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Social cues influence perception of others' pain

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Running Head: SOCIAL INFLUENCES ON PAIN OBSERVATION

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23

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32

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34

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

38

39

Abstract

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

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

53 **Results:** Experiment 1 revealed that perceivers' pain estimates were significantly and
54 substantially higher for stimuli following Social_{HIGH} than Social_{LOW} cues (Cohen's $d = 1.26$,
55 $p < .001$), and paralleled by increased skin conductance responses. Experiment 2
56 replicated the effect of social cues on pain judgments ($d = 0.58$, $p < .001$). However, social
57 cues did not influence post-study pain management recommendations, potentially due to
58 memory limitations.

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

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64 *Key words: social influence; social norms; pain management recommendation; empathy;*
65 *vicarious pain;*

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Introduction

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Accurate perception of others' pain and empathy for their suffering are essential for social interaction and altruistic behaviors 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 behavior—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 behavior are wrongly attributed to assumed personality features (e.g., 'attention-seeking') rather than to pain experience.

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Such misattributions may underlie multiple forms of bias in judgment 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 behaviors (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 expression and 'ground truth' self-reports (from the UNBC-McMaster Shoulder Pain Expression dataset (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).

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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 judgments when evidence is ambiguous or not completely trusted. However, the complex and multifaceted nature of such biases leave open the questions of whether judgments 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,

101 we studied whether judgments of patients' pain from facial expressions and movements
102 could be influenced by elementary social cues about other observers' pain judgments,
103 which are devoid of prior cultural associations.

104 Social context comes in many forms, but one of the most powerful is knowledge of
105 others' opinions. Information about others' judgments can induce both public conformity
106 (Asch, 1956) and influences on private judgments (Craig & Prkachin, 1978; Platow et al.,
107 2007; Koban & Wager, 2016; Willroth et al., 2017; for reviews, see Koban et al., 2017).
108 Powerful influences on many areas of human experience and decision-making have been
109 reported, including effects on aesthetic preferences (Berns et al., 2010; Campbell-
110 Meiklejohn et al., 2010; Klucharev et al., 2009; Mason et al., 2009; Zaki et al., 2011), visual
111 perception (Berns et al., 2005; Dirupo et al., 2021), prosocial behaviors (Nook et al., 2016),
112 responses to affective stimuli (Willroth et al., 2017) and reported pain experience (Yoshida
113 et al., 2013; Koban & Wager, 2016; Bajcar, et al. 2023). Individuals in these studies
114 adjusted their estimation to keep consistent with perceived group norms, with moderate
115 to large effect sizes (e.g., Koban & Wager, 2016). It can be challenging to disentangle
116 effects on private experience from those on meta-cognitive evaluations or public
117 communication, but at least in some cases the types of social cues we use here can
118 influence autonomic responses (e.g., skin conductance) and brain responses to painful
119 events (Koban & Wager, 2016; Koban et al., 2019).

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

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Experiment 1**Method****Participants**

138 Fifty healthy volunteers, recruited in the CU Boulder community and Boulder-
139 Denver metro area, participated in the experiment (29 female, mean age = 22.3, age range
140 18-53 years old). The sample size was determined prior to the start of the study. All
141 participants were screened for a history of psychiatric or neurologic problems and were
142 free of pain conditions. The study was approved by the Institutional Review Board at the
143 University of Colorado Boulder and conducted in accordance with the Declaration of
144 Helsinki of 1975, as revised in 1983. Participants provided written informed consent and
145 were paid for their time.

