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Heart rate synchrony in minimal social interactions in relation to mimicry

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Humans align their physiology during social encounters, but the mechanisms driving this autonomic coupling remain unclear. Mimicry has been proposed as a driver, yet existing evidence is largely correlational and limited to precisely matched movements. We causally tested whether two forms of mimicry, copying a partner's choices or motor actions, can induce heart rate synchrony during a controlled, non-verbal art selection task. In the Choice group (21 dyads), a confederate mimicked (or not) the participant's picture choice but not their hand action. In the Motor group (20 dyads), a confederate mimicked (or not) the participant's right-hand movements but chose from a different picture pair. Dyadic heart rate synchrony was quantified using mixed-effects models of trial-level heart rate fluctuations. Partners' heart rates covaried within and across trials, but neither the presence nor the type of mimicry altered this coupling. After modelling temporal trends and comparing real dyads with time-matched pseudo-dyads, the observed synchrony was largely explained by shared task and timing dynamics rather than dyad-specific physiological alignment. Thus, instructed mimicry alone is insufficient to elicit dyad-specific cardiac coupling in minimal, tightly structured interactions. More broadly, these results caution against interpreting physiological synchrony as interpersonal alignment without accounting for shared temporal structure.

1. Introduction

Humans have a striking tendency to align with one another during social interactions. This alignment manifests across multiple levels, ranging from observable actions [1,2] and choices

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[3,4] to the involuntary coupling of autonomic signals such as heartbeats [5], electrodermal activity [6] or respiration [7]. This latter form, termed physiological synchrony, refers to the covariation of continuous autonomic signals between people [8]. This phenomenon has been extensively documented across a wide range of contexts, including mother–child interactions [9–11], therapist–client sessions [12–14], romantic couples [15–17], speed dating [6,18] and collective rituals [5,19]. However, the conditions under which physiological synchrony emerges, and its underlying drivers, remain unclear.

One mechanism proposed to facilitate physiological synchrony is coordination at a behavioural level [8,20]. It has been hypothesized that during coordinated action, partners' perception–action systems become coupled through mutual prediction and adjustment to each other's behaviour, potentially leading to convergence in physiological signals such as heart rate [21]. Researchers typically distinguish two forms of motor coordination that differ in timing. Motor synchrony refers to moving in perfect unison [22], for example, people rocking their chairs in tandem [23]. Motor mimicry, in contrast, involves copying a partner's actions after a brief delay [24], such as mimicking postures and gestures [25]. Alignment in behaviour can also take a more abstract form, known as choice mimicry, which refers to copying one's choices, for example, selecting the same artwork [26]. Our earlier work [27] suggests that being mimicked in choices elicits a stronger mirror neuron system engagement than being mimicked in actions. The central question that motivates the present study is whether either motor or choice mimicry is sufficient to induce heart rate synchrony.

A recent meta-analysis [28] shows a modest correlation between motor coordination and physiological synchrony, but individual studies suggest this relationship is highly context dependent, with most existing evidence based on perfectly matched movements. For example, in complex joint action tasks, greater movement coordination during LEGO building [29] was associated with stronger heart rate coupling, yet the timing of speech turns was a stronger predictor, implicating conversational processes. In contrast, in a model-car construction task [30], tightly synchronized hand movements were not associated with heart rate coupling, which the authors attributed to limited emotional engagement. Moreover, in structured rhythmic contexts, such as the dyadic Mirror Game [31], synchronous or mimicked 'dance-like' handle-sliding motions were linked to heart rate synchrony, although matched exertion could account for part of the effect. Similarly, improvised or synchronous drumming elicited heart rate coupling [32,33], yet cardiac synchrony persisted even under deliberately unpredictable tempo [33], suggesting influences beyond matched motor timing. Overall, these mixed findings raise the question of whether motor coordination alone can drive heart rate synchrony or whether additional factors, such as conversational turn-taking or shared exertion, may be necessary.

Evidence directly linking motor mimicry to heart rate synchrony remains limited. Two naturalistic studies observed both phenomena but did not test their association: posture mimicry and heart rate synchrony were highest during periods of relational tension in psychotherapy [34], and several forms of motor mimicry and heart rate synchrony were observed on blind dates [18]. Thus, while motor mimicry and heart rate coupling have been observed together in naturalistic interactions, their specific association remains largely unexamined.

To isolate the causal effect of motor coordination on heart rate synchrony, recent studies have shifted to minimal, non-verbal tasks. Using wavelet coherence, Flory *et al.* [35] found that although heart rate synchrony increased during joint tapping compared to baseline, it did not differ between real pairs and pseudo-pairs, suggesting a shared task-induced response. Moreover, Boukarras *et al.* [36] showed that heart rate coupling during a dyadic object-grasping task was not modulated by whether partners executed synchronized or mimicked actions. Notably, heart rate synchrony rose when dyads switched to a novel version of the task compared with repetition blocks, a pattern the authors attribute to heightened reciprocal engagement and performance monitoring. While these studies suggest that motor coordination alone may not drive heart coupling, we still lack a test of whether motor mimicry by itself can elicit heart rate synchrony. Whether choice mimicry can induce cardiac coupling has never been tested, leaving a gap that the present study addresses.

The current study extends the minimal joint-action paradigms [35,36] by using an art selection task. Here, partners take turns to make art choices, during which a confederate either mimics or does not mimic the participant's actions or choices. We therefore test whether motor and choice mimicry vary in their capacity to evoke heart rate synchrony. This design also allowed us to pursue a secondary goal: investigating the understudied behavioural effects of mimicking on the mimicker. The existing evidence is inconsistent and restricted to facial mimicry: while Stel & Vonk [37] reported increased perceived closeness and interaction smoothness for both mimickee and mimicker, Kulesza *et al.* [38] found no effect on the mimicker's liking of the mimickee. Our study therefore examines the impact of performing motor and choice mimicry on the mimicker's own perception and affiliation towards the mimicked participant.

1.1. The present study

In the current study, we examined whether motor and choice mimicry, where one individual mimics and the other is mimicked, could induce heart rate synchrony. Participants were divided into two groups, each experiencing a distinct type of mimicry while interacting with two separate confederates during an art choice task (figure 1A). In the Choice group, the participant selected a painting by pointing, after which the confederate verbally indicated either a preference for the same painting (Mimicry condition) or a different one (No-mimicry condition). In contrast, in the Motor group, the confederate either mimicked their right-hand pointing movement (Mimicry condition) or performed a different right-hand movement (No-mimicry condition). The heart rates of participants and confederates were continuously measured using electrocardiography (ECG), and after each condition, confederates provided ratings of their social perception and affiliation towards the mimicked participant. Heart rate synchrony was assessed by evaluating the similarity in trial-by-trial changes in the partners' average heart rates using mixed-effects models. This mixed design allowed us to test the causal effect of mimicry on cardiac synchrony both between groups (Choice versus Motor) and within each group (Mimicry versus No-mimicry). All analyses were exploratory and were not preregistered. We nonetheless predicted that choice mimicry would produce stronger heart rate synchrony than motor mimicry, given the stronger mirror neuron system engagement in prior work [27] and recent null findings for the effect of motor coordination on heart rate synchrony [35,36].

