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

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Running Title: Clinician-patient synchrony mediates pain

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JPAIN-D-19-01264 - Highlights

1. Clinician-patient movement synchrony higher in sociocultural group concordant dyads
2. Higher clinician-patient movement synchrony predicts reductions in patients' pain
3. Higher clinician-patient movement synchrony predicts increased trust in clinician
4. Clinician-patient movement synchrony mediates concordance effects on patients' pain
5. Clinician-patient synchrony mediates concordance effects on trust in clinician

## Abstract

Pain is an unfortunate consequence of many medical procedures, which in some 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. Participants (N=66) were randomly assigned to the clinician and patient roles and were grouped into C-P dyads. Clinicians administered painful stimuli to patients as an analogue of a painful medical procedure. We manipulated the perceived C-P similarity of each dyad using groups ostensibly based on shared beliefs and values, and each patient was tested twice: Once with a same group clinician (concordant, CC) and once with a clinician from the other group (discordant, DC). Movement synchrony was calculated as a marker of nonverbal communication. We tested whether movement synchrony mediated the effects of group concordance on patients' pain and trust in the clinician. Movement synchrony was higher in CC than DC dyads. Higher movement synchrony predicted reduced pain and increased trust in the clinician. Movement synchrony also formally mediated the group concordance effects on pain and trust. 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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## Perspective

This article demonstrates that movement synchrony in clinician-patient interactions is an unobtrusive measure related to their relationship quality, trust towards the clinician, and pain. These findings suggest that interpersonal synchrony may be associated with better patient outcomes, independent of the specific treatment provided.

Keywords: Medical pain, placebo, therapeutic alliance, clinician-patient communication, trust toward the clinician

## Introduction

Pain is a primary reason patients seek medical care and is a feature of a large number of clinical disorders. Pain is also an unfortunate consequence of many medical procedures that can become chronic and debilitating [65,98,99,117]. Pain in post-operative and other contexts is associated with poor mental health, disability, and costs in work productivity and family relationships [2,3,7,18,25,51,105,142,145]. Prevention and effective relief of acute pain may improve clinical outcomes, avoid clinical complications, save healthcare resources, and improve quality of life [36].

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An important, but under-explored, aspect of the biobehavioral context surrounding pain is the interpersonal context, and interactions between clinicians and patients in particular [104]. Indeed, clinician-patient (C-P) communication may play a key role in clinical outcomes [8,12,17,21,29,50,54,100,113,153] affecting patients' satisfaction [43,44,150] and trust in clinicians [87]. Moreover, effective C-P communication can improve patients' outcomes, providing a partial explanation for the large placebo effects that are sometimes observed in pain [144]. For instance, analgesia can be produced by social observation of others showing signs of pain relief [32,33,71] and social touch [57–59].

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 [28]. Aspects of C-P discordance — particularly, discordance in race and gender — may negatively affect multiple clinical outcomes

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[10,15,19,22,26,28,34,60,73,116,126,141,147,149], including pain assessment [103,127] and trust in the clinician [60]. In contrast, shared sociocultural group membership (e.g., race, gender, and language) has been reported to increase patient satisfaction and to decrease pain levels [30,40,70,90,92].

C-P concordance may have multiple benefits, but some of the most important include enhancing the therapeutic alliance and trust in the clinician [35,89]. The therapeutic alliance is thought to be grounded in the coupling between the clinician's and patient's brains, providing access to internal states, which facilitates emotional sharing and common understanding, [20,83,124] which has in turn been associated with pain reduction [6,46,106].

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, and engaged posture are associated with stronger C-P relationships and improved patients' health outcomes and satisfaction [44,77,79,84,102,107,123,131].

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Movement synchrony is a particularly important aspect of interpersonal synchrony 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.

Humans tend to coordinate their movements and imitate the postures and actions of others [13,109,128]. This interpersonal motor (movement) synchrony is easy to interpret and understand because the link between perception and motor action is highly automatic [41,118,151]. 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 [23,66,67,130].

