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Clinician-patient movement synchrony mediates social group effects on interpersonal trust and perceived pain

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Abstract:	Background Pain is an unfortunate consequence of many medical procedures that in many patients becomes chronic and debilitating. Among the factors affecting medical pain, clinician-patient (C-P) similarity and nonverbal communication are particularly important for pain diagnosis and treatment. We tested the role of C-P nonverbal communication on (1) perceived clinician trustworthiness and (2) patients' pain perception in an experimental pain study in healthy volunteers. Methods Participants (N=66) were grouped into C-P dyads, with one participant assigned to the clinician and the other to the patient role. Clinicians administered painful stimuli to patients. We manipulated the perceived C-P similarity of each dyad, and each patient was tested twice: Once with a clinician who shared their core beliefs and values (concordant, CC) and once with a clinician who did not (discordant, DC). Interactions were videotaped and movement synchrony was calculated as a marker of the nonverbal communication. Mediation models tested whether movement synchrony mediated the effects of group concordance on patients' pain and trust in the clinician. Results Movement synchrony captured from video was higher in CC than DC dyads ($F(1, 31)=16.06$, $p=0.0003$, Cohen's $d=0.71$). Higher movement synchrony predicted reduced pain ($F(1, 35)=8.49$, $p=0.006$, Cohen's $d=0.49$) and increased trust in the clinician ($F(1, 30)=7.76$, $p=0.009$, Cohen's $d=0.51$). Movement synchrony also formally mediated the group concordance effects on pain (mediation effect=-3.07, $p=0.005$) and trust (mediation effect=7.03, $p=0.001$). Conclusions Movement synchrony in clinician-patient interactions is an unobtrusive measure related to C-P relationship quality, trust towards the clinician, and pain. These findings increase our understanding of the role of nonverbal C-P communication on pain and related outcomes, and suggest that interpersonal synchrony may be associated with better patient outcomes, independent of the specific treatment provided.
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Clinician-patient movement synchrony mediates social group effects on interpersonal trust and perceived pain

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Abstract

Background: Pain is an unfortunate consequence of many medical procedures that in many patients becomes chronic and debilitating. Among the factors affecting medical pain, clinician-patient (C-P) similarity and nonverbal communication are particularly important for pain diagnosis and treatment. We tested the role of C-P nonverbal communication on (1) perceived clinician trustworthiness and (2) patients' pain .perception in an experimental pain study in healthy volunteers

Methods: Participants (N=66) were grouped into C-P dyads, with one participant assigned to the clinician and the other to the patient role. Clinicians administered painful stimuli to patients. We manipulated the perceived C-P similarity of each dyad, and each patient was tested twice: Once with a clinician who shared their core beliefs and values (concordant, CC) and once with a clinician who did not (discordant, DC). Interactions were videotaped and movement synchrony was calculated as a marker of the nonverbal communication. Mediation models tested whether movement synchrony mediated the effects of group concordance on patients' pain and trust in the .clinician

Results: Movement synchrony captured from video was higher in CC than DC dyads ($F(1, 31)=16.06$, $p=0.0003$, Cohen's $d=0.71$). Higher movement synchrony predicted reduced pain ($F(1, 35)=8.49$, $p=0.006$, Cohen's $d=0.49$) and increased trust in the clinician ($F(1, 30)=7.76$, $p=0.009$, Cohen's $d=0.51$). Movement synchrony also formally mediated the group concordance effects on pain (mediation effect=-3.07, .p=0.005) and trust (mediation effect=7.03, p=0.001)

Conclusions: Movement synchrony in clinician-patient interactions is an unobtrusive measure related to C-P relationship quality, trust towards the clinician, and pain. These findings increase our understanding of the role of nonverbal C-P communication on pain and related outcomes, and suggest that interpersonal synchrony may be associated with better patient outcomes, independent of the specific .treatment provided

Background

Pain is the primary reason patients seek medical care and a feature of a large number of clinical disorders. It is also an unfortunate consequence of many medical procedures that in many patients becomes chronic and debilitating[1]. Recent estimates suggest that 22–67% of patients after thoracotomy, 30–81% of patients after a limb amputation, and 11–51% of women after breast surgery developed chronic post-surgical pain [1–4]. Pain in post-operative and other contexts is associated with poor mental health, disability, and costs in work productivity and family relationships [5–1112,13]. Prevention and effective relief of acute pain may improve clinical outcomes, .avoid clinical complications, save healthcare resources, and improve quality of life [14]

Recent work has shown that psychosocial, cultural, and behavioral factors are a key part of pain management and care [15–2115,16] Individual studies and systematic reviews have consistently found that pain beliefs and avoidance [22,23,24,25,25,26,27,2829,30] and negative affect--particularly anxiety and depression [22,23,24,25,25,26,27,2829,30]are consistently associated with higher levels of pain, poor functioning, and worse outcomes after multiple treatments, including spine surgery, nerve blocks, spinal cord . stimulator implant, physical therapy, and opioid treatment [25,27,31–37]

An important, but under-explored, aspect of the biobehavioral context surrounding pain is the interpersonal context, and interactions between clinicians and patients in particular [38]. Indeed, clinician-patient (C-P) communication may play a key role in clinical outcomes [39–4445–48]. For example, previous studies have shown a relationship between clinicians' nonverbal behavior and patients' satisfaction [49–51] and trust in clinicians [52], highlighting the importance of the therapeutic C-P relationship [53,54]. Moreover, effective C-P communication can improve patients’ outcomes, providing a partial explanation for the large placebo effects that are sometimes observed in pain [55]. Recent studies demonstrated that clinicians’ care and empathy can alter patients’ experience in clinical settings, resulting in analgesia or hyperalgesia [56–61]. For instance, providing emotional support can substantially improve objective and patient-centered outcomes during childbirth [62–65] In experimental studies, analgesia can be produced by social observation of others showing signs of pain relief [66–68], social touch [69–71] , and other interpersonal manipulations. For example, changing the meaning of pain experience by (a) normalizing pain as ‘healthy’ [72] or (b) voluntarily choosing pain on behalf of a close other [73] can both causally reduce the intensity of evoked pain in experimental studies. A large medical literature demonstrates the importance of C-P concordance, i.e., the match in perceived group membership between clinicians and patients. C-P concordance is related to multiple factors, particularly similarity perceived values and shared culture. Aspects of C-P discordance--particularly, discordance in race and gender--may negative affect multiple clinical outcomes [74–77 78–81 79,82–84 79,85,86 87 88], including pain [89,90] and trust in the clinician [88]. In contrast, shared sociocultural group membership (e.g., race, gender, and language) has been reported to increase patient satisfaction and to decrease pain levels [91–94]. In addition, we previously found that interacting with a concordant simulated ‘clinician’ with similar values resulted in reduced pain .compared with treatment by a discordant clinician [95]