2. Methods

2.1. Participants and confederates

These data were collected as part of a previous study designed to assess the neural and behavioural effects of being mimicked [27]. A total of 65 participants were recruited from a local database for this experiment. Eligibility criteria required participants to be over 18 years old, fluent in English and have normal or corrected-to-normal vision. Seven participants were excluded: two due to technical issues or limited English proficiency and five due to incomplete confederate measures. This resulted in a final behavioural sample of 57 participants (48 females, 9 males; $M_{\text{age}} = 23.3$, $\text{s.d.}_{\text{age}} = 3.98$). Due to technical issues with ECG recording (§2.6), heart rate synchrony analyses were conducted on 41 participants, each paired with a confederate. A simulation-based sensitivity analysis indicated that, with the present sample, we had approximately 80% power to detect a small effect of mimicry on heart rate synchrony, similar in magnitude to the meta-analytic estimate of the association between behavioural and physiological synchrony ($r = 0.18$) [28]. Full details are provided in the electronic supplementary material.

Five female master's students from non-psychology disciplines at University College London (UCL) were hired to act as confederates ($M_{\text{age}} = 24.4$, $\text{s.d.}_{\text{age}} = 2.9$). Four were Chinese and one was Italian. They were assigned stage names, kept unaware of the study's aims and hypotheses and instructed to act as fellow participants. They were encouraged to use natural non-verbal cues, such as eye contact and smiling, during the interaction. Using a confederate design allowed us to manipulate mimicry in a controlled, trial-by-trial manner across dyads.

All participants and confederates provided written informed consent before the study. Participants received £15 for their time, while confederates were compensated at a rate of £10 per hour. The experiment received ethical approval from the UCL Research Ethics Committee (Approval ID: 5975/003).

2.2. Mimicry manipulation

Participants were randomly assigned to one of two groups: the Choice group or the Motor group. They were instructed to remain silent, rest their left hand on their lap and indicate their art preference by pointing to the chosen picture with the index finger of their right hand. Both groups followed

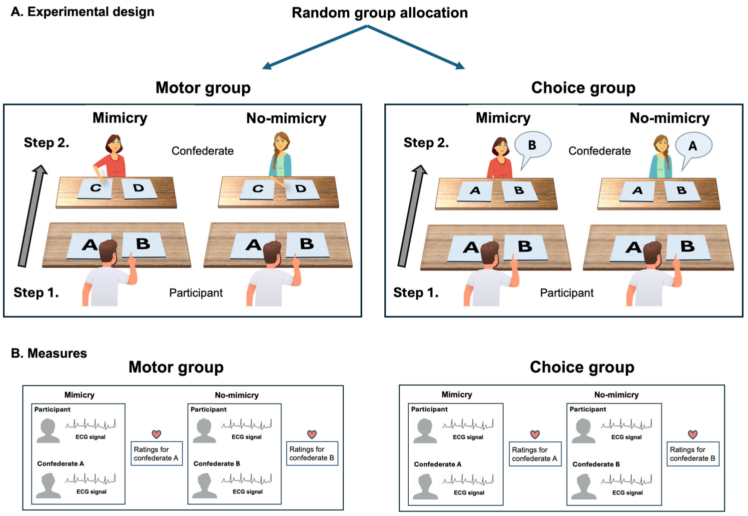

Figure 1. (A) An overview of the experimental design. Before the experiment, participants were randomly allocated to either the Motor group or the Choice group, where they interacted with two different confederates. In the Choice group, participants were shown pairs of paintings that matched those presented to the confederate. After selecting a painting by pointing, participants heard a pre-recorded voice command triggered by the confederate expressing a preference for either the same painting (Mimicry condition) or a different one (No-mimicry condition). In the Motor group, participants were presented with different pairs of paintings from those shown to the confederate. After pointing to a painting, participants observed the confederate performing the same right-hand pointing movement (Mimicry condition) or a different movement towards another painting (No-mimicry condition). (B) Measures. During the experimental procedure, ECG data were continuously recorded for both participants and confederates. After each condition, confederates answered rating questions assessing their social perception and affiliation towards the participant.

an identical experimental procedure, which included one Mimicry condition and one No-mimicry condition, each involving a different confederate. Throughout these interactions, ECG data were continuously recorded from both the participant and the confederate (figure 1B). To minimize cognitive load on confederates, they were cued on each trial whether to mimic or not by the presence or absence of a full stop after the number on the picture sheet.

In the Choice group, both the participant and the confederate were presented with identical pairs of paintings. On each trial, the participant pointed to their preferred picture, then the confederate pressed a button on a keyboard on their lap to generate a pre-recorded voice command indicating their choice (figure 1A). In Mimicry trials, the confederate selected the same picture as the participant, thus mimicking their choice. In No-mimicry trials, the confederate selected the opposite picture, ensuring that their choice did not mimic the participant's. Using different response modalities (pointing versus voice command) allowed us to isolate choice mimicry from motor mimicry.

In the Motor group, the participant and confederate were presented with two distinct pairs of paintings to limit the influence of shared choices. On each trial, the participant first pointed with their right hand to their preferred picture, and the confederate then pointed with their right hand to a picture (figure 1A). In Mimicry trials, the confederate used exactly the same motor action as the participant. Depending on the participant's movement, this involved either ipsilateral right-hand movements (both selected the picture nearest their right shoulder) or contralateral right-hand movements (both reached across the body to select the picture nearest their left shoulder). This way, the confederate performed anatomical imitation [39], engaging the same muscles and arm kinematics as the participant. In No-mimicry trials, the confederate executed the alternative right-hand action not used by the participant (e.g. if the participant made an ipsilateral movement, then the confederate made a contralateral movement).

Each experimental condition in both groups consisted of 30 trials. The Mimicry condition included 17 Mimicry trials, 8 No-mimicry trials and 5 baseline trials. Conversely, the No-mimicry condition consisted of 17 No-mimicry trials, 8 Mimicry trials and 5 baseline trials. During baseline trials, a single pair of images was presented only to the participant, with no paintings shown to the confederate. Given the brief trial duration (20 s) and the slow temporal dynamics of cardiac responses [40], our primary analysis of heart rate synchrony focused on the overall condition level (Mimicry versus No-mimicry), not individual trial types. An analysis based on trial types was conducted using the fNIRS data and is reported in a separate publication [27].

