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Building trust: Heart rate synchrony and arousal during joint action increased by public goods game

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HIGHLIGHTS

- Public Goods Game introduces trust related conditions during a joint action task.
- Heart rate arousal is increased in the trust related condition.
- Heart rate synchronization is increased in the trust related condition.
- Heart rate synchrony is predictive of the participants' expectations.
- Physiological coordination maybe a marker of a trust building process.

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ABSTRACT

The physiological processes underlying trust are subject of intense interest in the behavioral sciences. However, very little is known about how trust modulates the affective link between individuals. We show here that trust has an effect on heart rate arousal and synchrony, a result consistent with research on joint action and experimental economics. We engaged participants in a series of joint action tasks which, for one group of participants, was interleaved with a PGG, and measured their heart synchrony and arousal. We found that the introduction of the economic game shifted participants' attention to the dynamics of the interaction. This was followed by increased arousal and synchrony of heart rate profiles. Also, the degree of heart rate synchrony was predictive of participants' expectations regarding their partners in the economic game. We conclude that the above changes in physiology and behavior are shaped by the valuation of other people's social behavior, and ultimately indicate trust building process.

1. Introduction

The ability to participate in cooperative tasks necessarily depends upon trust, that is, commitment to the other participants for the accomplishment of future collective goals [6]. Expressing and reciprocating trust is an important signaling mechanism that influences cooperative behavior among individuals, groups, and organizations [20,22,25,33,40,41]. For example, when two or more individuals decide to partake in a joint action that involves risk, one participant must trust the other with the expectation of reciprocity or there can be no cooperation [12,43].

Numerous studies have found that positive interactions lead to higher trustworthiness and cooperation [15,46]. One of the primary means of investigating trust is through the use of economic games [3,7,8,21,34]. As a method, economic games are usually thought of as measurement instruments that capture trust. One of the most well-known economic games measuring trust is the Public Goods Game (PGG). Briefly, participants are asked to contribute to a common investment which is subsequently proportionally increased and split equally between participants. In this game the total outcome is maximized if each participant contributes maximally but individual outcome maximizes when participants do not contribute. Thus, the PGG is both a model of trust and a model for trust ([23], 87–125).

In our study, it is expected that the use of the PGG would prime participants to focus on their relationship to one another (i.e. the quality of their interaction) and display trust or positive affect [60]. In this study, we wanted to explore whether there would be physiological markers in the individual or in the couple, during an online trust building process, as exemplified by the PGG.

We had 37 pairs of participants' construct model cars using LEGO building bricks in 4 consecutive 10-minute sessions [56,42], while

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participants' heart rates were measured during the interaction to provide continuous measures of synchrony and arousal. After each building session, participants completed brief questionnaires in which they reported their experiences of the interactions with their partner regarding cooperation, experience of fun, and control over the building task. Additionally, we collected new data from another 20 pairs of participants using the same experimental setup, with the modification that after each building exercise the participants played a PGG. In this condition, which we entitled the Trust Condition (TC), participants were asked to play the PGG between each of the building sessions, while the previously collected data set was treated as the Control Condition (CC), in which no economic game was employed (Fig. 1).

We tested the effect of inducing trust on two different levels: On subjective experience, and on (continuous measures of) physiological response and behavior. We predicted that participants' heart rate profiles would be more synchronized during the TC, demonstrating an autonomic response to high levels of affective coupling between the participants [18,26,35,36]. In addition to heart rate synchronization, we predicted that increased heart rates would indicate an overall increase of arousal during the TC, as a result of positive excitement and increased social interaction awareness [59].

2. Methods

2.1. Participants

The original study [56] included a total of 74 participants (average age: 23.5 yrs. $SD = 3.5$ yrs.). The newly collected data set consisted of 40 participants (average age: 23.3 yrs. $SD = 2.6$ yrs.). All were students from Aarhus University. Participants were randomly assigned to pairs. Using standardized forms in the subjects' native language, the pairs were given instructions regarding the building sessions. The experiment lasted 75 min. Our protocol was reviewed and approved by the Danish National Ethics Committee. All participants signed an informed consent form.