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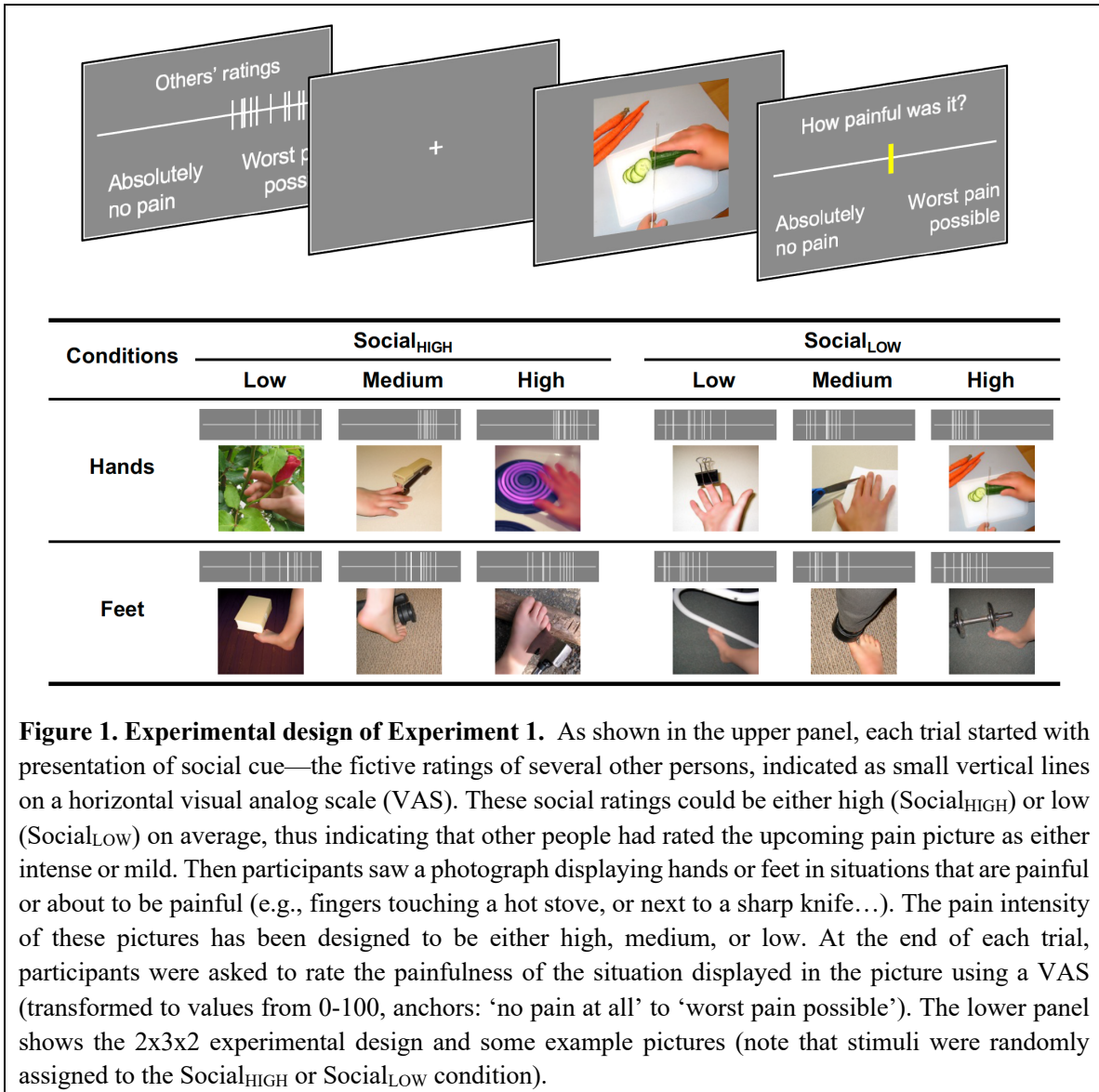
Materials and Procedures

148 **Target stimuli.** Participants' judged the painfulness of a set of 72 pictures taken from
149 the database of Jackson et al. (2006), which depicted injuries or potential injuries to hands
150 or feet (see Figure 1). These were stratified into three levels of pain intensity based on
151 prior work, with 24 pictures in each category.