In this study, we simulated clinical interactions and manipulated feelings of similarity between participants who played the roles of patients and clinicians (hereafter clinicians and patients) by assigning them to color groups ostensibly based on their shared beliefs and values. Each "patient" (and "clinician") was paired with a "clinician" (and "patient") in a concordant group and in a discordant group. In Losin et al., 2017, we previously found that patients with concordant clinicians felt more trust and similarity towards their clinician, which in turn predicted lower pain ratings [95]. In the current study, we extend this work by investigating the role of 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 concordant clinicians and that that effect 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.

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## Methods

### Participants

Eighty individuals (40 male) aged 19 to 54 years old (mean = 26.19, SD = 9.43) were recruited and tested in dyads as reported in Losin et al., 2017 [95]. 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.

## Measures

### Pain rating

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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) [9]. 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 [9].

### Patient perceptions 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 a scale ranging from 0 (not at all) to 150 (extremely) [95]. The patients also completed The Wake Forest Physician Trust Scale [64], 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 [138]; 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]. We modified the language of the Wake Forest Physician Trust Scale to apply to the medical simulation context. For example, "You have no worries about putting your life in your doctor's hands" and "You completely trust your doctor's decisions about which medical treatments are best for you" were modified to read “You completely trust the green/yellow doctor and his/her decisions about how to perform the study procedures.” and “You have no worries about putting your safety in green doctor’s hands.”  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.

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**Movement synchrony analysis**

The video was processed by Motion Energy Analysis (MEA) software [120], 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

[1,108,115,121]. 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 [39]). Head motion has also been used to analyze nonverbal dyad interactions in psychotherapy [114,120,121]. 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, for each dyad we identified 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 1 presents the running window cross-correlations of the maximal three lags for a CC dyad (Fig. 1A) and a DC dyad (Fig. 1B). All lags were very close to zero (M=0.63, SD=1.43, min=0, max=11=1/3 sec).

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## Study Design

### Group assignment and manipulation check

To manipulate feelings of interpersonal similarity between participants, we created artificial sociocultural (green and yellow) groups on the basis of participants' core beliefs and values (a modification of the minimal group paradigm) [134]. 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) [134]. We then randomly assigned participants to play doctor or patient roles. Each participant took part in two simulated clinician-patient interactions, one with an interaction partner from the same group (concordant, CC) and one with an interaction partner from a different group (discordant, DC). Participants were recruited and tested in groups of 4, with one doctor and one patient in each color group. Because previous studies have shown an effect of subject-experimenter gender concordance on pain ratings, each group was either all male or all female [4,93].

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 [5], (2) religious beliefs and values from the Duke University Religion Index, [80] and (3) politically polarized beliefs and values used in a previous study [96]. Participants completed the PBVQ online via Qualtrics (Qualtrics Labs, Inc).

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Upon arrival at the lab, all participants reviewed the PBVQ as a reminder of its contents, 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

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between participants in the same group or result in any consistent association between group identity (green or yellow) and a particular belief or value orientation. Therefore, any consistent effects of the group manipulation were likely caused by the 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 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 [146] regarding their group membership (e.g., ‘‘I am proud to be a member of the green/yellow group”). Participants also responded to three questions designed to assess how realistic participants felt the current study was on a 150-point visual analog scale (0 = no belief to 150 = strongest belief), which we refer to as the Study Belief Index. These questions were: 1. To what degree did you believe the study was about investigating the effects of personal beliefs and values on the clinical interaction?, 2. To what degree did you believe the groups were assigned based on your reported personal values?; and 3. How realistic did the simulated clinical interactions feel to you? Each was rated on a 100 point scale from 0 (not at all) to 100 (completely). Summing these (Cronbach's alpha=0.88) was meant to provide a rough indication of how much participants believed in the premise of the study and found it realistic, rather than provide a psychometrically validated measure. 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.’’ Responses to 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

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simulated clinical interactions (patient participants: mean = 75.63, SD = 28.66; clinician participants: mean = 84.46, SD = 28.78).

**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, 2B). Clinicians practiced the interaction with patients by going through the entire procedure including introducing themselves, describing the procedure, and administering the procedure, on the experimenter training them not on patients. The patients went through the 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 a group assignment. Thus, yellow and green patients, as well as yellow and green clinicians, were trained together (Fig. 2A, 2B).