C-P concordance may have multiple benefits, but some of the most important include enhancing the therapeutic alliance and trust in the clinician [96,97]. The therapeutic alliance is thought to be grounded in the coupling between the therapist’s and patient’s brains, providing access to internal states, which facilitates emotional sharing and common understanding [98]. Recent research has examined elements of the C-P relationship and has revealed that interpersonal factors such as communication [99], social support [100,101] and expectations of pain reduction [102,103] have been reported to influence pain [104]. Other studies have reported a decrease in disease-related pain when clinicians had been trained in improving the C-P relationship [60,105,106]. However, social influence and C-P communication in particular have been under-studied in medical settings. We need more research to investigate C-P interactions in order to understand the features of interpersonal C-P interaction that could affect health .outcomes. That is the goal of the current study

Though they are demonstrably important, the mechanisms underlying C-P communication are understudied, and measures of effective C-P communication are lacking. One important aspect concerns nonverbal behavior, and in particular interpersonal synchrony. A large literature of nonverbal communication demonstrates that eye contact, supportive touch, smiling, nodding, engaged posture are associated with stronger C-P relationships and improved patients’ health outcomes and satisfaction [107–114]. Movement synchrony is a particularly important aspect because it both provides a basis for inferred self-similarity and concordance (potentially increasing trust and therapeutic alliance) and can be measured non-invasively in .interpersonal interactions. We elaborate on this below

Movement Synchrony as a Behavioral Measure to Assess Interpersonal Behavior

The human ability to behave in synchrony with other individuals has important evolutionary significance [115]. Movement synchrony is frequently observed in the animal kingdom in various forms, e.g., synchronized periodic movements to create acoustic signals [116–118], synchronized collective movements among predators while hunting [119] and synchronized reactions to stressful and dangerous situations [119–121]. Humans also tend to coordinate their movements and imitate the postures and actions of others, whether they are aware of this or not [115,122,123]. Interpersonal synchrony could occur in any perceptual-motor system that operates automatically, such as breathing and heart rate patterns [69,124,125], facial expressions [126], eye gaze [127], or body movements [128,129]. For example, participants in a Spanish fire-walking ritual and close others observing them demonstrated synchronized heart rates; this synchrony did not occur with other members of the audience [125]. Interpersonal motor (movement) synchrony is easier to interpret and understand (vs. physiological synchrony) because the link between perception and motor action is highly automatic [130–132]. Thus, motor activity provides a continuous stream of behavior that can be spontaneously and effortlessly synchronized, even when a person’s conscious attention is directed elsewhere [133,134]. Moreover, our tendency to automatically mimic and synchronize movements with others has been suggested to result in emotional contagion [135,136], affect social behavior [135,137] and play a key role in the development of empathy [138]. Indeed, during C-P interactions, certain nonverbal behaviors such as smiling, nodding, eye contact, and forward trunk lean affect patient’s ratings of the clinician's interpersonal skills, their relationship quality, and their rapport [139–142]. In clinical settings, practicing active listening, which blurs the boundaries with the patient and increases the feeling of similarity, results in increased C-P movement

.synchrony [143]

In addition, because it can be readily measured from interpersonal interactions, movement synchrony may be useful as a behavioral marker for effective interactions [144–146]. Currently, there is a large initiative to develop measures related to pain and its biological correlates (biomarkers) [147–151], including behavioral measures, but measures .of interpersonal communication are still lacking

In this study, we use an experimental procedure to test a model in which C-P concordance influences pain in a manner mediated by interpersonal movement .synchrony (Fig. 1)

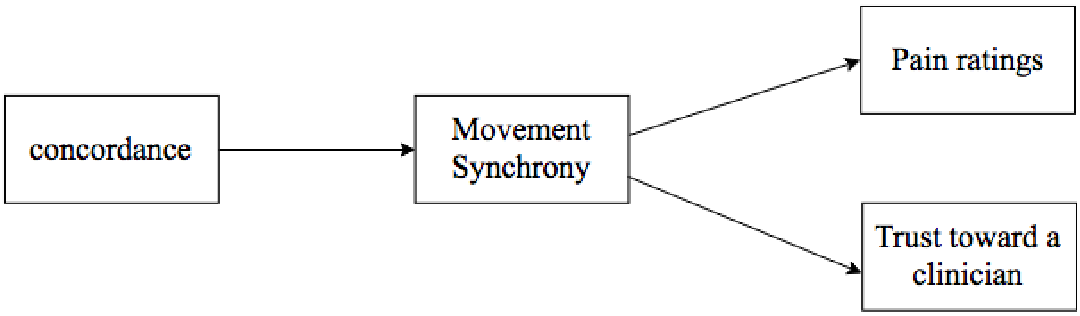

FIgure 1. Proposed mediation model: movement synchrony mediates the effects of .group concordance on pain perception and trust toward the clinician

In addition, trust toward the clinician is a very significant clinical outcome, especially for a long-term therapy, that could be enhanced by the patient's feeling of interpersonal similarity [152,153]. For example, Street et al. (2008) showed that higher feelings of patients' similarity to clinicians predicted increased levels of trust toward the clinician and increased treatment adherence [154]. In addition, there is evidence that interpersonal synchrony affects trust [155,156]. Based on these findings, we also suggest that interpersonal synchrony mediates the effect of C-P similarity on patient trust

.toward the clinician

In the current study we used the data partially reported in Losin et al. (2017) [95]. As described in [95], we simulated clinical interactions applying a modified minimal group paradigm, [157] manipulating feelings of similarity between participants who played the roles of patients and clinicians. Because similarity of patients' personal beliefs and values to their physicians have been reported to predict health outcomes [154], we used responses to a self-reported assessment of personal values and beliefs related to politics, gender, and religion to constitute the groups. Thus, each "patient" (and "clinician") was paired with a "clinician" (and "patient") in a concordant group and in a discordant group. The initial study reported that patients reported feeling less .pain with a clinician that was perceived as more similar and trustworthy

The key element of the current study was the motor synchrony between clinicians and patients, calculated from the recorded video of the interaction. We predicted that there would be lower pain ratings when patients were paired with group-concordant clinicians and that would be mediated by their motor synchrony

We also predicted that higher ''patient'' ratings of trust toward the ''clinician" in concordant interactions would be mediated by the motor synchrony between the .partners