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

163 **Procedure.** As shown in Figure 1, each trial started with the presentation of a
164 social cue (presented for 3 s). After a jittered 2-4 s delay, a target injury stimulus was
165 presented for 5 s. After a second jittered 2.5-8.5 s delay, participants were asked to rate
166 how much pain the person was experiencing in the injury depicted ("How painful was it?")
167 on a horizontal visual analog scale which remained on-screen until 4.5 s elapsed. The
168 scale ranged from 0 to 100, with anchors being "*absolutely no pain*" and "*worst pain*"

169 possible". The inter-trial interval had a jittered duration of 4-10 s. The task lasted about 30
 170 minutes. At the end of the experimental session, two empathy questionnaires (the
 171 Interpersonal Reactivity Index, IRI, Davis, 1980 and Basic Empathy Scale in Adults, BES-
 172 A, Carré et al., 2013) were administered. However, we do not report these correlations in
 173 Study 1, as the sample size is insufficient to yield stable correlations (Schönbrodt &
 174 Perugini, 2013).
 175



176
 177 **Figure 1. Experimental design of Experiment 1.** As shown in the upper panel, each trial started with
 178 presentation of social cue—the fictive ratings of several other persons, indicated as small vertical lines
 179 on a horizontal visual analog scale (VAS). These social ratings could be either high (Social_{HIGH}) or low
 180 (Social_{LOW}) on average, thus indicating that other people had rated the upcoming pain picture as either
 181 intense or mild. Then participants saw a photograph displaying hands or feet in situations that are painful
 182 or about to be painful (e.g., fingers touching a hot stove, or next to a sharp knife...). The pain intensity
 183 of these pictures has been designed to be either high, medium, or low. At the end of each trial,
 184 participants were asked to rate the painfulness of the situation displayed in the picture using a VAS
 185 (transformed to values from 0-100, anchors: ‘no pain at all’ to ‘worst pain possible’). The lower panel
 186 shows the 2x3x2 experimental design and some example pictures (note that stimuli were randomly
 187 assigned to the Social_{HIGH} or Social_{LOW} condition).
 188

189 **Skin conductance.** Electrodermal activity was measured at the index and middle fingers
 190 of the left hand and recorded using a BIOPAC MP150 system and Acknowledge software
 191 at 500-Hz sampling rate. Electrodermal data was low pass filtered offline with a cutoff of

192 5-Hz (61dB Butterworth), down-sampled to 50Hz, segmented from 2s before to 8s after
193 stimulus onset, corrected relative to the baseline window (-2s to stimulus onset) for each
194 trial, and averaged across all trials per condition. The mean electrodermal activity between
195 2-8s after stimulus picture onset was used for statistical analyses.

196

197 **Analysis**

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

209

210 **Results**

211 **Behavioral results**

212 As shown in Figure 2a, perceived pain ratings increased significantly with normative
213 stimulus intensity level (low < medium < high), linear contrast $t(49) = 16.27$, $p < .001$,
214 Cohen's $d = 2.32$, indicating that perceivers discriminated the pre-normed intensity levels,
215 in line with previous studies (Jackson et al., 2006; Krishnan et al., 2016). Confirming our
216 main hypothesis, pain ratings were also strongly affected by the preceding social
217 information, with Social_{HIGH} trials leading to significantly higher pain ratings than Social_{LOW}
218 trials, $t(49) = 8.83$, $p < .001$, Cohen's $d = 1.26$. Stimuli depicting hands versus feet were
219 not rated differently from each other ($p = .26$).