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**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 as an analogue to a painful medical procedure (Fig. 2C). 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 using a script programmed in E-Prime stimulus presentation software (E-Prime 2.0; Psychology Software Tools, Inc, Pittsburgh, PA). Thermal stimulation was delivered to 4 evenly spaced locations on the volar surface of the left forearm of the patient at 3 target temperatures (46.5°C, 47.5°C, and 48.5°C) using a 16x16 mm contact Peltier thermode (Medoc, Inc, Ramat Yishai, Israel). 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 asking the patient if they were ready and the trials were separated by variable delays. Fig. 2C 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 [62,74]. 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.

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**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 [140,155].

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 (Fig. 3). 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). All the reported model coefficients are unstandardized.

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Finally, the mediation effect was defined as a*b and statistical inferences were made based on the approach described above [140,155]. Cohen's d statistics were provided as estimates of the model effect sizes [31]. Robust inferential methods are available that perform well with relatively small sample sizes [125,152]. Here we reanalyzed the data using an extension of this approach for linear mixed models [81] based on multivariate MM-estimators via R package robustlmm. Generally, the procedure fits weight for each observation using the Mahalanobis distance, i.e., the tail observations receive less weight. The estimated significance of the model 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 [156].

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 the participants were not engaged in interpersonal interaction during those times. In addition, trust toward the clinician was estimated at the end of each section. Thus, the data used in the mediation models had the appropriate temporal order.

In addition, we initially tested whether patients' and clinicians' movement intensities were associated with movement synchrony, patients' pain rating, and their trust in the clinician. Variables with significant contribution were included in the mediation analysis as control variables.

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## Results

### Manipulation checks and descriptive statistics

Patient participants (mean = 10.62, SD = 3.54) as well as clinician participants (mean = 9.03, SD = 3.97) reported moderate to strong identification with their assigned group (3 = no identification to 18 = strongest identification), confirming the validity of the grouping manipulation. Table 1 presents descriptive statistics of the patients' pain ratings, trust in their clinicians, and movement synchrony by group concordance.

### 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 intensity increased movement synchrony (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, these factors were included as control variables 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) so it was not included in subsequent analyses.

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**Mediation analysis**

The concordance manipulation did not directly affect patients' pain ratings (B=-2.45, 95% CI [-5.54, 0.59], F(1, 32)=2.60, p=0.11). However, the concordance 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]).

Moreover, adjusting for the concordance manipulation, movement synchrony was associated with decreased patient pain ratings (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). This effect remained after controlling for trust in clinicians (B=-60.47, 95% CI [-100.50, -21.07], F(1, 32)=9.12, p=0.005 Cohen's d=0.53 [0.17, 0.89]). Finally, C-P movement synchrony mediated the effect of C-P concordance on patient pain ratings (indirect=-3.07 [-5.94, -0.82], p=0.005).

For the second mediation model with trust toward the clinician as an outcome, patients in the congruent condition reported an increased level of trust toward the clinician (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 an increase in 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 concordance. 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). In addition, 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. 5), suggesting complete mediation of the effect of C-P movement synchrony on the pain rating concordance bias. Finally, we found that both outcomes (patient 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]), suggesting that the discovered similar mediation patterns for two study outcomes may underlie shared mediation mechanism.

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## 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) 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.

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 [28,34,73] including pain [103,127] and trust toward clinicians [56,60], 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 [22,26,147,149], low adherence to physician recommendations [15,19,26], less utilization of some preventive services [26,69,126,141], more missed medical appointments, [15] and substitution of alternative medicine for conventional care [10]. Among the mechanisms of poorer patient experiences in discordant C-P interactions is poorer quality communication [35].