Methods

Participants

Eighty individuals (40 male) aged 19 to 54 years old (mean = 26.19, SD = 9.43) were recruited and tested in dyads. Videos of both participants in each dyad were recorded throughout the interaction using tripod-mounted cameras. Due to video recording failures or poor video quality, 14 simulated interactions were excluded from the analysis, resulting in a final sample size of 66 participants (34 male). Participants were in the moderate range in socioeconomic status (SES; mean = 33.55, SD = 12.32, scale from 8 to 66) and reported no current or recent neurological or psychiatric diagnoses. They also reported no use of psychoactive or pain medications, pain-related medical conditions, or unusual pain sensitivity. Participants were recruited through the Sona paid subject pool at the University of Colorado Boulder, which included members of the university and surrounding community. Only subjects from the Sona database who met the inclusion criteria were contacted. The study was approved by the University of Colorado Boulder institutional review board and .written informed consent was obtained from all participants

Group Assignment and Manipulation Check

To manipulate feelings of interpersonal similarity between participants, we created artificial sociocultural groups on the basis of participants' core beliefs and values. Participants were paired with two different partners one assigned to be of the same group (concordant, CC) and one of a different group (discordant, DC), and underwent a simulated interaction with an opposite role partner, playing the role of clinician and patient (a modification of the minimal group paradigm) [158].Participants were recruited and tested in groups of 4, with one 'patient' and one 'doctor' in each of the two groups pairing up to form a CC and a DC dyad. Because previous studies have shown an effect of subject-experimenter gender concordance on pain ratings, each group was .either all male or all female [159,160]

One week before the main laboratory session, participants completed the Personal Beliefs and Values Questionnaire (PBVQ), with a composite measure that included questions about the following: (1) gender role beliefs and values from the World

Values Survey Wave 5 [161], (2) religious beliefs and values from the Duke University Religion Index, [162] and (3) politically polarized beliefs and values used in a previous .study [163]. Participants accessed the PBVQ online via Qualtrics (Qualtrics Labs, Inc) Upon arrival at the lab, all participants repeated the PBVQ as a reminder, and the experimenter explained that ‘‘We’re going to use your answers to that questionnaire to divide you into 2 groups. For confidentiality reasons, we’re going to use color labels of green and yellow to assign the groups, but you can assume those in your color group have more similar values to yours than those in the other group.’’ In order to avoid deception, participants were assigned to either the “yellow” or the “green” groups based on the correlations in their PBVQ responses and given group color-coded garments to wear during the session. However, the actual values and beliefs of the participants on a given day varied randomly because participants were not recruited for the study based on this information. Therefore, the group assignment did not systematically affect the degree of belief and value similarity between participants in the same group or any consistent association between group identity (green or yellow) and a particular belief or value orientation. Therefore, any consistent effects of the group manipulation could be associated only with the subjects’ assumption of shared values and beliefs resulting from the group assignment – similar to the effects of real-world shared group membership perceived during brief clinical interactions. To test the efficacy of the group manipulation, participants completed a 3-item Group Identification Questionnaire at the end of the study, modified from the Collective Identification Scale [164] regarding their group membership (e.g., ‘‘I am proud to be a member of the green/yellow group”). Participants’ responses on a 150-point visual analog scale (0 = no belief to 150 = strongest belief), the Study Belief Index, indicated moderate to strong belief in the stated purpose of the study, the stated basis for group assignment, and the realism of the simulated clinical interactions (patient participants: mean = 75.63, SD = 28.66; clinician participants: mean = 84.46, SD = 28.78). The participants were told that the study aims to investigate ‘‘the effects of people’s ’’.personal beliefs and values on their experience when they get medical care

Clinician and Patient Assignment and Training

Participants were randomly assigned to the role of patient or clinician and provided with clothing to match their role: hospital gowns for patients or white lab coats with scrubs for clinicians (Fig. 2A, 2C). Clinicians practiced an interaction with patients by administering the heat stimulation procedure to the patients. The patients went through heat familiarization task and practiced making continuous within-trial and overall post-trial pain intensity ratings. Participants were trained in the simulated clinical interaction in groups of two based on their role, not group assignment. Thus, yellow and green patients as well as yellow and green clinicians were trained together .(Fig. 2A, 2C)