2.3. Procedure

The experiment was conducted in person at the Institute of Cognitive Neuroscience in London. Before visiting the laboratory, volunteers were randomly assigned to either the Choice or Motor group. Upon arrival, participants first signed a consent form. They then received instructions outlining a cover story, which stated that they would take part in an art game with two other participants to explore new ways of experiencing art. Participants were instructed to indicate their preference by pointing to one of two paintings, after which the other participant (a confederate) would make a choice. A brief, two-trial training phase was then completed to familiarize them with the task. Next, the participant was fitted with an fNIRS cap (fNIRS data are reported in [27]) and three ECG electrodes on the left side of their chest to monitor heart rate (§2.6). In a separate room, confederates A and B were also prepared with ECG electrodes attached in the same manner. For both the participant and confederates, wearable Bluetooth devices for ECG acquisition were attached to their clothing.

Once preparations were complete, confederate A entered the testing room and sat at a table across from the participant, about 1 m apart. A set of 60 individual picture sheets was arranged on the table between them, initially covered by a blank sheet. After ECG signals were checked, the procedure started with the removal of the blank sheet. Each trial followed a sequence of pre-recorded voice commands. A trial was initiated with the command 'Trial start', followed by 'Which picture do you like?'. The command 'Participant one' then prompted the participant to point to their preferred picture, after which 'Participant two' signalled to the confederate to make their choice. Each trial concluded with the 'Trial end' command. The participant completed 30 trials with confederate A, lasting approximately 10–13 min. Immediately after, confederate A was escorted to another room to complete rating questions on a laptop assessing their social perception and affiliation towards the participant (§2.4).

Next, confederate B, with ECG electrodes already in place, entered the room. The experimental procedure was repeated for another 30 trials, with confederate B adopting the opposite behaviour to that of confederate A (e.g. No-mimicry if confederate A had performed Mimicry). After completing the task, confederate B was escorted out of the room and completed the same set of rating questions as confederate A. The participant also answered the same set of questions after each condition to assess the effects of being mimicked, the results of which are detailed in a separate publication [27]. Following the ratings, the fNIRS cap and ECG equipment were removed from the participant. They then completed additional measures and answered a series of debriefing questions about the study's goal. Finally, the participant was informed of the study's true purpose, compensated for their involvement and thanked. Trial order, condition order and confederate appearance were counterbalanced. The entire experiment lasted approximately 90 min.

2.4. Rating measures

After each condition, confederates completed several questionnaires. First, they rated their current affective state on a 0 (*negative*) to 100 (*positive*) scale in response to the question 'How did you feel during the art game with the participant?'. Next, they rated their social perception of the participant using 10 items on a 6-point scale (1 = *definitely not* to 6 = *definitely yes*). These items were divided into five-item subscales measuring perceived warmth (e.g. 'Do you think the participant is a warm person?') and perceived competence (e.g. 'Do you think the participant is competent?'). Perceived rapport was then measured with three questions on a 0 (*negative*) to 100 (*positive*) scale (e.g. 'I think the participant and I established rapport') [41]. Perceived closeness was assessed with the Inclusion of Other in the Self Scale [42], in which confederates chose one of seven overlapping-circle diagrams (1 = *no overlap*, 7 = *most overlap*). Finally, confederates rated the participant on seven attributes (e.g. generosity, hostility) [43] on a scale from 1 (*not at all*) to 100 (*very much*). All rating items are listed in electronic supplementary material, table S1.

2.5. Behavioural data analysis

Analyses of confederates' ratings were conducted in R (v. 4.4.2) using linear mixed-effects models with the *lmer* function from the lme4 package [44]. Perceived warmth and competence were analysed separately, with fixed effects for group (Choice versus Motor) and condition (Mimicry versus No-mimicry), and simple effects of condition examined in follow-up models fitted separately within the Choice and Motor groups. The same modelling approach was applied to additional ratings of perceived affective state, rapport, closeness, and positive attributes. For all models, factors were dummy-coded with 'Motor' and 'No-mimicry' as the reference levels.

2.6. Heart rate data acquisition and preprocessing

Heart rate data were acquired from both the participant and the confederate using BioSignalsPlux ECG sensors. These sensors were connected to wearable BioSignalsPlux acquisition devices (PLUX Biosignals, Portugal), which sampled data at either 500 or 1000 Hz with 16-bit resolution. Both devices communicated via Bluetooth with a single laptop running OpenSignals, the proprietary data acquisition software from BioSignalsPlux.

Raw ECG recordings from participants and confederates were processed with Kubios HRV Scientific (v. 4.0.3; Kubios Oy, Kuopio, Finland) [45] to extract beat-to-beat R-R intervals (RRIs). First, the software automatically detected motion- and electrode-related artefacts, and any continuous noisy segments were flagged and treated as missing data. Next, R-peaks were identified with Kubios' adaptive threshold algorithm. Intermittent abnormal intervals, such as those produced by ectopic or missed beats, were then corrected by cubic-spline interpolation. Any erroneously assigned or missed R-peaks were additionally corrected manually after visual inspection. The RRI series were detrended using the smoothness-priors method with a cut-off frequency of 0.035 Hz. Finally, a 4 Hz cubic-spline interpolation was applied to generate an evenly spaced RRI time series.

Data were excluded from the final analysis for several reasons. First, one participant was removed after preprocessing indicated arrhythmic-like signals. Additionally, for a given condition, a dyad was removed if timestamps were missing or the recording was incomplete for either individual. This data loss occurred for two technical reasons: errors resulting from the manual recording of timestamps in OpenSignals, and signal interruptions caused by Bluetooth connectivity issues when two devices were connected simultaneously. Finally, specific trials in the Choice group (28 out of 1550) were excluded when the confederate's keyboard malfunctioned. Overall, 44.6% of dyad-condition cells were excluded from the initial sample of 65 dyads for the heart rate synchrony analysis, primarily due to missing or incomplete recordings. The final dataset comprised 41 dyads, 10 of which contributed data from only one condition.

A custom MATLAB script (v. R2021b; MathWorks, Natick, MA, USA) was used to segment the pre-processed RRI data into conditions based on timestamps, then aligned the RRI signals within each dyad and finally converted the values to heart rate (60/RRI). Given that each trial lasted only about 20 s, capturing temporal synchronization of heart rate changes within a single trial was challenging. Therefore, our primary analysis assessed heart rate synchrony by examining whether heart rate fluctuations were linked between the confederate and the participant across multiple trials.

2.7. Heart rate data analysis

Heart rate data were analysed in R. Mean heart rate was calculated for each participant and confederate on every trial. Two initial linear mixed-effects models tested the effects of group (Choice versus Motor) and condition (Mimicry versus No-mimicry) on mean heart rate, with simple-effect comparisons obtained using the *emmeans* function. Trial-level heart rate values were then z-scored separately for participants and confederates within each dyad and group × condition combination. To assess heart rate synchrony, linear mixed-effects models were fitted to predict a participant's heart rate from the confederate's heart rate (and vice versa), with group and condition included as moderators. Simple slopes and their comparisons were estimated using the *emtrends* function. To evaluate trial-to-trial influence, lag-1 heart rate terms were computed for each dyad within every group × condition combination and included as predictors in cross-lagged linear mixed-effects models, again with group and condition as moderators. Across all models, factors were dummy-coded with Motor and No-mimicry as the reference levels. Finally, for both heart rate synchrony and trial-to-trial influence, we fitted four simple mixed-effects models (one per group × condition cell).