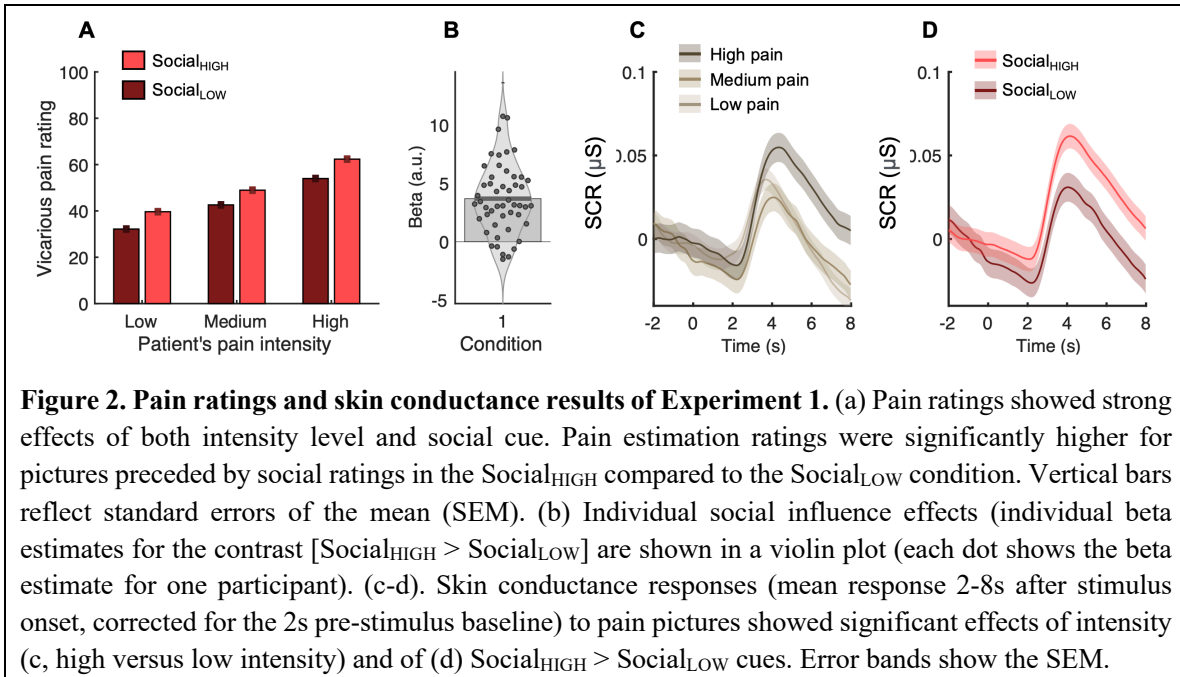
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221 **Skin conductance results**

222 Skin conductance responses were higher for high compared to low intensity images,
223 $t(49) = 1.93$, $p = .029$, Cohen's $d = 0.27$. In line with our prediction, SCR were also
224 significantly higher for pain stimuli preceded by high (Social_{HIGH}) compared to low
225 (Social_{LOW}) social ratings, $t(49) = 2.58$, $p = .006$, Cohen's $d = 0.37$ (Figure 2b). This

226 indicates that social ratings do not only impact self-reported pain judgments, but also
 227 physiological responses to observed pain.

228



229

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

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239

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Experiment 2

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Methods

242

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

248

249

Participants

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210 participants took part in the online survey. One of them was excluded because of very
 251 low ratings (>3 STD below the mean), leaving a sample of 209 participants (114 females,
 252 93 males, 2 non-binary/other, mean age=34.8 years, age range 19-70 years). The study
 253 was approved by the Institutional Review Board at the University of Colorado Boulder and
 254 in accordance with the Helsinki Declaration of 1975, as revised in 1983. All participants
 255 provided online informed consent, accessed the survey on the Qualtrics software

256 (Qualtrics, Provo, UT. <http://www.qualtrics.com>), and were paid for their time via Amazon
257 mTurk.