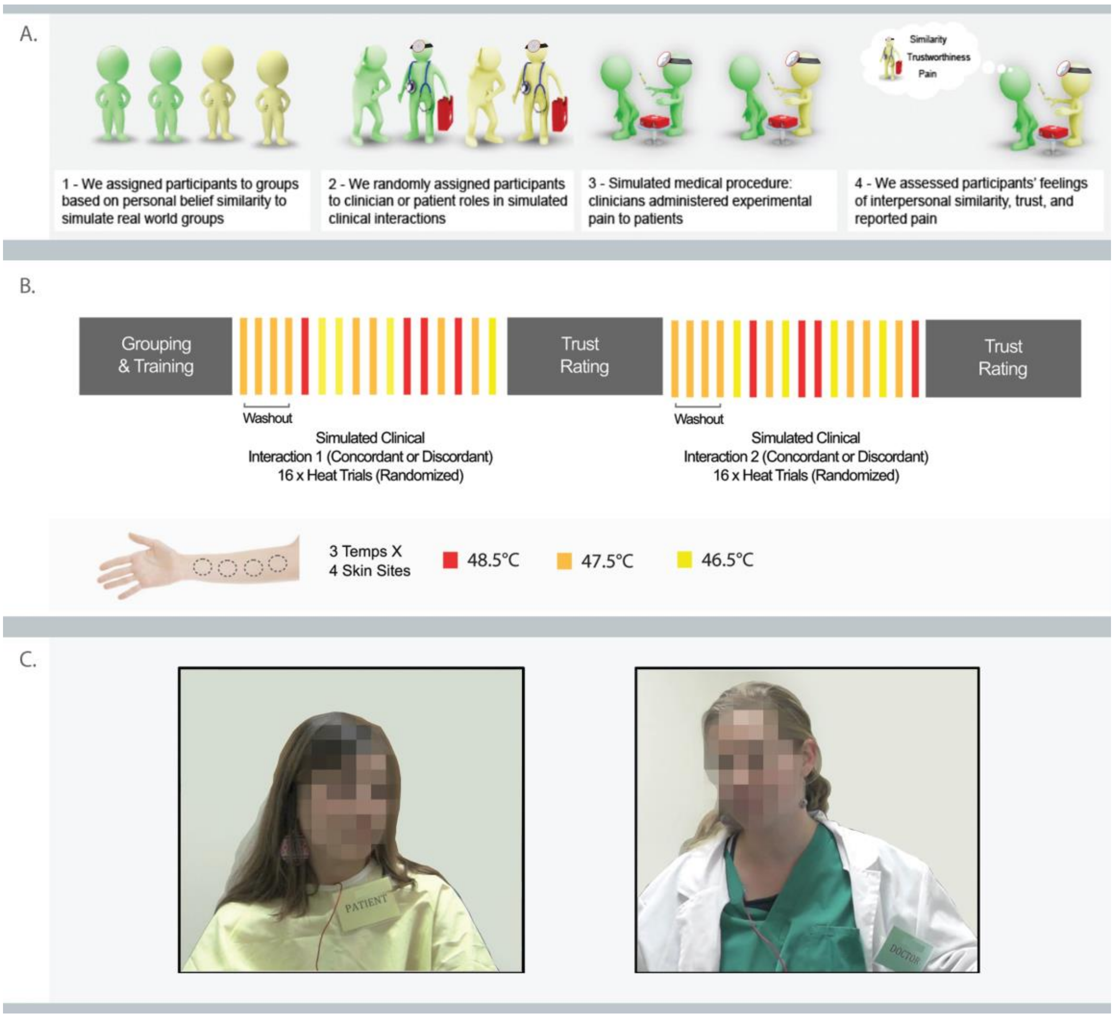

Figure 2. The design of the current study. A. We randomly assigned participants to the role of either patient or clinician (1 in each group/dyad). During each study session, a patient took part in two simulated clinical interactions, one with a clinician from the same color group (CC interaction) and one with a clinician from the other color group (DC interaction), with the interaction order counterbalanced. B. Each clinical interaction included 16 heat trials: a medium heat ''washout'' stimulus (47.5°C) delivered to each skin site (4 trials) at the beginning of the heat stimulation procedure for the initial habituation of the skin site to contact heat followed by a single trial at each temperature on each of the 4 skin sites (12 trials) in a randomized order. C. An example of the recorded clinical simulation. Participants were provided with clothing to match .their roles: hospital gowns for patients and white lab coats with scrubs for clinicians

Clinician and Patient in Simulated Clinical Interaction

During each study session, a patient took part in two simulated clinical interactions, one with a clinician from the same color group (concordant interaction) and one with a clinician from the other color group (discordant interaction), with the interaction order counterbalanced across participants. During the session, the experimenter was seated at a table behind and partially out of view of the subjects to track the quality and safety of the heat procedure while maximizing the realism of the simulated .clinical interaction

At the start of the clinical interaction, the clinician introduced himself or herself to the patient, repeating the explanation of the heat stimulation procedure and reminding the patient that it was being applied analogously to a painful medical procedure (Fig. 2B). The clinician also reminded the patient that the thermal stimulation could be stopped at any point if the pain became intolerable. The clinician was also allowed to engage in conversation on any other topic to establish rapport with the patient throughout the .interaction. Afterwards, the clinician applied the thermal stimulation to the patient

Thermal stimulation was applied by E-Prime software (E-Prime 2.0; Psychology Software Tools, Inc, Pittsburgh, PA) and was delivered to 4 evenly spaced locations on the volar surface of the left forearm of the patient using a 16x16 mm contact Peltier thermode (Medoc, Inc, Ramat Yishai, Israel). Thermal stimulation was administered at 3 target temperatures (46.5°C, 47.5°C, and 48.5°C). All heat stimuli were 11 seconds in duration, consisting of 7.3 seconds at the target temperature, and 1.85-second ramp periods to get to/from the target temperature from/to the 32°C baseline temperature. Each trial was preceded by the clinician's cue ''Get Ready!'' and the trials were separated by variable delays. Fig. 2B provides a more detailed explanation of the trial and task structure. Each clinical interaction included 16 heat trials: a medium heat ''washout'' stimulus (47.5°C) delivered to each skin site (4 trials) at the beginning of the heat stimulation procedure for the initial habituation of the skin site to contact heat followed by a single trial at each temperature on each of the 4 skin sites (12 trials) in a randomized order [165,166]. The clinician intermittently reminded the patient throughout the procedure that he/she may terminate the heat .stimulation at any time if the pain became intolerable or for any other reason

Pain Rating

At the end of each trial, patients rated the overall pain intensity experienced on a 100-point generalized, labeled magnitude scale using a computer mouse (0 = no experience, 100 = strongest imaginable experience) [167]. Intermediate ticks were marked at 1.4 (barely detectable), 6 (weak), 17 (moderate), 35 (strong), and 53 (very strong); only the labels and not the numbers were visible to the patients. The general labels on the scale have been reported to allow for effective comparison of sensory and affective experiences across modalities and people, and the label spacing has been .reported to provide the scale with ratio properties [167]

Patient perceptions of similarity and trust toward the clinician

After each simulated clinical interaction, the patients completed the following questionnaires about their trust toward their clinicians. The trust toward the clinician was measured by a trust visual analog scale (TVAS), a single-item measure that asked participants to rate how much they trusted the clinician (‘‘I trust the green/yellow clinician’) on scale ranging from 0 (not at all) to 150 (extremely) [95]. The patients also completed The Wake Forest Physician Trust Scale [168], a clinically validated 10-item measure that assessed the patient’s perceptions of the clinician’s behavior and the patient’s trust in the clinician [169]; patients rated their trust toward the clinicians on a scale from 1 (strongly agree) to 5 (strongly disagree), and the responses were summed with higher values corresponding to more trust [95]. Because of the conceptual overlap in The Wake Forest Physician Trust Scale and the TVAS, they were rescaled and averaged to create a single composite measure of patients' trust toward clinicians on a .scale 0 to 150, with higher values reflecting higher levels of trust

Movement synchrony analysis

The video was processed by Motion Energy Analysis (MEA) software [128], designed to quantify movement in digital video recordings. Detection of frame-by-frame change allowed an objective quantification of movement occurring in spatially predefined regions of interest (ROIs). The method is based on the fact that each individual frame of a black-to-white scale has a fixed number

of pixels that represent a distribution of gray-scale values ranging from 0 (black) to 255 (white). Motion energy is defined as differences in grayscale pixels between consecutive video frames [129,170–172]. MEA thus generates time series of raw pixel changes within an ROI, and a second-order Butterworth low-pass filter with a cutoff at 2.4 Hz was applied prior to further analyses. Head motion synchrony was used as a marker of interpersonal synchrony based on previous studies using automatic techniques for measuring synchrony in velocity (for review, see [173]). Head motion has also been used to analyze nonverbal dyad interactions in psychotherapy [128,129,174]. In the current study, the participants' head movements were tracked via Samsung HMX-QF30 HD ((1,280 x 720 60p) video camera. Because the dyads may have differed in the dynamics of their interaction, we identified for each dyad the three lags that showed the maximal correlation using 10-second running windows (applying windows of 5 and 15 seconds yielded similar results) and exploring all possible lags within a 5-second lag in each direction. The Fisher Z-transformed values of the maximum cross-correlations were averaged for each C-P interaction. Figure 3 presents the running window cross-correlations of the maximal three lags for a CC dyad and a DC dyad. All lags were very close to zero (M=0.63, SD=1.43, min=0, .max=11=1/3 sec)