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These findings increase our understanding of how the biobehavioral context surrounding painful experiences influences pain perception. They fit with a broader literature showing that social, cultural, and contextual factors influence pain perception [37,82,94,132]. Contextual factors, including the 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. Especially, movement synchrony in social interaction may be important for a variety of reasons. Humans show a tendency to imitate the postures or actions of others [109,128]. This capacity develops early in life [49,91]. It plays a key role in the development of infant-mother bonding and in social communication [45,129] and may be an important

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ingredient of empathy more broadly [11]. Previous studies have highlighted the role of interpersonal synchrony in adaptive emotion-regulation [48,55,97,143], including regulation of anxiety and depression [121], touch-induced analgesia [58,59], and joint attention [42]. 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 [97], and reduce anxiety and negative mood, all of which have been linked to pain relief [72,95]. Synchrony may have bidirectional effects; mimicking others appears to increase receptivity to others' preferences, and being mimicked may increase feelings of affiliation [135].

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 [27,53]. A meta-analysis of these and other manipulations of visual-kinesthetic 'body illusions' showed large therapeutic effects [16]. Beyond the pain context, research has suggested that joint movement or movement synchrony is important for 'kinesthetic empathy' [11], 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 [11,47] that enable a response to the other's emotional state [139,154]. Moreover, oxytocin, a hormone that is reported to encourage social bonding, has also been reported to enhance movement synchrony [75]. 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

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relationships remain to be tested more completely in future studies. In addition, because it can be readily measured from interpersonal interactions, movement synchrony may be useful as a behavioral marker for effective interactions [133,136,137]. Currently, there is a large initiative to develop measures related to pain and its biological correlates (biomarkers) [61,76,78,110,122], including behavioral measures, but measures of interpersonal communication are still lacking.

Indeed, in the United States, about 50% of all patients leave an office visit without an adequate understanding of what the clinician has told them [101]. Interpersonal movement synchrony could be used as a marker of the C-P communication quality. It is easier to interpret and understand (as compared to physiological synchrony) because the link between perception and motor action is highly automatic [41,118,151]. Thus, the 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 [111,148]. Moreover, our tendency to automatically mimic and synchronize movements with others has been suggested to result in emotional contagion [85,112], to affect social behavior [85,86] and to play a key role in the development of empathy [119]. 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 [23,66,67,130]. Since movement-based cues can strengthen C-P relationship and improve patients' health outcomes and satisfaction [44,77,79,84,102,107,123,131] biomarker of the clinical interaction quality, especially because it could be measured in a simple way using just a video camera.  In clinical settings, practicing active listening can increase C-P movement synchrony, possibly by blurring the boundaries with the patient and increases the feeling of similarity [68].

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Increased C-P movement synchrony could be a valuable addition to interventions, and may improve the C-P relationship. However, future studies should further investigate the mechanisms of movement synchrony dynamics. For example, we should strive to better understand the synchrony's onsets and offsets, the factors that drive the synchrony (e.g. empathy), as well as the nature of the movement synchrony affecting health outcomes. Such research may result in the development of Artificial Intelligence that will help clinicians to establish safe and efficient communication with their patients.

Because our findings bear on the perceived similarity of group membership between clinicians and patients, they also bear on issues of ethnic and racial disparities in health care. Discordance between a patient and a clinician may affect both parties. The nature of the discordance is most likely implicit [38,52,103], 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.

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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. This 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 a 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 lies in demonstrating causal effects in a controlled setting, complementing ecological studies of clinical interactions 'in the wild'. In addition, we calculated C-P synchrony based on head movements. However, C-P synchrony may be reflected in multiple types of data. Head movement data are interesting in part because they can be easily obtained from video camera data and can thus be easily deployed in clinical and research settings. Future studies should address this point by capturing C-P synchrony in whole-body movements, neuro-physiological signals, and voice. Also, we recognize that artificial synchrony is complex—for example, if participants realize they are being mimicked then the effects could be substantially altered—and that the parameters that govern optimal synchronization in dyadic settings require further research [63]. Finally, we did not try to infer a causal relationship between pain sensitivity and trust in the clinician. This causality may be complex; for example, movement synchrony may affect pain sensitivity, which in turn modulates trust in the clinician. Indeed, it has been reported that high (vs. low) movement synchrony affects trust and interpersonal liking during the Trust Game paradigm by modulating pain sensitivity [88].

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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 [14,24]. 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.