Two additional control analyses examined whether within-block temporal dynamics could account for the observed heart rate synchrony, using trial-level heart rate values z-scored separately for each participant and for confederates within each participant × condition combination. First, a linear mixed-effects model with trial number within block predicting participants' heart rate was compared to an otherwise identical model that also included confederate heart rate. Second, a permutation test compared the observed heart rate coupling coefficient to a null distribution from time-matched pseudo-dyads.

3. Results

3.1. Individual mean heart rate responses

To explore the effects of group (Choice versus Motor) and condition (Mimicry versus No-mimicry) on mean heart rate, we fitted separate linear mixed-effects models for participants and confederates. For participants, heart rate (HR_ppt) was modelled as: HR_ppt ~ Group * Condition + (1 | Participant); for confederates, heart rate (HR_conf) was modelled as: HR_conf ~ Group * Condition + (1 | Participant) + (1 | Confederate). Among participants, a significant interaction between group and condition ($\beta = 2.34$, $p < 0.001$) indicated that mimicry affected heart rate differently in the two groups. Bonferroni-adjusted comparisons showed that being mimicked in choices increased participants' heart rate by approximately 0.69 b.p.m. relative to not being mimicked ($p = 0.003$), whereas being mimicked in actions reduced heart rate by around 1.65 b.p.m. ($p < 0.001$). For confederates, there was also a significant interaction between group and condition ($\beta = -6.11$, $p < 0.001$), but in the opposite direction: mimicking choices reduced confederates' heart rate by approximately 3.46 b.p.m. compared to not mimicking ($p < 0.001$), whereas mimicking actions increased it by about 2.65 b.p.m. ($p < 0.001$). These effects are illustrated in figure 2 and full statistical results are provided in electronic supplementary material, table S2.

3.2. Real-time heart rate synchrony

We first tested whether partners' heart rates covaried within the same trial. A linear mixed-effects model tested whether a confederate's heart rate (HR_conf) predicted a participant's heart rate (HR_ppt), and whether this coupling varied by condition (Mimicry versus No-mimicry) and group (Choice versus Motor). The model was specified as: HR_ppt ~ HR_conf * Condition * Group + (1 | Participant). The confederate's heart rate was a positive predictor of the participant's heart rate ($\beta = 0.16$, $p < 0.001$; figure 3). Condition and group showed no main effects, and no interactions with confederate heart rate (all $p \geq 0.22$). To clarify the pattern of non-significant effects, we conducted Bonferroni-adjusted simple-slope tests, which showed no Mimicry versus No-mimicry differences within Choice ($\beta = 0.04$, $p = 0.472$) or Motor ($\beta = -0.01$, $p = 0.878$) and no Choice versus Motor differences within Mimicry ($\beta = -0.02$, $p = 0.749$) or No-mimicry ($\beta = -0.07$, $p = 0.223$). A reciprocal model: HR_conf ~ HR_ppt * Condition * Group + (1 | Participant) confirmed that the participant's heart rate also significantly predicted the confederate's ($\beta = 0.16$, $p < 0.001$; electronic supplementary material, figure S2).

To verify that this real-time coupling persisted within each group and condition, four simpler models (HR_ppt ~ HR_conf + (1 | Participant)) were estimated. In all experimental contexts, we observed positive associations between the confederate's and the participant's heart rates (figure 4). In Mimicry conditions, the confederate's heart rate was a significant predictor in both the Choice ($\beta = 0.13$, $p = 0.003$) and the Motor ($\beta = 0.15$, $p = 0.001$) groups. The same pattern emerged in No-mimicry conditions, where the confederate's heart rate remained a positive predictor in the Choice ($\beta = 0.08$, $p = 0.042$) and Motor ($\beta = 0.16$, $p < 0.001$) groups. Together, these analyses demonstrate similar patterns of heart rate across participants and confederates during the experimental task, which were unaffected by both the presence and form of mimicry. Full statistics for all models are provided in electronic supplementary material, table S3.

3.3. Time-ordered heart rate influence

We next examined whether the confederate's heart rate on the previous trial ($t - 1$) predicted the participant's heart rate on the current trial (t), and whether this influence was moderated by condition or group. A cross-lagged mixed-effects model was specified as: HR_ppt(t) ~ HR_conf($t - 1$) * Condition * Group + (1 | Participant). The analysis revealed that the confederate's heart rate on the prior trial was a positive predictor of the participant's heart rate on the subsequent trial ($\beta = 0.16$, $p < 0.001$). As with the real-time analysis, this trial-to-trial influence was not significantly moderated by condition

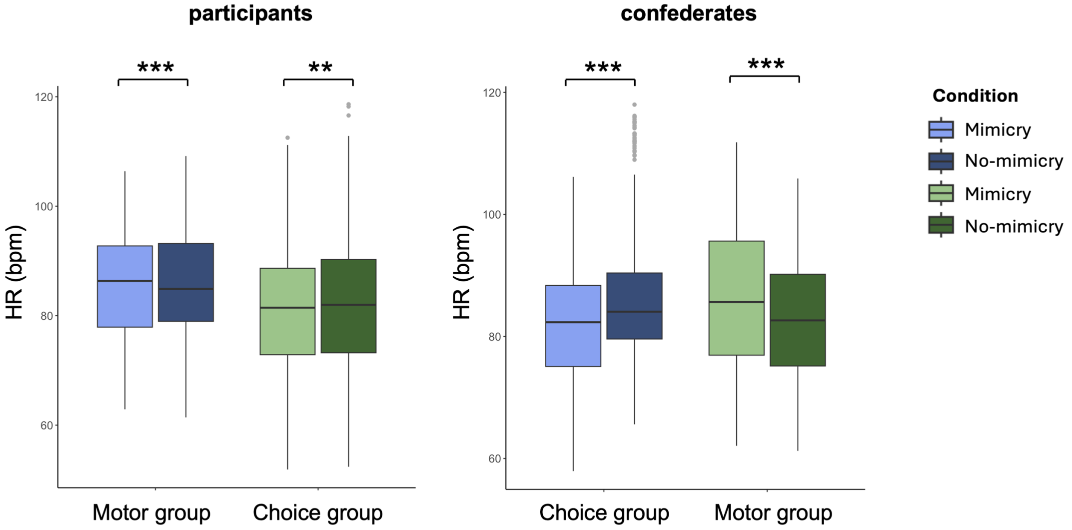

Figure 2. Mean heart rates across group and condition. Trial-level average heart rate (b.p.m.) for participants and confederates, presented separately for experimental group (Choice versus Motor) and condition (Mimicry versus No-mimicry). Asterisks indicate significant condition effects within each group (**$p < 0.01$, ***$p < 0.001$).