Statistical analysis

We applied the multilevel modeling (MLM) framework for the hypothesis testing and assumed random intercepts for patients and clinicians to treat the nested nature of the data with R package lme4. The model allowed taking the dependent structure of the data into account. In our case, we modeled C-P interactions nested in clinicians (2 data points) and patients (2 data points). Using this framework, mediation models were tested using a quasi-Bayesian Monte Carlo method with 5000 simulations and .White's heteroskedasticity-consistent estimator for the covariance matrix [175,176]

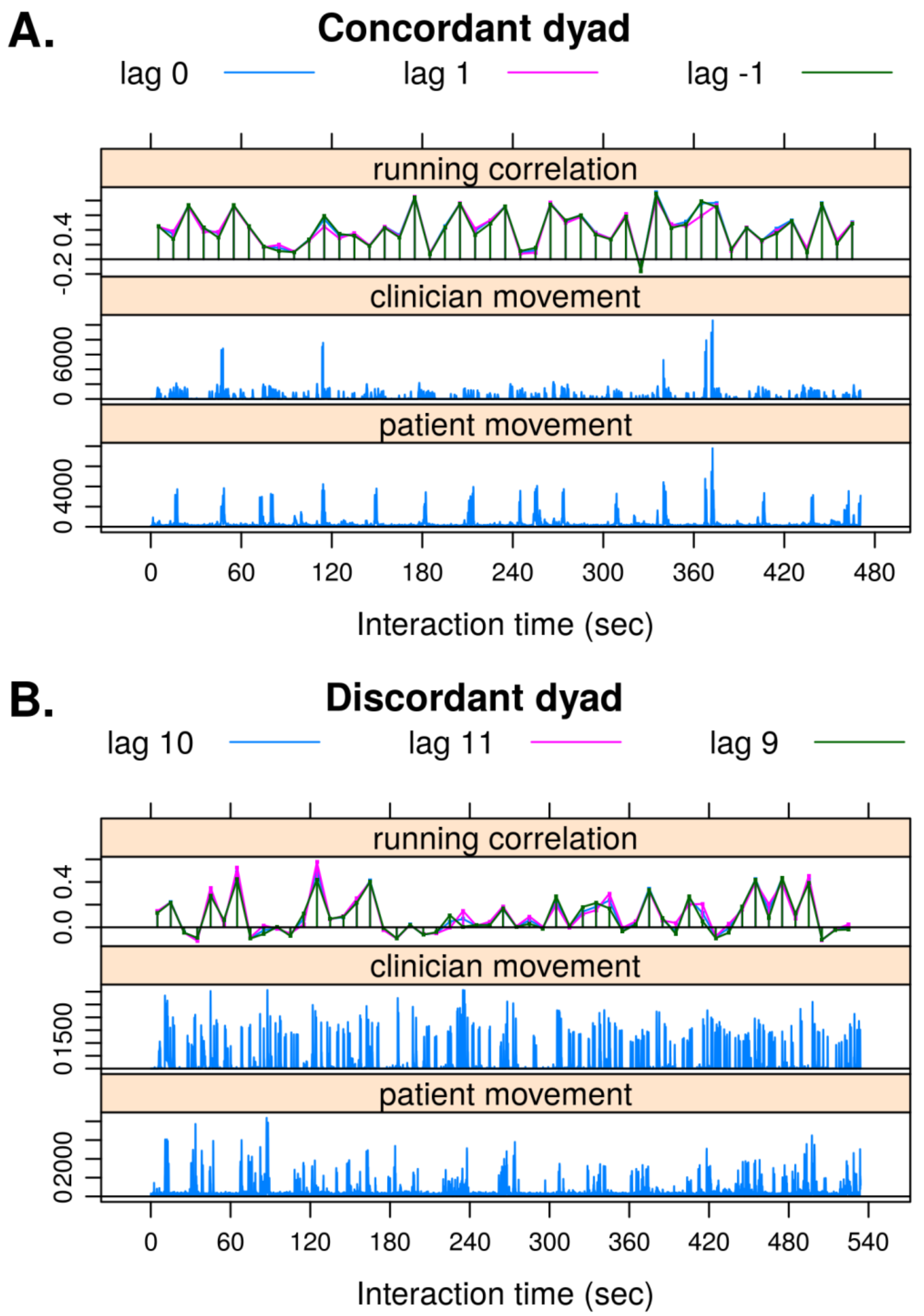

Figure 3. Example of the movement data and windowed cross-correlations for the 3 lags of the maximum correlation: (a) a CC C-P dyad and (b) a DC Trust in clinician C-P dyad. The y-axis represents the windowed cross-correlations, and the x-axis represents the interaction time. The running windows are 300 frames (10 s) of length. The top subplot presents the moving window correlation over time. The middle and bottom .subplots represent the clinician's and the patient's movement activity, respectively

To examine a mediation model in which the grouping manipulation predicts changes in movement synchrony, which in turn predicts patient pain rating, we conducted a series of analyses (Figure 1). The outcome measure for the mediation analysis was the patient pain rating at the end of each trial. Here we applied the following two models as described above: (a) to test the group concordance effect on movement synchrony; and (b) to test the association between movement synchrony and pain ratings, .conditioned on the effect of the belief manipulation (group concordance)

Finally, the mediation effect was defined as a*b and statistical inferences were made based on the approach described above [175,176]. Cohen's d statistics were provided as estimates of the model effect sizes [177]. Robust inferential methods are available that perform well with relatively small sample sizes [178,179]. Here we reanalyzed the data using an extension of this approach for linear mixed models [180] based on multivariate MM-estimators via R package robustlmm. Generally, the procedure fit a weight for each observation using the Mahalanobis distance, i.e., the tail observations receive less weight. The significance of the model estimated was calculated using a robust Wald test and the mediation effect was tested based on the approach proposed by Zu and Yuan (2010) in which a bootstrap estimation of mediation effect was combined .with a robust estimation routine [181]

It is important to emphasize that patients pain level was measured after the heat stimuli were terminated, and the video fragments of the ratings were cut from the analysis of motor synchrony because at that moment the participants were not engaged in the interpersonal interaction. In addition, trust toward the doctor was estimated at the end of each section. Thus, the data used in the mediation models had .the appropriate temporal order