258

259 **Materials and Procedures**

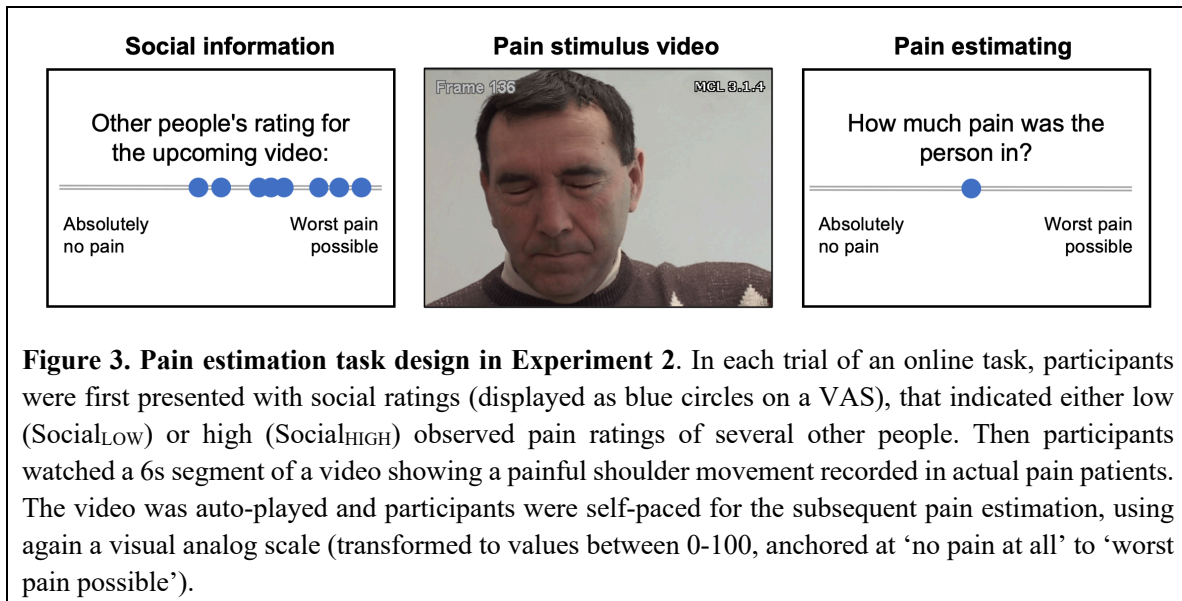
260 **Stimuli.** 36 distinct social cues (18 each for Social_{HIGH} and Social_{LOW}) were generated in
261 same way as in Experiment 1, except that vertical lines were replaced with gray circles to
262 match the look of the visual analog scales on Qualtrics (see Figure 3). The target stimulus
263 set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

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

280 **Design.** This experiment was carried out on the online survey platform Qualtrics.
281 A 2 (social cue: Social_{HIGH}, Social_{LOW}) × 3 (intensity: high, medium and low) within-subject
282 design was used, as in Experiment 1. The main dependent variable was participants' pain
283 judgments. In addition, treatment recommendations served as additional dependent
284 variables. Since half of the 12 patients were assigned to the Social_{HIGH}, the other half to
285 the Social_{LOW} condition, and only one video still for each patient was used for the treatment
286 questions, the "intensity" predictor was not tested for this secondary analysis of treatment
287 recommendations.

288 **Procedure.** The online survey opened with a consent form and an information
289 sheet. Participants answered questions asking about gender, professional, experience in

290 the domain of health care and experience of pain conditions. For the main task, each of
 291 the 36 trials started with the presentation of a social cue (Social_{HIGH} or Social_{LOW}) for 2 s,
 292 followed by a video depicting a shoulder pain patient moving their shoulder (6s). At the
 293 end of each trial, participants rated the patient's pain on a horizontal visual analog scale
 294 ranging from 0 to 100 (Figure 3).
 295



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

315

316 **Analysis**

317 For pain estimation, the data were analyzed using a multilevel GLM. Within-subject
 318 predictors were social cue (Social_{HIGH} or Social_{LOW}) and patients' pain intensity (low,
 319 medium, or high). The dependent variable was perceivers' estimates of the patients' pain.