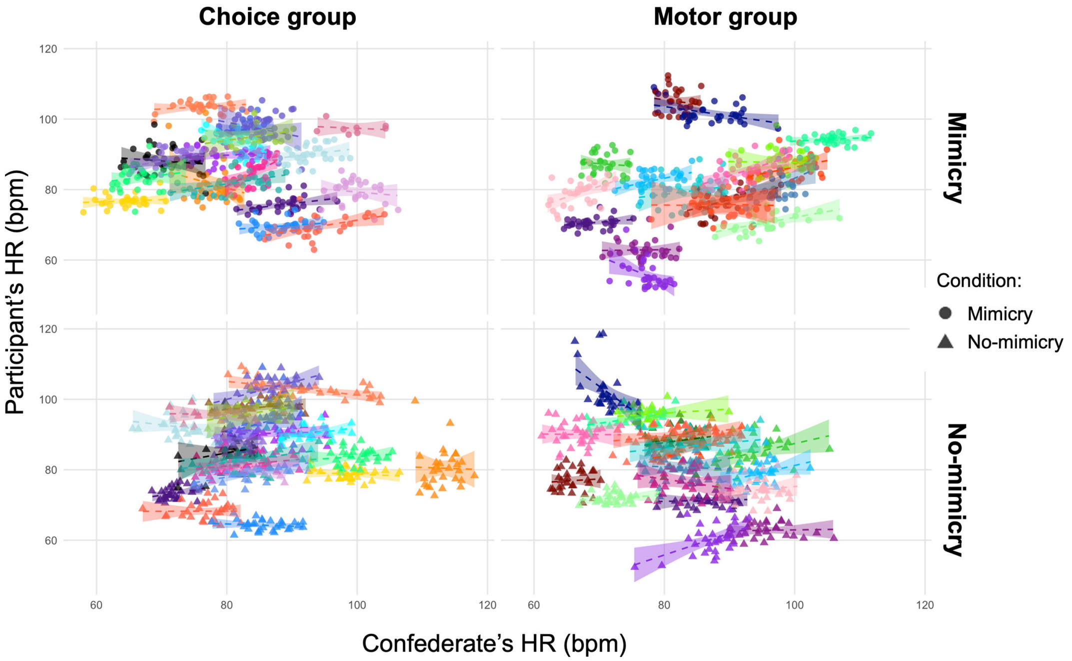

Figure 3. Real-time covariation in partners' heart rates. Each colour represents an individual dyad, and each point corresponds to the trial-level mean heart rate for a participant (y-axis) and the corresponding confederate (x-axis), with fitted regression lines illustrating within-dyad associations. Shapes indicate condition: circles for Mimicry and triangles for No-mimicry. The generally positive fitted lines indicate that higher confederate heart rates are associated with higher participant heart rates, regardless of the presence or form of mimicry.

or group (all $p \geq 0.223$). A reciprocal model: HR_conf(t) ~ HR_ppt(t − 1) * Condition * Group + (1 ∣ Participant) confirmed that the participant's prior heart rate also significantly predicted the confederate's subsequent heart rate ($\beta = 0.15$, $p < 0.001$).

To confirm this time-ordered covariation within each specific experimental context, four simpler models: HR_ppt(t) ~ HR_conf(t − 1) + (1 ∣ Participant) were estimated. The analysis showed that lagged associations between partners' heart rates were evident across all conditions in both groups (figure 5B). In Mimicry conditions, the confederate's prior heart rate significantly predicted the participant's subsequent heart rate in both the Choice ($\beta = 0.11$, $p = 0.013$) and the Motor ($\beta = 0.11$, $p = 0.022$) groups. The same pattern emerged in No-mimicry conditions, where the confederate's prior heart

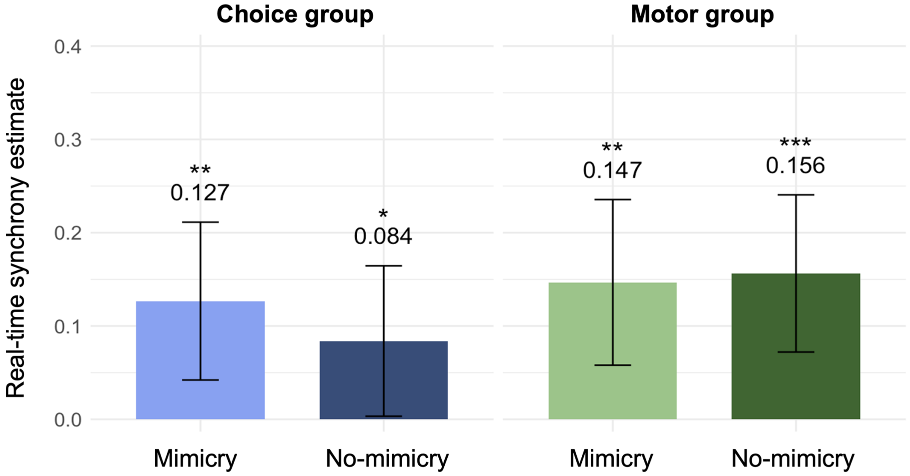

Figure 4. Real-time covariation in partners' heart rates by condition and group**.** The estimated strength of influence (with 95% CIs) of the confederate's heart rate on the participant's heart rate for each combination of experimental group (Choice, Motor) and condition (Mimicry, No-mimicry). Asterisks indicate coupling estimates significantly different from zero ($*p < 0.05$, $**p < 0.01$, $***p < 0.001$).

rate remained a positive predictor in the Choice ($\beta = 0.15$, $p < 0.001$) and the Motor ($\beta = 0.16$, $p < 0.001$) groups. Together, these results suggest bidirectional trial-to-trial associations in heart rate that unfolded independently of the mimicry manipulations. Full statistics for all models are provided in electronic supplementary material, table S4.

3.4. Control analyses of temporal dynamics

Additional control analyses tested whether the observed heart rate synchrony could be attributed to within-block trial time trends. Specifically, we considered the possibility that heart rate might decrease linearly over trials as participants relaxed after arriving at the laboratory, which could in principle account for some of the apparent synchrony. Plotting heart rate over time for participants and confederates showed a gradual increase within each block in both partners (figure 6), suggesting slow drifts in heart rate may be important. Interestingly, participants' heart rates appeared to reset between blocks, consistent with a task-related effect at the point of the confederate change rather than a simple physiological drift over time. We tested these patterns statistically as follows.

We first fitted a mixed-effects model with trial number within block as a predictor of participants' heart rate: HR_ppt ~ trial + (1 | Participant). The trial number showed a robust positive effect on participants' heart rate ($\beta = 0.03$, $p < 0.001$), indicating a gradual increase in heart rate across trials within each block (figure 6). Next, we fitted an otherwise identical model that also included confederate heart rate as a predictor: HR_ppt ~ trial + HR_conf + (1 | Participant). Adding confederate heart rate did not improve model fit ($\chi^2(1) = 0.88$, $p = 0.347$), and the fixed effect of confederate heart rate was non-significant ($\beta = 0.02$, $p = 0.35$). Thus, once this within-block time trend was accounted for, the confederates' heart rate did not explain any additional variance in the participants' heart rate.