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## Figure Legends

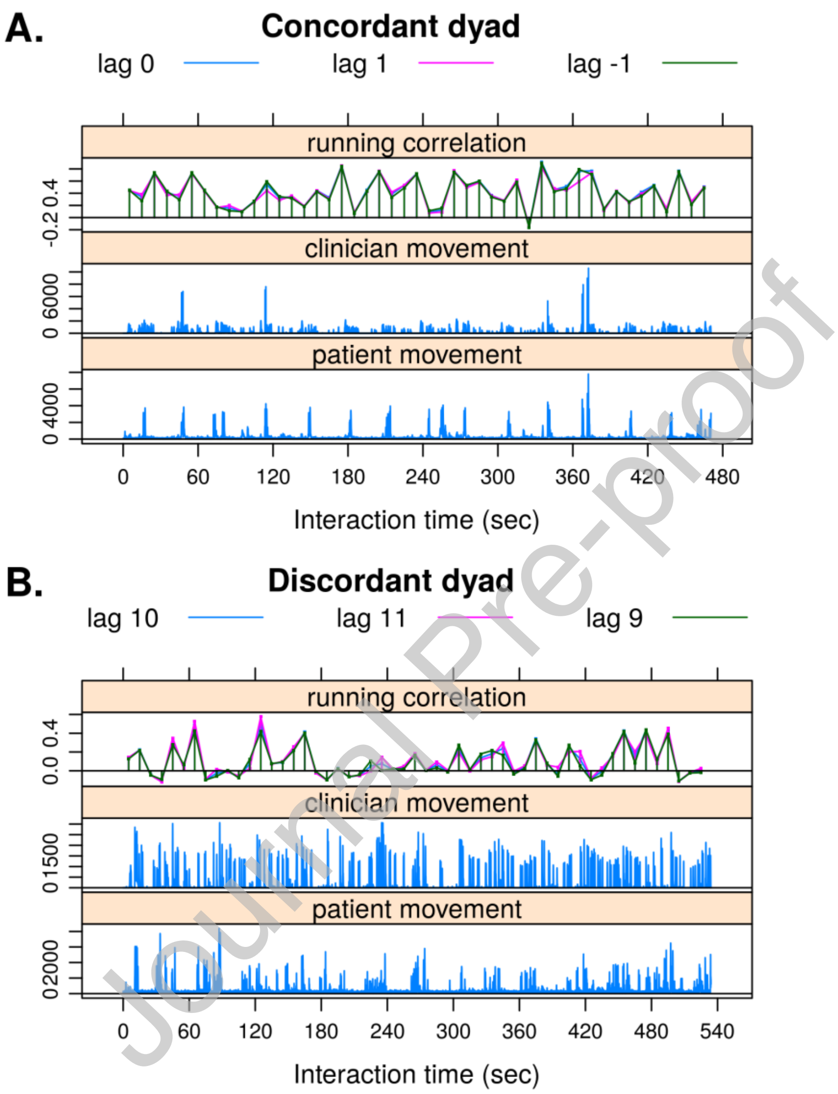


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Figure 1. Example of the movement data and windowed cross-correlations for the 3 lags of the maximum correlation: **(A)** a CC C-P dyad and **(B)** a DC C-P dyad. The y-axis represents: 1) the moving window correlation over time (top subplot); 2) the clinician's and the patient's movement intensity (middle subplot); 3) and the patient's movement intensity (bottom subplot),. The x-axis represents the interaction time. The running windows are 300 frames (10 s) of length. The numbers associated with the lag segments (e.g. lag 10) reflect the lagged difference (in # of frames ) between the interacting subjects that maximize the movement synchrony between them. Because

the camera frequency is 30 Hz, lag 10 in Figure 1B indicates that the patient mostly led the partner (clinician) in his/her movements for about ⅓ of a second.