320 Additionally, perceivers' trait empathy and personal experience, including health care work
 321 experience (binary, yes or no) and personal pain experience (yes or no) were added in
 322 the model (effects coded with 1 and -1) as moderators to examine whether these personal
 323 characteristics affect the magnitude of the social influence effect.

324 We conducted additional multi-level GLMs to assess social influence on pain
 325 management recommendations and hypothetical prescription (dose of medicine and
 326 sessions of psychotherapy) for each patient. For the forced-choice question on which
 327 treatment would be more helpful, pain medicine vs. psychotherapy, we calculated the
 328 perceiver-wise proportion of the total 12 trials (one trial for each patient) in which
 329 medicine/psychotherapy was prescribed to patients cued with Social_{HIGH} or Social_{LOW}
 330 information. To test for social influence in pain management recommendations preference,
 331 we performed paired t-tests on the proportion prescribed medicine for Social_{HIGH} vs.
 332 Social_{LOW} cues. Pearson correlation coefficients were calculated to examine whether
 333 participants with more empathy showed larger social influence.

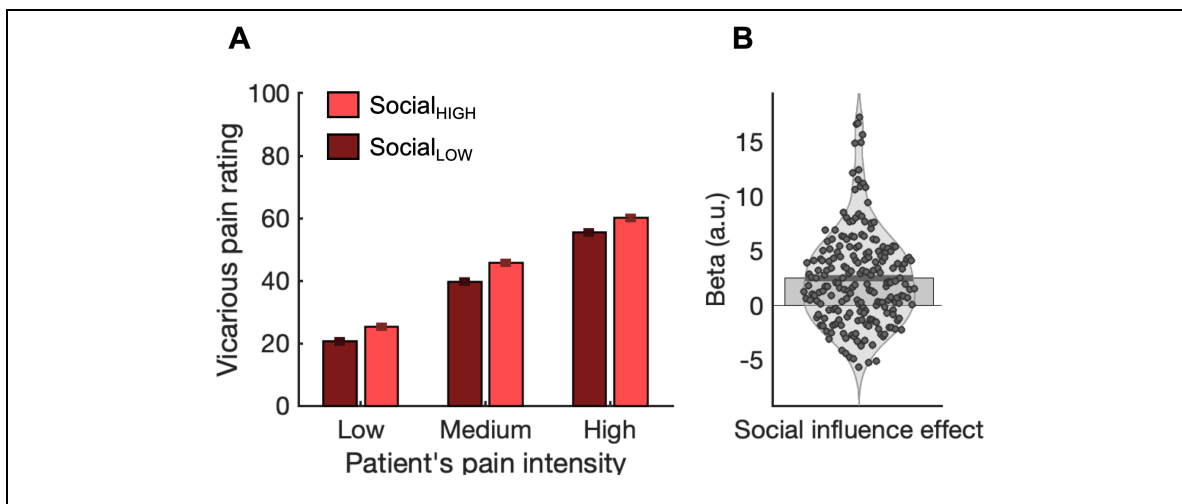
334

335 Results

336 *Social influence on pain estimation*

337 Consistent with the findings of Experiment 1, greater patients' pain intensity led to higher
 338 pain estimations, $t(208) = 27.8$, $p < .001$, Cohen's $d = 1.93$. Further and in line with our
 339 main hypothesis, videos preceded by Social_{HIGH} information led to significantly higher
 340 observed pain ratings than those preceded by Social_{LOW} information, $t(208) = 8.33$,
 341 $p < .001$, Cohen's $d = 0.58$ (Figure 4).

342



343

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

348

349 ***Social influence on pain management recommendations***

350 Social cues did not influence post-task prescriptions (for dose of pain medicine, $t(208) = -$
 351 $0.21, p = .83$; for sessions of psychotherapy, $t(208) = 0.41, p = .68$). Paired t-tests on
 352 Social_{HIGH} and Social_{LOW} trials revealed no significant preference for psychotherapy vs.
 353 medication: $t(208) = 1.59, p = .11$, Cohen's $d = 0.11$.