In a complementary analysis, we asked whether real dyads showed stronger heart rate coupling than time-matched pseudo-dyads. We first fitted a mixed-effects model with confederate heart rate as the sole predictor of participants' heart rate: HR_ppt~HR_conf + (1 | Participant). We then used the fixed effect of confederate heart rate from this model ($\beta = 0.12$, $p < 0.001$) as the test statistic for a permutation test. We then generated a null distribution of slopes by randomly re-pairing participants and confederates within each trial (forming time-matched pseudo-dyads) and refitting the same model 1000 times. The mean slope in pseudo-dyads was also positive ($\beta = 0.09$), and although the slope for real dyads was slightly higher ($\beta = 0.12$), it did not differ significantly from this null distribution (two-sided permutation test, $p = 0.137$), indicating that similar levels of apparent coupling can arise from time-matched but randomly paired heart rate series. Together, these control analyses suggest that the apparent heart rate synchrony in this task is largely driven by shared temporal and task-related dynamics rather than dyad-specific synchrony.

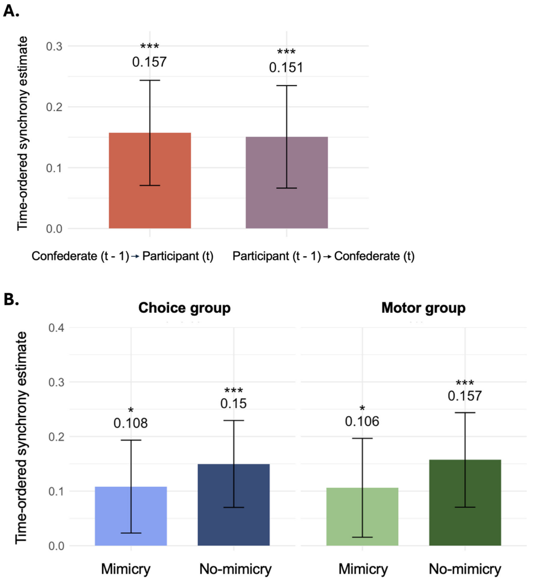

Figure 5. Time-ordered heart rate influence. (A) Estimates (with 95% CIs) for the overall bidirectional lagged influence, showing confederate's prior heart rate ($t - 1$) predicting participant's current heart rate (t) and participant's prior heart rate ($t - 1$) predicting confederate's current heart rate (t). These overall effects were not significantly moderated by condition or group. (B) Estimates (with 95% CIs) of confederate's prior heart rate ($t - 1$) influencing participant's current heart rate (t) within each combination of group (Choice, Motor) and condition (Mimicry, No-mimicry). Asterisks indicate coupling estimates significantly different from zero (*$p < 0.05$, ***$p < 0.001$).

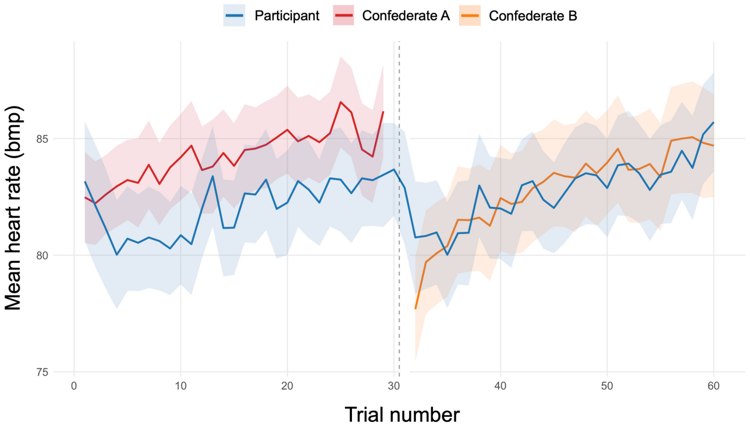

Figure 6. Mean heart rate across the experiment. Trial-level average heart rate (b.p.m.) for participants and confederates across the 60 trials. The vertical dashed line between trials 30 and 31 marks the transition between Confederate A (block 1) and Confederate B (block 2). Heart rates of both participants and confederates exhibit a slow, shared upward drift within each block, and the sharp drop at the block boundary highlights a return to a lower arousal baseline with the introduction of the new confederate.

3.5. Confederates' ratings of participants

Exploratory linear mixed-effects models were used to assess whether group (Choice versus Motor) and condition (Mimicry versus No-mimicry) affected confederates' impressions of participants' warmth and competence. The model was specified as: Perceived warmth (or competence) ~ Group * Condition + (1 ∣ Confederate) + (1 ∣ Question). The analyses revealed no significant main effects or interaction for either warmth or competence (figure 7A). For perceived warmth, there were no significant effects of group ($\beta = -0.12$, $p = 0.296$), condition ($\beta = 0.04$, $p = 0.745$) or their interaction ($\beta = -0.01$, $p = 0.953$). Similarly, for perceived competence, no significant effects were found for group ($\beta = -0.11$, $p = 0.268$), condition ($\beta = -0.14$, $p = 0.277$) or their interaction ($\beta = 0.17$, $p = 0.254$). No significant effects of condition were found in the follow-up models conducted separately within the Choice and Motor groups (figure 7A; electronic supplementary material, table S5). These results indicate that neither the presence nor the type of mimicry influenced confederates' perceptions of participants. This pattern of

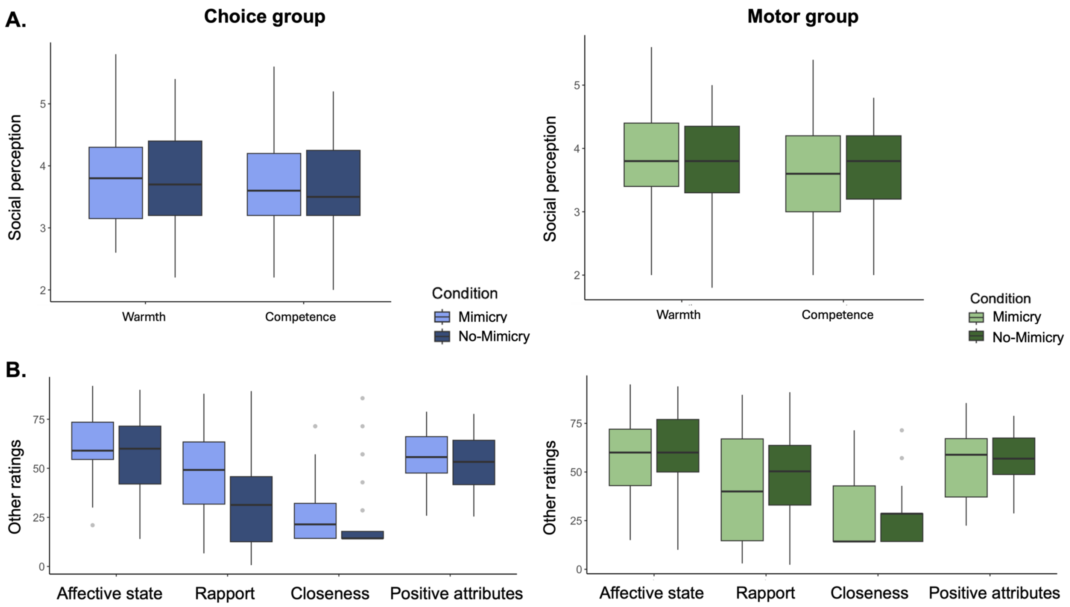

Figure 7. Confederates' social perception and other ratings of participants. (A) Perceived warmth and competence ratings of participants by confederates, presented separately for the Choice and Motor groups and by condition (Mimicry versus No-mimicry). (B) Additional ratings of participants by confederates, including their current affective state, perceived rapport, closeness with participants and positive attributes of participants also presented separately for the Choice and Motor groups and by condition (Mimicry versus No-mimicry). Both panels show that neither performing mimicry nor its type significantly affected confederates' ratings of participants.