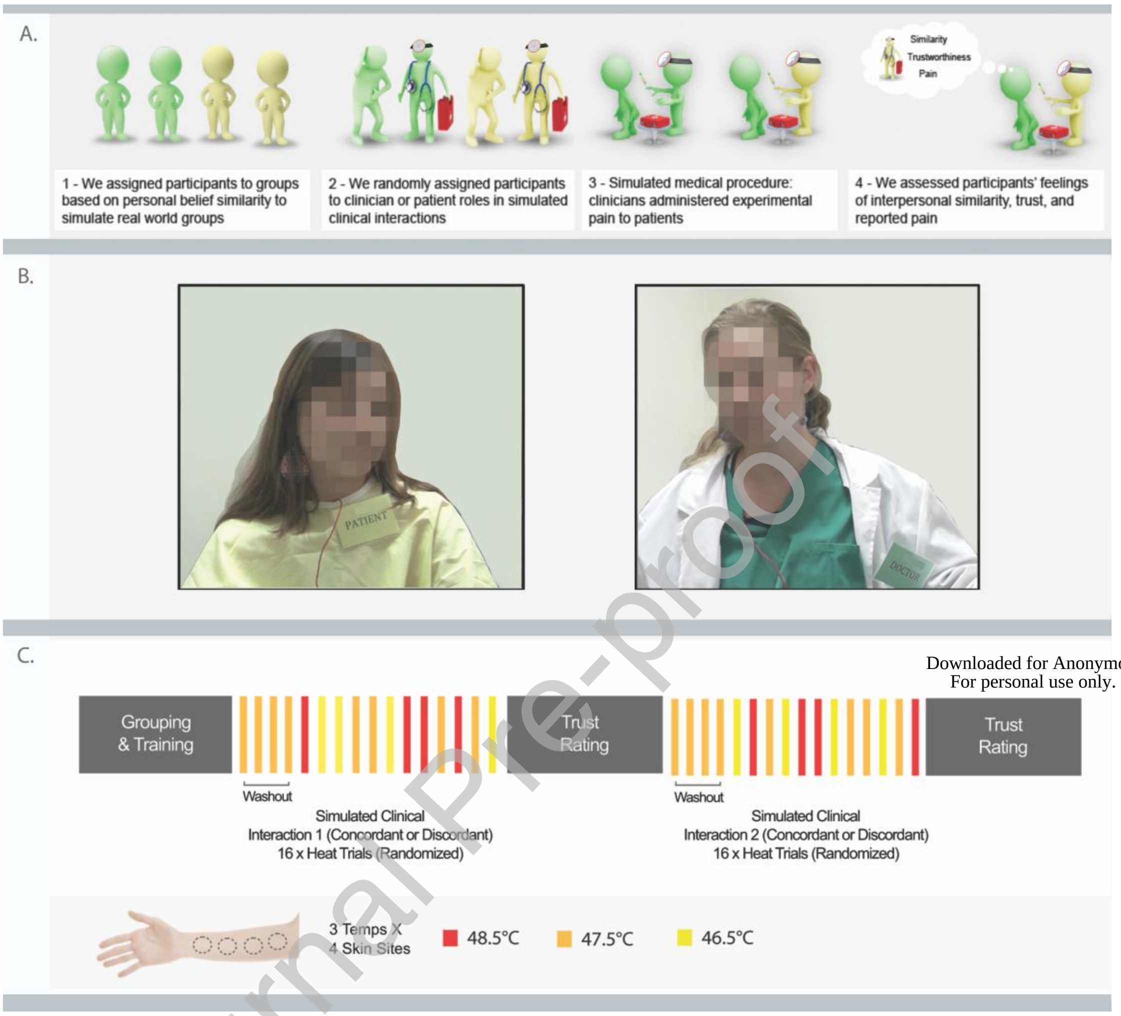


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Figure 2. The design of the current study. **(A)** We randomly assigned participants to the role of either patient or clinician (1 in each group/dyad). During each study session, a patient took part in two simulated clinical interactions, one with 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)** 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. **(C)** 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.