354

355 ***Individual differences in social influence on pain estimation***

356 Individual differences in the magnitude of social influence effects were not significantly
 357 correlated with trait empathy as measured with the Empathic Concern subscale of the IRI
 358 ($r = .10, p = .08$). Perceivers with higher trait empathy showed numerically larger social
 359 influence on pain estimation, but based on the small estimated effect size here, larger
 360 sample sizes are needed to characterize relationships between self-reported empathy and
 361 task performance-based measures of observed pain.

362 Out of 209 perceivers, 41 reported work experience in healthcare settings and 127
 363 reported personal persistent pain experience. However, neither perceivers' healthcare
 364 working experience, $t(208) = 0.18, p = .86$, nor their personal experience with pain,
 365 $t(208) = 0.68, p = .50$, moderated the effect of social cues on pain estimation.

366

367

367 **Discussion**

368 Being attuned to the feelings and pains of others is a prerequisite for empathic responding
 369 in social interactions. Accurately estimating patients' pain is especially important in
 370 medical settings, where it informs diagnosis and treatment approaches. It is therefore
 371 important to better understand the factors that might influence and bias pain perception.
 372 Our results show that abstract social cues about others' pain ratings strongly modulate
 373 participants' estimates of others' pain. This main finding replicated across two different
 374 experimental settings and for different observed pain cues, including videos of actual
 375 patients suffering from shoulder pain. Study 1 further demonstrated that high (vs. low)
 376 social ratings increase autonomic (skin conductance) responses to observed pain cues,
 377 suggesting a modulation of implicit physiological responses as well as explicit judgments.

378 The effect size for physiological modulation was small, however, compared to the large
379 and robust effects on judgment.

380 The finding that pain judgments are susceptible to social influence is meaningful in
381 several ways. In medical and health care settings, doctors and caregivers might
382 underestimate or overestimate patients' pain based on social information (e.g., from peers,
383 text books), which might even overrule self-reported pain ratings from the patients
384 themselves (Dirupo et al., 2021). As a potential consequence, patients may receive
385 inadequate or excessive treatment (Cremeans-Smith et al., 2003), especially in
386 combination with other pain estimation biases such as those related to gender or minority
387 status (Hoffman, et al., 2016; Losin et al. 2020; Zhang et al., 2021; Mende-Siedlecki et al.,
388 2021, Hadjistavropoulos, et al., 2014). Together, such contextual biases may lead to
389 systematic errors in patients' pain estimations in clinical settings (Dirupo et al., 2021;
390 Kappesser et al., 2006).

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

401 Observational learning plays an especially important role in development.
402 Children's pain responses are shaped by observing parents' verbal and nonverbal pain
403 behaviors such as facial pain expressions in pain situations (for a review, see Goubert et
404 al., 2011). Similarly, children's empathic responses to others' suffering could be influenced
405 by how their parents and other role models respond to others' suffering. Social influence
406 might thus be employed as a promising tool for enhancing empathy and altruistic behavior.
407 For instance, an experimental study has shown that donations to homeless shelters
408 increased when individuals were exposed to high empathy ratings or to more generous
409 donation behaviors of others (Nook et al., 2016). This effect, and other effects on social
410 perceptions, may be explained as a rational (i.e., Bayesian) inference over multiple
411 sources of information (Baker, et al., 2009; Houlihan, et al., 2023). Social cues can also

412 guide attention to relevant dimensions of sensory input (e.g., its aversiveness or
413 painfulness); thus, participants may pay more attention to affective aspects of a stimulus
414 when they expect it to be more painful.

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

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

443 The present study has several limitations. Study 1 used a convenience sample of
444 mainly young and healthy participants recruited from the University of Colorado Boulder
445 community, potentially limiting its generalizability to other, more diverse populations.

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

470

471 **Conclusions**

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

479

480

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483

484

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