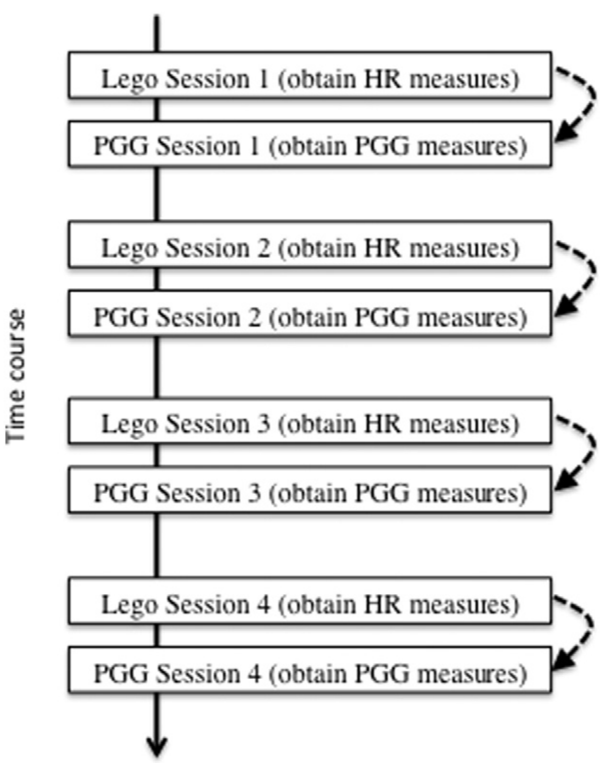

Fig. 1. Experimental procedure: A Public Goods Game was played after each building session, while heart rate measures were collected during the building sessions.

2.2. Public goods game

In the PGG [37], participants determine how much money (given to them by the experimenters) they should contribute to a common pool. The sum of the players' contributions to the common pool is then multiplied by a factor (>1 and less than the number of the participants) and split evenly between them. Each participant also keeps the amount of money they did not contribute to the common pool. Given this setup, the total payoff is optimized for the group when players contribute all their funds. By definition, each participant consumes an equal share of the common pool, even if one of them contributed nothing to it. The standard Nash Equilibrium in a one-shot experiment is zero contribution, although it would be collectively rational to contribute everything.

2.3. Procedure

Participants were instructed to make optimally performing and esthetically pleasing cars. Participants were involved in four building sessions.[2] As aspects of coordination might be observed on the level of autonomic synchronization [19,54], participants' heart rates were recorded during all sessions with a Polar Team2 heart rate monitor around the chest. The heart rate monitors recorded the subjects' heartbeats as beats-per-minute in 1-second intervals.[3] For each 10-minute building session, participants received the same set of LEGO bricks as well as specialized instructions for the design and construction of their model car. Immediately upon completing each session, participants rated the building task according to their perceived cooperation, experience of fun, and control over the building of the car model's design. In the TC, in addition to the questionnaire, participants received 100 DKK (~13.5 €, Average amount given per person: 460 DKK, $SD = 98$ DKK) from the experimenter, a paper-sheet with instructions on how to play the PGG, and a decision-sheet, where they could indicate how much from the given money they wanted to contribute and how much their expectation about the other participant's investment was. However, participants did not get feedback on how much money they would earn per game — participants were informed about their compensation only after the study was over. In the TC, participants were informed that they would play a PGG every after building session. A trial version of the PGG was implemented before the first building session. In the CC condition, participants received 450 DKK (~60.5 €).

3. Results

3.1. Data analysis

Multivariate Recurrence Quantification Analysis (MVRQA) was used to assess the degree of synchrony at the level of heart rate profiles during the building sessions. MVRQA is a time series analysis technique that measures the relationship between three or more time series and can be used to quantify their degree of synchrony [52], and recurrence-based analyses are prominent for the analysis of temporal coordination and has been used in a variety of studies [36,47,50]. To conduct recurrence analysis, the time series are projected into a phase space by the method of time-delayed embedding [51]. The time series are plotted against

[2] In order to keep the same procedure as in the original study [56] we employed three modes of interaction: The Egalitarian Condition, where participants received no instructions regarding building except building an optimally performing and esthetically pleasing car. The Hierarchical Condition, where one participant had to make all design decisions while the other could only assist. This condition was enacted twice in back-to-back sessions, so that each participant played the role of designer or assistant once. The Turn Taking Condition, where participants were asked to take turns in constructing the car. The order of these modes of interaction was randomized for each pair of participants. The above manipulation is helpful in assessing that the physiological findings are not a result of the modes of interaction but of the economic game priming.