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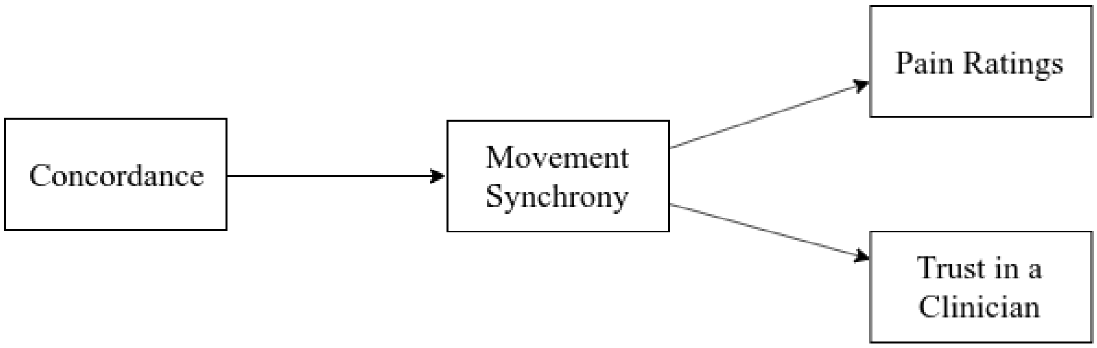


Figure 3. Proposed mediation model: movement synchrony mediates the effects of group concordance on pain perception and trust toward the clinician.