non-significant findings extended to the other measures, including current affective state, perceived rapport, closeness and positive attributes (all $p \geq 0.164$; figure 7B). Detailed results for perceived warmth and competence are reported in electronic supplementary material, table S5, and all other ratings in electronic supplementary material, table S6.

4. Discussion

Research has only begun to specify the conditions under which physiological synchrony emerges during social interaction. Much prior work has focused on correlational links between motor coordination and heart rate coupling, leaving the causal influence of different forms of mimicry unclear. To address this gap, the present study compared choice and motor mimicry in a tightly controlled, non-verbal art choice task to test whether either form modulates heart rate synchrony. Participants in the Choice or Motor group interacted with confederates who either mimicked or did not mimic them. Although partners' heart rates covaried within and across trials, this coupling was not influenced by the presence or type of mimicry. Control analyses further indicated that the apparent synchrony reflected shared temporal and task-related dynamics rather than dyad-specific physiological alignment. We also found no evidence that performing mimicry affected the mimicker's social perception or affiliation. Together, these findings suggest that in this minimal, tightly structured interaction, mimicry was insufficient to drive dyad-specific heart rate synchrony.

4.1. Apparent heart rate synchrony

Initial analyses suggested that partners' heart rates were tightly coupled across all conditions. However, this apparent synchrony was largely explained by shared temporal structure: time-matched pseudo-dyads showed comparable coupling to real dyads, and within-block time trends captured much of the observed covariation. This indicates that partners' heart rates were primarily shaped by shared task dynamics and common experimental constraints, rather than by dyad-specific physiological coupling.

Several factors could have contributed to this relatively uniform pattern of autonomic responses. Simply being in the same room and experiencing external events simultaneously (e.g. ambient noise, page turns) or responding to shared task cues on each trial could have aligned partners' heart rates [8,46]. The voice commands imposed a common auditory rhythm, and attentive listening to shared sounds can synchronize listeners' heartbeats [47,48]. Similarly, joint visual attention to the artworks, which are known to elicit distinct heart rate changes [49,50], may have synchronized autonomic responses as partners monitored and anticipated the art choices on each trial.

Apparent synchrony may also have arisen from the task's sensorimotor demands. On every trial, the participant pointed to indicate a choice, and the confederate responded with either the same gesture (Motor group) or a button press (Choice group). As even minimal actions are often timed to specific heartbeat phases [51–53], the cue-driven timing could have imposed a shared temporal structure that drove partners' individual cardiac patterns into synchrony. The task's turn-taking structure, which requires mutual monitoring and anticipation of each other's actions [54], may have strengthened this effect. In line with this account, it has been proposed that interoceptive simulation of a partner's cardiac-motor patterns is a key mechanism underlying physiological synchrony [55].

Our paradigm involved a minimal, tightly controlled interaction with strong task demands, and each partner's behaviour was constrained by the trial structure. Such a design may have limited the continuous, bidirectional exchange of socially relevant information that theoretical accounts highlight as important for interpersonal physiological coupling [20,56]. In a similarly highly constrained, non-verbal setting, Flory *et al.* [35] examined heart rate synchrony during a self-paced joint finger-tapping task in which partners established and maintained a shared rhythm. Although cardiac coherence increased relative to baseline, real and pseudo-dyads did not differ, leading the authors to attribute the observed alignment to a common, task-evoked psychophysiological mode rather than dyad-specific coupling. In contrast, Boukarras *et al.* [36] observed dyad-specific heart rate synchrony during a less tightly structured joint object-grasping task, which involved continuous monitoring and adjustment to a partner's behaviour across various coordination modes. Together with the present findings, this suggests that when minimal, non-verbal interactions are highly structured and offer little scope for ongoing social information exchange, heart rate coupling may primarily reflect shared task dynamics.

4.2. Motor and choice mimicry

Contrary to our prediction, neither choice nor motor mimicry affected cardiac coupling. Apparent heart rate synchrony did not differ between Mimicry and No-mimicry conditions in either the Choice or Motor groups. A sensitivity analysis indicated that the study was well powered to detect effect sizes typically reported for associations between behavioural coordination and physiological synchrony [28], suggesting that any undetected mimicry effect on heart rate coupling is likely to be very small. These findings extend prior causal work showing that motor coordination alone does not modulate cardiac alignment in minimal social settings [35,36], and demonstrate that this null effect also holds for both motor and abstract form of mimicry, copying choices. Mimicry therefore seems insufficient to drive heart rate synchrony unless additional mediators, absent from our design, are present. Our instructed copying left little opportunity for genuine affective exchange, the pathway through which mimicry is thought to foster physiological synchrony [57,58]. Moreover, mimicry in our paradigm was one-sided: although participants and confederates continuously exchanged choices, only the confederate imitated the participant. This eliminated the mutual adaptation that characterizes improvisational motor tasks, where movement and cardiac synchrony co-occur [29,31,32]. Together with the strong task structure, these constraints likely limited the opportunity for mimicry to influence dyad-specific autonomic dynamics. Future research should use more ecologically valid paradigms to causally test when, and if, mimicry can drive physiological synchrony.

Although mimicry did not influence heart rate coupling, we observed unpredicted differences in average heart rate across different blocks of trials. When participants' choices were copied, their heart rate increased slightly, whereas when their actions were copied, it decreased slightly. This finding may reflect different cognitive demands: the explicit nature of choice mimicry likely required more processing and thus heightened arousal [59,60], while subtle action matching probably went unnoticed and demanded less effort. Supporting this interpretation, more participants in the Choice group than in the Motor group correctly identified the study's purpose [27]. Confederates showed the reverse pattern: their heart rate decreased while copying choices but increased while copying actions, probably reflecting task demands. Pressing a key to mimic a choice requires minimal effort, whereas reproducing a participant's hand action is more demanding and may engage greater sensorimotor mapping. Taken together, these opposing arousal patterns suggest that mimicry altered the average heart rates of mimickees and mimickers in opposite ways. Future studies should systematically vary mimicry type, salience and motor demands to untangle their distinct effects on individual physiology.