[3] In order to keep the same procedure as in the original study [56] each participant also wore an ActiGraph GT3X+ accelerometer on each wrist. The degree of hand movement synchrony did not differ as a function of playing the PGG ($t(210) = -0.47$, $p = .677$).

themselves at some time lag, according to a delay-parameter (from here on DEL). The number of times that the data is plotted against itself is determined by the dimension-parameter (from here on DIM). The time series are normalized before the embedding procedure to ensure that the recurrence measures are not overly influenced by the magnitudes of participants' hand movement accelerations but, rather, are based on the sequence of accelerations [16].

Fig. 2 provides an example. Let us say we have two sets of pairs of signals (S) each, all with the same average frequency content (f) plus random noise (e). S = sine(f) + e. However, f is changing over time. While the changes of f are different for the two signals in set 1 (Fig. 2a), the changes of f are the same for the two signals in set 2 (Fig. 2a). Hence, the two pairs of signals differ in the degree of synchrony among them, where set 1 (Fig. 2a) exhibits a relatively low degree of synchrony, while set two (Fig. 2c) exhibits a relatively high degree of synchrony.

The evolution of these two sets of signals can now be represented as a recurrence plot. The recurrence plot represents each set of three signals as the distances between the data points. That is, if the two signals exhibit very different dynamics, the distances between the signals will be large. If the three signals exhibit very similar dynamics, these distances will be small. Small distances that fall below a pre-defined threshold yield recurrent structures on the recurrence plot, while large distances do not. Hence, in a recurrence plot, periods with a high degree of synchrony are marked by black areas (recurrence), while periods with a low degree of synchrony are marked by empty spaces (no recurrence). As can be seen in Fig. 2, the set of signals with a low degree of synchrony exhibits fewer recurrences, while the set of signals with a high degree of synchrony exhibits more recurrences.

To assess synchrony more thoroughly, however, it is important to determine whether the recurrences in the recurrence plots connect to each other. Isolated points of recurrence could simply be the result of chance — two random variables could exhibit many individual recurrences, if variables are drawn from the same distribution and that distribution has a restricted range of values. In contrast, we are interested in recurrence that perseveres over time, that is to say, where the three signals do not merely cross each other accidentally, but exhibit continued coordination with each other. In recurrence quantification analysis, the extent to which coordination occurs in terms of such "trajectories" can be captured by the measure %Determinism [39,49]. %Determinism is defined as the number of points in a recurrence plot that form adjacent diagonal line structures divided by the number of all points on the plot and has been used in several studies to quantify interpersonal coordination (Fig. 2a/b).

Each individual data set was normalized by z-scoring. The embedding parameters were determined based on the individual, single hand movement accelerations and heart rate profiles, using the first local minimum of the average mutual information function to estimate the delay parameter (DEL) and the first local minimum to of the false-nearest neighbor function to estimate the dimensionality (DIM) of the