Results

Control variables

The absolute level of movement of the patient and clinician may have been related to their movement synchrony or the patients' pain perception and trust toward the clinician. For this reason, the association between the movement intensity of both clinicians and patients with movement synchrony, pain ratings and trust was initially tested. Patient movement synchrony increased pain ratings (B=.0005, 95% CI [.0002, .0007], F(1, 55)=12.96, p=0.0007, Cohen's d=0.48 [0.21, 0.75]), decreased patients pain ratings (B=-.034, 95% CI [-.064, -.005], F(1, 33)=5.21, p=0.03, Cohen's d=0.40 [0.04, 0.75]), enhanced trust toward the clinician (B=.092, 95% CI [.009, .172], F(1, 63)=4.87, p=0.03, Cohen's d=0.28 [0.03, 0.53]), and therefore, they were included in the subsequent analyses. Clinician movement intensity was not related to patient movement synchrony (B=.0001, 95% CI [-.0001, .0003], F(1, 57)=1.42, p=0.24), pain ratings (B=.015, 95% CI [-.013, .043], F(1, 34)=1.08, p=0.30), or trust toward the clinician (B=.045, 95% CI [-.028, .1109], F(1, 63)=1.45, .p=0.23)

Mediation analysis

The similarity manipulation did not affect patients' pain rating (B=-2.45, 95% CI [-5.54, 0.59], F(1, 32)=2.60, p=0.11). However, similarity manipulation enhanced movement synchrony (Fig.4A) (B=0.05, 95% CI [0.03 0.08], F(1, 31)=16.06, .p=0.0003, Cohen's d=0.71 [0.34, 1.07])

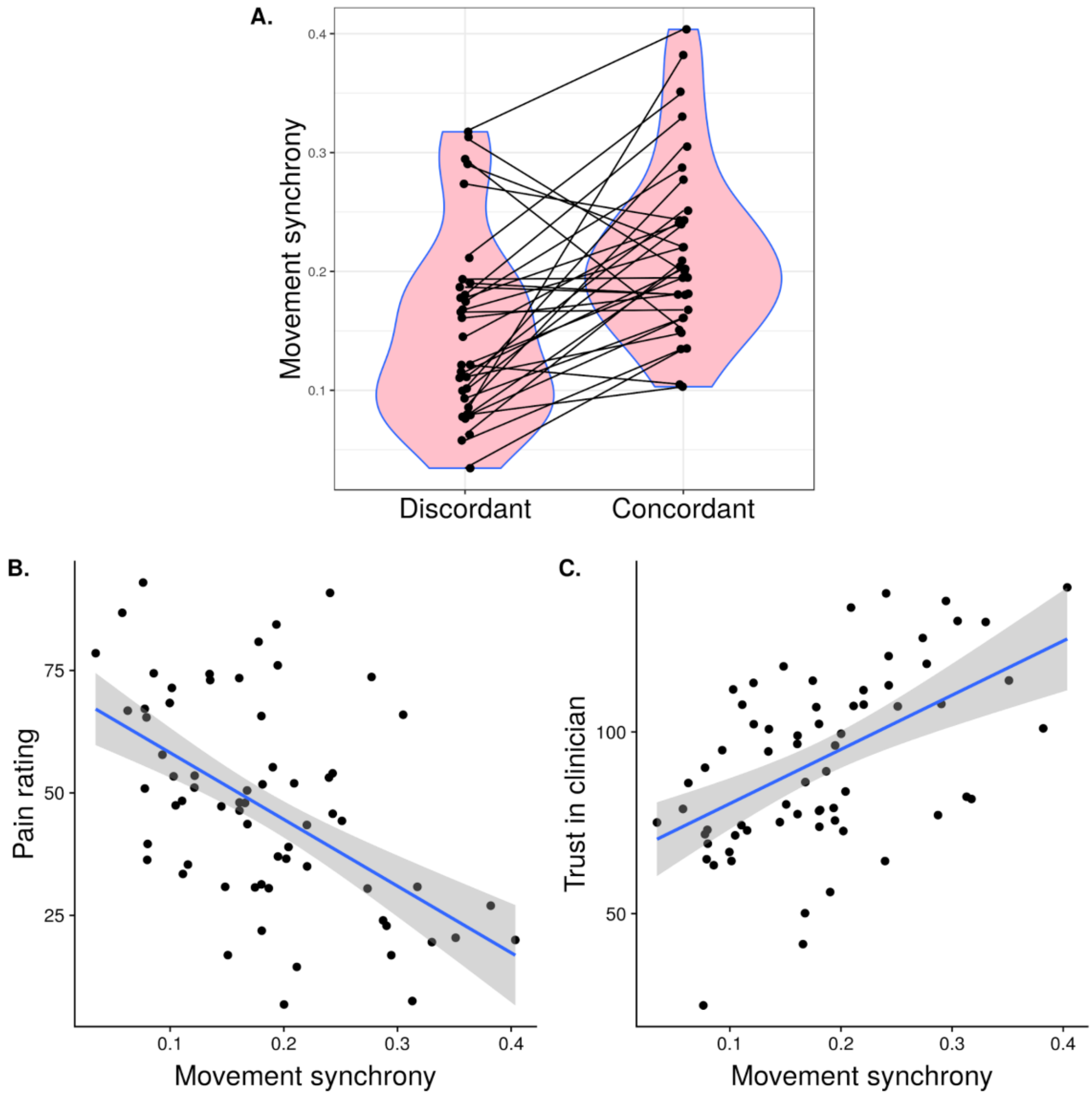

Figure 4. A. Movement synchrony differences between concordant and discordant dyads, based on the experimental manipulation of their perceived belief similarity (Cohen's d=0.71). B. Movement synchrony is negatively associated with patients' pain ratings (Cohen's d=0.49) . C. Movement synchrony is positively associated with patients' trust toward the clinician Cohen's d=0.45. Model prediction lines with corresponding .95% confidence intervals are presented

Moreover, adjusting for the concordance manipulation, movement synchrony was associated with decreased patients' pain rating (B=-55.18, 95% CI [-95.22, -17.20], F(1, 35)=8.49, p=0.006, Cohen's d=0.49 [0.15, 0.84]) (Fig. 4B). Finally, C-P movement synchrony mediated the effect C-P concordance on patient pain ratings (indirect=-3.07 [-5.94, -0.82], p=0.005) (Fig. 5A). Conditioning on the effect of movement synchrony, the concordance group effect was not significant anymore .(B=0.35, 95% CI [-3.16, 3.98], F(1, 29)=0.04, p=0.85)

