al., 2009; Houlihan et al., 2023). Social cues can also guide attention to relevant dimensions of sensory input (e.g. its aversiveness or painfulness); thus, participants may pay more attention to affective aspects of a stimulus when they expect it to be more painful.

Some previous studies have found positive correlations between individual differences in social influence effects and trait empathy, particularly the IRI (Koban & Wager, 2016). This could be potentially explained by an increased effect of social context cues in those with higher empathic traits. Study 2 was designed to assess these correlations with a larger sample size, providing more precise estimates of the correlation strength (Schönbrodt & Perugini, 2013). These correlations were weak, with a small effect size ($r=0.10$); thus, it is unclear whether there is a significant relationship. There is increasing recognition that self-report and task performance-based measures often assess different constructs (Mazza et al., 2021), and we believe this is the case here: Judgements of others' pain in a task-based setting has the advantage of being able to measure performance, and biases including social influence, against a ground truth; but it may not be strongly related to self-reported empathy.

In non-experimental settings, group average judgements can be remarkably accurate compared with the individual judgements—known as the wisdom of the crowd effect (Surowiecki, 2004). Thus, in some situations, following others can be adaptive. However, the wisdom of the crowd is a statistical phenomenon based on many independent judgements. It may break down in situations in which people strongly influence each other's judgement, such as online social networks. As shown in the present study, merely showing others' estimation—even when they are nonpredictive of the upcoming stimuli—leads to substantial changes in pain reports and even in less controllable physiological responses to observed pain. Similar effects may be at play when observing other people's behaviour directly or in the 'ratings' or 'likes' that are ubiquitous on social media. Lorenz et al. (2011) showed that social influence undermined the wisdom of crowds by diminishing the diversity of group and narrowing judgement distribution around a wrong value. Such effects could further increase biases and estimation errors in that convergence of (biased) social opinions can boost people's confidence in their estimation (Lorenz et al., 2011). A potential negative consequence is that people are more likely to make mistakes and less likely to detect and correct errors.

The present study has several limitations. Study 1 used a convenience sample of mainly young and healthy participants recruited from the University of Colorado Boulder community, potentially limiting its generalizability to other, more diverse populations. Further, the stimuli we used in Study 1 depicted injured body parts (hands or feet) without showing faces. Such de-identified pain situations may seem somewhat artificial compared to real-life situations of detecting others' pain and experiencing empathy. These stimuli may also enable participants to put themselves in the shoes of the observed others and thus estimate the pain from an egocentric view, as the pain situations could be perceived in both first and third-person perspectives (Jackson et al., 2006). These limitations were not present in Study 2, which demonstrated social influence effects in an older and more diverse sample and using dynamic and more naturalistic stimuli depicting real patients' pain and facial expressions. We also note that we did not find an effect of social ratings on pain management recommendations. This may suggest that social influence effects on specific judgements (e.g. pain judgements) do not necessarily translate to another type of decisions (i.e. treatment decision). However, a limitation in the design was that it included only a relatively small number of patients (six for the Social$_{HIGH}$, six for the Social$_{LOW}$ condition) and the recommendation did not immediately follow the social information or the initial rating. Thus, it is possible that participants may not explicitly remember the social information for each pain cue (but see Bajcar et al., 2023 for temporally extended social influence effects on self-reported pain). We also note that online participants may be less attentive to the task than lab participants or than practitioners who judge patients' pain in clinical settings, thus potentially leading to smaller and less transferable social influence effects in online samples. Further studies could test other variants of this task to further investigate how social influence changes pain judgements and treatment decisions, in different samples of non-experts and in medical professionals. Finally, we note that future studies with larger sample sizes are needed to explore the role of individual differences in social influence effects.

5 | CONCLUSIONS

Previous findings indicate important social and cultural biases when it comes to reporting one's own and estimating other persons' pain. Here we show, across two different studies, using two different experimental settings and different types of observed pain cues, that the perception of others' pain is strongly influenced by the opinions of other raters. Future studies could test how perceived social norms influence pain estimation in clinical settings, and how they interact with other social and cultural biases to affect pain and treatment outcomes.

AUTHOR CONTRIBUTIONS

Study conception and design: Lanlan Zhang, Tor Wager and Leonie Koban; *Funding*: Tor Wager. *Material preparation, data collection and first draft*: Lanlan Zhang; *Data analysis*: Lanlan Zhang and Leonie Koban; *Data interpretation and critical revision*: Tor Wager and Leonie Koban. All authors discussed the results, edited the paper, and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to disclose.

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