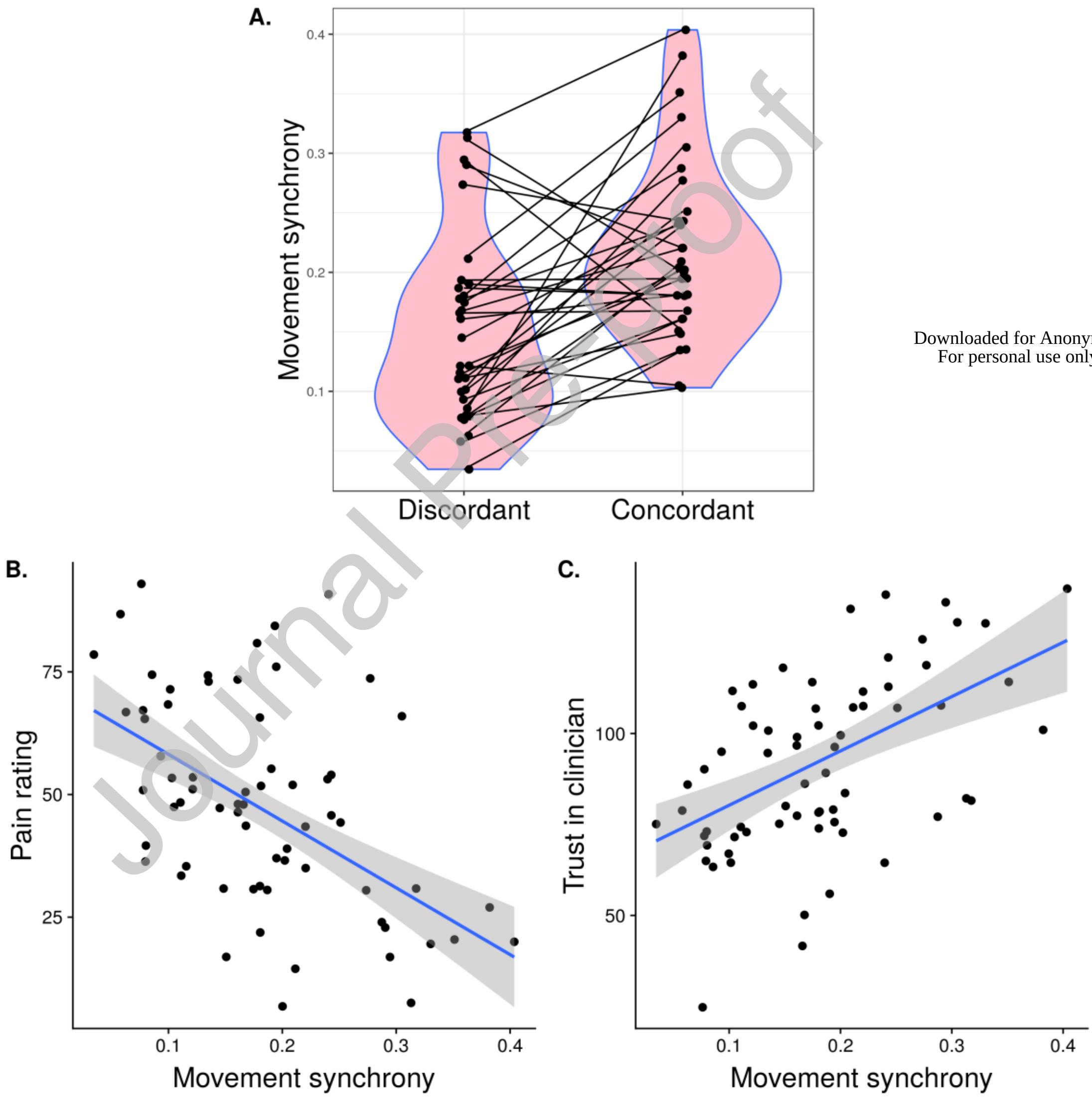


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Figure 4. **(A)** Movement synchrony differences between concordant and discordant dyads, based on the experimental manipulation of their perceived belief similarity (Cohen's d=0.71). **(B)** Movement synchrony is negatively associated with patients' 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.

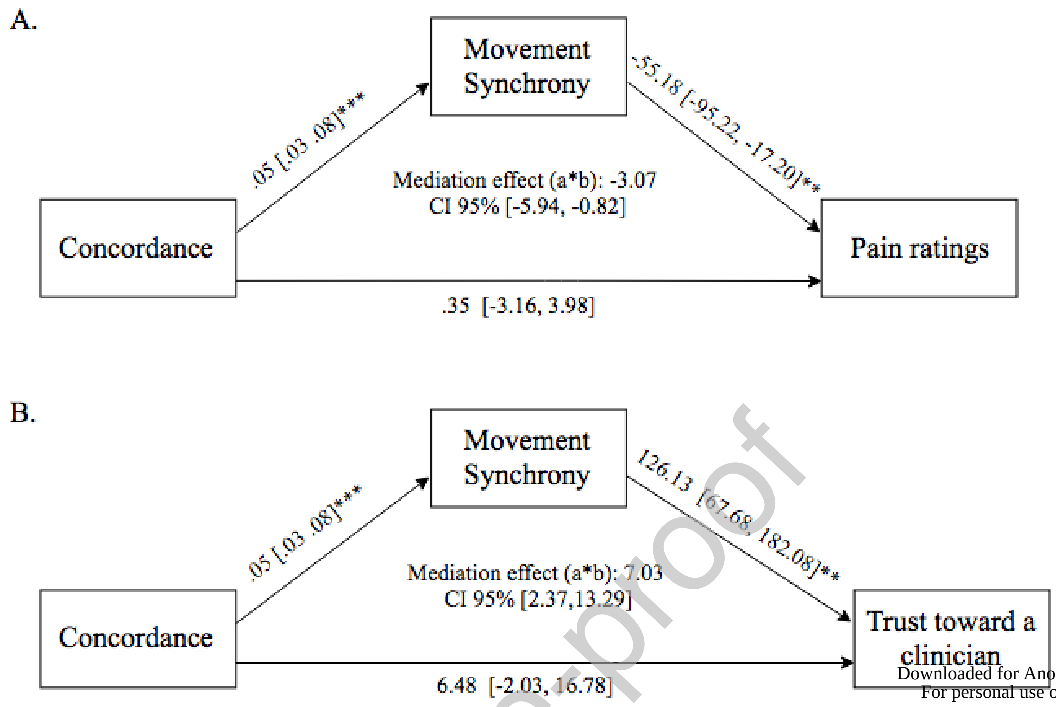


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Figure 5. Mediation model findings for **(A)** patient pain ratings and **(B)** patient trust toward the clinician. The numbers in the brackets show 95% confidence intervals for the estimates.

**Table Legend**

Table 1. Descriptive statistics of the variables of interest: Movement synchrony, Patient's Pain Ratings and Patients' Trust in the Clinician

| Variables | Discordant | Concordant | Total |
|---|---|---|---|
| Movement synchrony Mean (SD) | 0.148 (0.0779) | 0.219 (0.0752) | 0.182 (0.0840) |
| Pain Ratings Mean (SD) | 50.0 (22.1) | 46.0 (20.8) | 48.0 (21.4) |
| Trust in a clinician Mean (SD) | 83.5 (23.0) | 100 (22.9) | 91.7 (24.3) |