For the second mediation model with trust toward a clinician as a outcome, patients in the congruent condition reported an increased level of trust toward the doctor (B=13.59 [4.95, 23.84], F(1, 30)=7.76 , p=0.009, Cohen's d=0.51 [0.14, 0.88]) (Fig. 4C). In addition, movement synchrony was associated with increased patients' trust toward the clinician (B=126.13, 95% CI [67.68, 182.08], F(1, 56)=11.50, p=0.001, Cohen's d=0.45 [0.18, 0.71]), adjusting for the effect of group. Conditioning on the effect of movement synchrony, the concordance group effect was not significant anymore (B=6.48, 95% CI [-2.03, 16.78], F(1, 36)=1.58, p=0.21). Finally, C-P motor synchrony mediated the group difference in patients' trust toward the clinician (indirect=7.03 [2.37,13.29], p=0.001) (Fig. 5B), suggesting complete mediation of the .effect of C-P movement synchrony on the pain rating concordance bias

Finally, we found that both outcomes (patients' pain and trust in clinician) are negatively correlated when controlling for patient and clinician movements (B=-.0.33, 95% CI [-0.65, -0.06], F(1, 32)=5.40, p=0.03, Cohen's d=0.41 [0.05, 0.77])

Discussion

In this study, we tested the mediating role of C-P movement synchrony in the patient's analgesia and trust toward the clinician as a result of perceived similarity with the clinician. Our findings support the hypothesis that group-concordant (CC) dyads demonstrated a higher level of movement synchrony than group-discordant (DC)

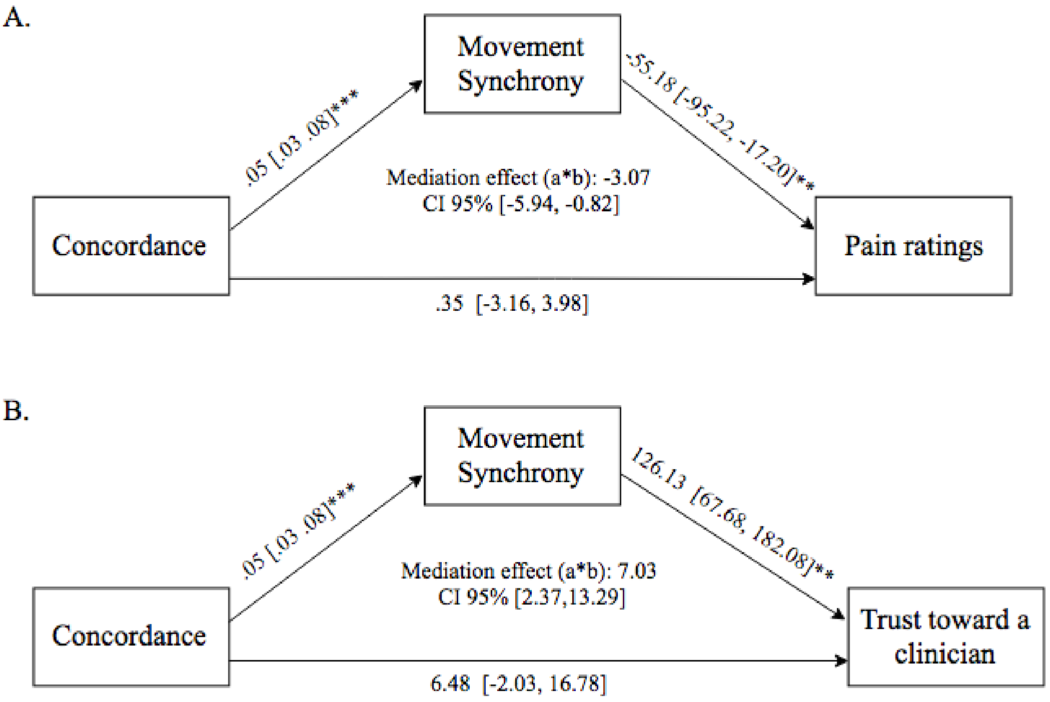

Figure 5. Mediation model findings for a) patients' pain ratings and b) patients' trust toward the clinician. The numbers in the brackets show 95% confidence intervals for .the estimates

dyads, which in turn predicted lower pain ratings in patients and greater trust toward the clinician. Mediation analyses showed that movement synchrony was a complete mediator of group concordance effects on perceived pain and trust toward the clinician, meaning that movement synchrony is sufficient to explain the interpersonal context effects on both pain and trust. Trust and pain were also associated, suggesting a link between them, though trust was not sufficient to explain the relationship .between movement synchrony and pain

These findings increase our understanding of how the biobehavioral context surrounding painful experiences influences pain perception. They fit in with a broader literature showing that social, cultural, and contextual factors influence pain perception [125,182–184]. Contextual factors, including effects of interpersonal communication, are often categorized as ‘top-down’ effects, as they are driven by how an individual conceives of the context in which pain and other symptoms occur. Such effects can be clinically significant. For example, a randomized controlled trial of enhanced vs. limited clinician-patient interactions showed substantial benefits in irritable bowel syndrome pain and functionality at 3 weeks [60]. Benefits were related to the quality of interpersonal interactions [61]. Our findings, combined with others, suggest that interpersonal communication may be quite important for pain .independent of the verum treatments supplied

As pain is the primary reason patients seek medical care and a strong driver of patient satisfaction [185], this study suggests that enhancing C-P interactions could be beneficial across medical settings. Across disorders, there are substantial inter-clinician differences in treatment responses [61,186], and substantial variations across clinics delivering the same nominal treatments [187]. Therapeutic alliance, a construct reflecting patients' acceptance of a treatment and affiliation with the clinician, has been identified as one of the most important factors influencing patient outcomes [188,189]. More broadly, social affiliation and perceived ingroup support are related to resilience against stress reactivity [190] and poor mental health [191], and possibly systemic inflammation [192]. But unpacking the factors leading to effective interpersonal communication has been challenging. Here, we identified one particular, under-appreciated aspect of interpersonal communication -- movement synchrony -- which .is an accessible target for measurement and intervention

Movement synchrony may be important for a variety of reasons. Humans show a tendency to imitate the postures or actions of others [122,123]. This capacity develops early in life [193,194]. It plays a key role in the development of infant-mother bonding and in social communication [195,196] and may be an important ingredient of empathy more broadly [197]. Previous studies have highlighted the role of interpersonal synchrony in adaptive emotion-regulation [198–201], including regulation of anxiety and depression [129], touch-induced analgesia [69,70], and joint attention [202]. Synchrony may influence trust and pain through several mechanisms. Movement synchrony may enhance receptiveness to clinicians' suggestions, increase social connection and perceived self-other overlap [200], and reduce anxiety and negative mood, all of which have been linked to pain relief [25,95]. Synchrony may have bidirectional effects; mimicking others appears to increase receptivity to others' preferences, and being .mimicked may increase feelings of affiliation [203]