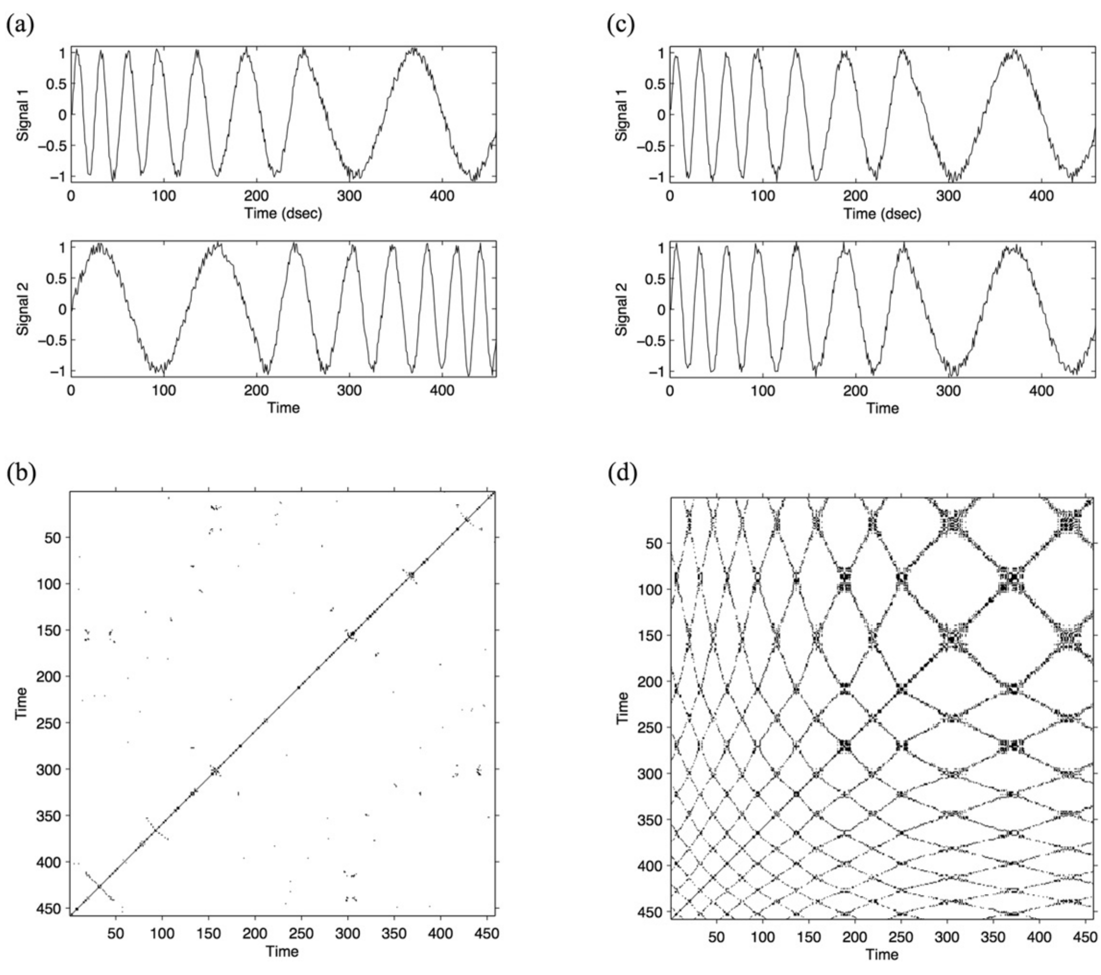

Fig. 2. Illustration of MVRQA on artificial signals, i.e. sine waves with added random noise. Panel a depicts a set of three sine waves that exhibit a relatively low degree of synchrony together with their associated recurrence plot (b). Fig. 1c depicts a set of three sine waves that exhibit a relatively high degree of synchrony with their associated recurrence plot (d). The recurrence plot in b is sparsely populated compared to d. Furthermore, the recurrence points are much less connected in b compared to d, as can be quantified by the measure %Determinism: While the plot in b exhibits %Determinism = 18.6% (low synchrony), the plot in d exhibits %Determinism = 54.1% (high synchrony).