Our secondary analysis also shows that performing choice or motor mimicry did not affect the confederate's social perception and liking of the participant. While facial and bodily mimicry in conversation has been found to increase the mimicker's perceived closeness [37], our result aligns with evidence from a constrained video-based facial mimicry task showing no change in the mimicker's liking [38]. The difference likely lies in interaction goals, as our motor and choice copying occurred in a task-oriented, non-verbal setting, which can weaken the affiliative motives thought to translate mimicry into increased liking [61]. Notably, the same task did increase liking in the person being copied, strongly for choice mimicry and subtly for motor mimicry [27], suggesting that in goal-directed contexts mimicry influences social perception in the target rather than the mimicker.

4.3. Disentangling time trends from dyadic heart rate synchrony

Building on methodological work on temporal structure in physiological synchrony [8,40,46], we provide a working example showing how unmodelled temporal trends can be incorrectly interpreted as interpersonal heart rate synchrony. In our initial analyses, we regressed participants' trial-level heart rate on confederates' heart rate and found that partners' heart rates appeared tightly coupled. However, these models did not include any explicit representation of time. Control analyses addressed this by modelling within-block temporal trends and comparing real dyads to time-matched pseudo-dyads. Once these temporal dynamics were accounted for, confederate heart rate no longer explained additional variance in participant heart rate, and real dyads did not differ from pseudo-dyads. Moreover, heart rate trajectories tended to increase across trials, rather than showing the monotonic decline expected from simple habituation (i.e. progressive relaxation over time). What appeared as cardiac synchrony in the initial models was therefore largely explained by shared time-on-task dynamics, illustrating how easily temporal structure can mimic dyad-specific physiological coupling if it is not explicitly modelled.

When one finds a pattern of synchrony, it is important to rule out alternative, non-interpersonal explanations. On this basis, we recommend that future work on physiological synchrony routinely (i) visualizes heart rate trajectories for both partners across the session to inspect overall trends (e.g. to check for simple habituation); (ii) incorporates explicit temporal structure into models (e.g. trial effects) so that any effect of the partner's physiology is estimated over and above time-on-task trends; and (iii) compares real dyads against time-matched pseudo-dyads (e.g. using permutation-based tests) to assess whether observed synchrony exceeds what would be expected from shared temporal and task structure alone. Together, these steps provide a practical analytic template for more robust tests of interpersonal physiological coupling.

4.4. Implications, limitations and future directions

This study advances current understanding of physiological synchrony by clarifying the conditions under which heart rate coupling does not reflect dyad-specific interaction. In a tightly controlled, non-verbal art choice task, cardiac coupling was unaffected by either motor or choice mimicry and was largely explained by shared temporal and task structure. These findings support previous reviews suggesting that behavioural matching alone is insufficient to generate interpersonal physiological coupling [8,20], and instead point to the importance of richer forms of reciprocal engagement for dyad-specific alignment. Methodologically, our results provide a cautionary example of how unmodelled temporal structure in tightly controlled social tasks can be misinterpreted as evidence for interpersonal physiological synchrony, underscoring the need to evaluate observed coupling against null models. Finally, we demonstrate that copying another person's choices or actions does not increase affiliative responses in the mimicker, indicating that the social benefits of mimicry may be asymmetric and context dependent.

We acknowledge several limitations. First, as this study was not originally designed to examine physiological synchrony, heart rate recordings were broken into short, self-paced blocks, giving each dyad a unique timeline. Although the mixed-effects approach we adopted is robust for detecting overall synchrony patterns [8], it is less sensitive to fine-grained, time-dependent coupling and the short trial durations precluded analyses such as wavelet coherence. Future research would benefit from longer trial duration and standardized block timing.

Second, in our motor paradigm, we implemented anatomical motor mimicry, in which the mimicker used the same effector (the right hand) to perform either the same (Mimicry) or a different (No-mimicry) action as the mimickee. Thus, the difference between these conditions was relatively subtle compared with previous confederate designs, in which No-mimicry conditions typically involved the confederate remaining still [25,62]. Furthermore, mirror-wise imitation [39,63], where a participant's right-hand action is copied by the confederate's left hand, may result in different effects on heart rate synchrony and the mimicker's affiliative responses. Future studies should therefore directly compare anatomical and mirror-wise motor mimicry within similar face-to-face paradigms.

Furthermore, cardiac synchrony may have been influenced by other interpersonal cues, such as covariations in pupil size or facial blushing [57,58], that we did not record. Future research should record a broader battery of physiological signals to determine whether mimicry or other subtle channels of coordination contribute to cardiac synchrony.

Our analysis of the mimicker's affiliative responses is based on ratings from only five confederates, as the experiment was originally designed to assess participants' responses to being mimicked. We nevertheless report these results as prior motor mimicry research has claimed that confederates tend to like the participants they copy [22,64], without providing statistical support. Given our null findings, future research should aim to replicate these findings with larger samples and more sensitive outcome measures (e.g. binary measures) [27] to rule out any potential subtle affiliative effects on the mimicker.

Despite these constraints, we provide causal evidence that neither choice mimicry nor motor mimicry drives heart rate alignment in structured, non-verbal interactions. By incorporating an abstract and previously underexplored form of mimicry, copying choices, we extend research on behavioural coordination and physiological synchrony beyond purely sensorimotor paradigms. Using a carefully controlled design, we assessed heart rate synchrony across and within both choice and motor mimicry. Our findings have important implications for multimodal synchrony research, showing that mimicry and physiological synchrony are not intrinsically linked. Finally, we also illustrate how unmodelled time trends can lead to apparent heart rate coupling and therefore emphasize the importance of incorporating control analyses when assessing physiological synchrony.

5. Conclusion

In conclusion, we showed that in a tightly controlled, non-verbal art selection task, cardiac coupling was not influenced by either choice or motor mimicry. Once time trends were modelled and real and pseudo-dyads were compared, the initially observed physiological synchrony was largely explained by shared temporal and task-related dynamics. These findings suggest that, in highly structured non-verbal interactions, mimicry alone is insufficient to produce dyad-specific physiological alignment. More broadly, our results highlight the importance of modelling temporal dynamics when interpreting physiological synchrony and help specify the conditions under which apparent heart rate coupling cannot be attributed to interpersonal processes.

Ethics. The experiment received ethical approval from the UCL Research Ethics Committee (Approval ID: 5975/003). All participants and confederates gave informed consent.

Data accessibility. Materials, analyses and pre-processed data are publicly accessible via the Open Science Framework (OSF) [65].

Electronic supplementary material is available online [66].

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors' contributions. P.W.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, validation, visualization, writing—original draft, writing—review and editing; A.M.: formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing—review and editing; S.K.: formal analysis, funding acquisition, investigation, methodology, resources, supervision, validation, visualization, writing—review and editing; A.F.d.C.H.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, resources, supervision, validation, visualization, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

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