Some research also suggests that movement and kinesthetic cues play a particularly important role in low-level inferences about what external objects or agents should be associated with the self. For example, in patients with phantom pain after limb amputation, seeing and feeling arm movements in synchrony can help patients 're-integrate' the brain representation of a severed limb and reduce phantom pain [204,205]. A meta-analysis of these and other manipulations of visual-kinesthetic 'body illusions' showed large therapeutic effects [206]. Beyond the pain context, research has suggested that joint movement or movement synchrony is important for 'kinesthetic empathy' [197], which relates to awareness of the dynamic interactions between self and other, i.e., movement sensations in response to someone else's body movements or postures [197,207] that enable a response to the other's emotional state [208,209]. Moreover, oxytocin, a hormone that is reported to encourage social bonding, has also been reported to enhance movement synchrony [210]. Based on this evidence, movement synchrony might serve to increase low-level (and perhaps unconscious) inferences of self-relatedness, accompanied by enhanced positive affect and conscious feelings of affiliation and trust, accompanied by potentially enhanced oxytocin levels. These .relationships remain to be tested more completely in future studies

Because our findings bear on the perceived similarity in group membership between clinicians and patients, they also bear on issues of ethnic and racial disparities in health care. Despite the best intentions of physicians to provide equal treatment to all, groups that are under-represented in the clinician workforce may experience a mismatch in group identity. Such perceptions may affect multiple patient outcomes [74–76] including pain [89,90] and trust toward clinicians [88,211], and thus patient-reported outcomes more broadly. Reduced trust due to low perceived concordance may also have other effects beyond what we tested here, including delays in seeking medical care or filling prescriptions [78–81], low adherence to physician recommendations [79,85,86], less utilization of some preventive services [79,82–84], more missed medical appointments, [85] and substitution of alternative medicine for conventional care [87]. Among the mechanisms of poorer patient experiences in discordant C-P interactions is poorer quality communication [97]. Thus, discordance between a patient and a clinician may affect both parties. The nature of the discordance is most likely implicit [90,212,213], but may be reflected in body movements during the communication between patients and healthcare providers, i.e., through kinesthetic cues. Assessing movement synchrony and related interpersonal variables may thus be a productive way of .understanding and improving the quality of care in clinical settings

These results should be interpreted in light of several limitations that need to be acknowledged. The use of artificial sociocultural groups allows for random assignment of individuals to groups, and thus assessments of causal effects of C-P concordance. it also potentially enhances the generalizability of our findings to a variety of groups. However, it is still unclear how the concordance effects we observed here will generalize to those of real-world sociocultural groups in clinical settings. We expect variation across groups related to the particular groups and cultures studied. Future studies should increase the ecological validity (realism) of the simulated clinical interactions, including studies with actual clinicians and patients in hospital or other clinical settings. Likewise, our use of experimentally evoked pain provided a controlled stimulus that can be randomized and causal effects inferred; but clinical pain has distinct characteristics that are likely to vary across pain conditions and patient populations. The value of this study is in demonstrating causal effects in a controlled setting, complementing ecological studies of clinical interactions 'in the wild'. Finally, we only measured C-P ratings of trust after the experimental pain procedure to increase the ecological validity and the believability of the simulated clinical interactions. Consequently, patients' ratings of trust toward clinicians may have been influenced by the unpleasant experience of the pain. However, because group assignment was conducted at the beginning of the experiment and was also related to patients' trust toward their clinicians, experiences of pain cannot .exclusively explain the positive effects of C-P concordance on trust

Conclusions

In conclusion, these findings increase our understanding of the role that nonverbal C-P interactions may play in pain perception and pain-related outcomes and the mechanisms that may underlie this relationship. The findings suggest interpersonal movement synchrony as a measurable mechanism that underlies the effect of clinician-patient similarity on patients' trust in clinicians and pain experienced during medical care. In addition, these findings contribute to a growing literature demonstrating improved patient outcomes through placebo effects based on improving C-P communication [214,215]. Supporting clinicians in finding commonalities with their patients and enhancing positive nonverbal communication could improve .patient outcomes and patient satisfaction, whatever the specific treatment provided

List of abbreviations

C-P=clinician-patient, CC=concordant, DC=discordant, TVAS=trust visual analog scale, MEA=Motion Energy Analysis, MLM=multilevel modeling

Declarations

Ethics approval and consent to participate

The study was approved by the University of Colorado Boulder institutional review .board (12-0504). Written informed consent was obtained from all participants

Consent for publication

Not applicable

Availability of data and material

The datasets analysed during the current study are available in the github repository, https://github.com/canlab/Doc_pat_sync

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

EL and TW designed the study, EL collected the data and did initial data analysis, PG analyzed the data and prepared the first draft, SA contributed to writing the manuscript. All the authors prepared the final version of the manuscript and approved .it

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Endnotes

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To whom it may concern:

Please find enclosed the manuscript "Clinician-patient movement synchrony mediates social group effects on pain assessment and trust" for consideration for publication as a Research Article in *BMC Medicine.*

Synchronizing movement with other individuals is an evolutionarily conserved phenomenon that impacts emotions, social behavior, and empathy. In many clinician-patient interactions, movement synchrony is thought to facilitate emotional sharing and common understanding, thereby improving therapeutic outcomes. Here we reasoned that clinician-patient synchrony might be an important factor in patients' perceptions of pain, a ubiquitous factor related to patient-reported outcomes and perceived care across medical conditions.

Using a controlled experimental setting, we tested this hypothesis by (i) simulating clinician-patient interactions, pairing patients with clinicians with similar (concordant) or dissimilar (discordant) group identity; (ii) exposing patients to painful stimuli; and (iii) recording and quantifying patients' pain, and movement synchrony as a measure of non-verbal communication and potential mediator of effects on pain. We show for the first time that patient-clinician concordance results in a higher level of movement synchrony and, consequently, decreased patient pain ratings and increased trust in the doctor. We further show that movement synchrony mediated the group concordance effects on perceived pain and trust in clinician.

These findings provide important new links between clinician-patient concordance, patient trust, and the pain experienced during medical care through clinician-patient movement synchrony. These findings also increase our basic understanding of how pain is shaped by interpersonal context. These data are of broad clinical significance; they suggest that clinicians that find common ground with their patients have improved non-verbal communication and, consequently, better patient outcomes, independent of the specific treatment provided.

I confirm that all authors have approved the manuscript for submission and that the content of the manuscript has not been published, or submitted for publication elsewhere. We believe that this paper will be of interest to your readership, and we hope that you consider it for publication.

Yours sincerely,

Tor D. Wager

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