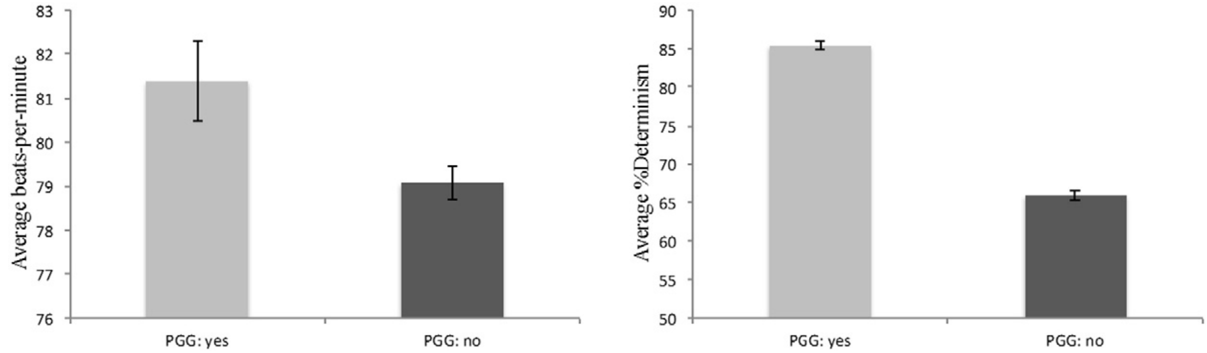

Fig. 3. Heart rate (1) and heart rate synchrony (2) are increased in TC where participants played the PGG after building (yes) compared to CC, where participants did not play the PGG (no).

phase-space [55]. Afterwards, the two heart-rate time-series were embedded into a phase-space in order to calculate the recurrence plot. For heart rate profiles, we used DEL = 2 and DIM = 3. The maximum norm was used to rescale the phase-space. A threshold of 35% of the maximum norm was adopted for the heart rate profiles.

Due to minor problems with the heart rate equipment, data from 19 out of the overall 228 building sessions was lost. After calculating heart rate and heart rate synchrony for each trial, we averaged those two measures across all sessions from each pair. Hence, for inferential analysis, we obtain a single value for each measure: heart rate and heart rate synchrony per pair.

3.2. Subjective task perception

In order to check the influence of the added PGG on the participants' perception of the task, participants were asked in an open-ended question to guess what the study was about after completing all building sessions. Participants' guesses were coded with regard to keywords related to obvious aspects of the experimental situation (e.g. "building", "teamwork", "decision-making"). The three categories were 1. building and construction, 2. social dynamics and cooperation, and 3. Trust, risk and economic incentives. A chi-square test was used to assess differences in the frequencies. Two independent raters that were blind to the hypothesis rated the presence or absence of each of the three categories in each participant's guesses.

According to Cohen's Kappa, the inter-rater-reliability between the two raters was satisfactory ($K = 0.770$, $p < .001$). Cases of disagreement between the two raters were randomly resolved (i.e., half the cases of disagreement were solved by randomly collapsing selecting the decision of one of the two raters).

In both conditions, a minority of participants believed that the study was about investigations of the building process (15.0% vs. 13.2%) $\chi^2 = 0.07$, $p = .798$. The majority of participants in both conditions believed that the study aimed at an investigation of interpersonal cooperation (77.5% vs. 88.2%), $\chi^2 = 2.19$, $p = .139$. However, the majority of the participants in the TC believed that the study was investigating effects of risk, trust and incentives (57.5%), while almost no one believed so when no PGG was added to the joint task (7.4%), $\boldsymbol{\chi}^2 = 32.98$, $p < .000$.

After each building session, participants were asked to rate their perceived difficulty and effort of the task, as well as their perceived satisfaction with the end product (i.e., the model car). The self-reports were subjected to an independent sample *t*-test with the between-participant factor PGG 2 × (yes vs. no). However, none of the questions differed as a function of playing the PGG (all $t > 1.87$, all $p > .067$).

3.3. Heart rate

During each building session, participants' heart rates were recorded with Polar heart rate monitors that participants wore around their chests. The overall level of rate (average beats-per-minute) during the building sessions and the strength of heart rate synchrony between participants (MVRQA, %Determinism) were subjected to an independent sample *t*-test with the between-participant factor PGG 2 × (yes vs. no). The results showed significantly higher heart rate for participants in the TC compared to those in the CC ($t(55) = -2.58$, $p = .013$). Furthermore, participants in the TC also exhibited a higher level of heart rate synchrony compared to those in the CC ($t(55) = 3.58$, $p = .001$) (see Fig. 3).

3.4. Relation between heart rate and the PGG

In order to see whether heart rate arousal or synchrony predicted the participants' performance in the TC, we specified regression models with investments and expectations of returns as dependent variables, and the heart rate predictors.

Because the data points come from a repeated measures design where each dyad participated in 4 building conditions, we averaged the values for heart rate synchrony and the PGG across all building conditions. Hence, we obtained a single value for heart rate synchrony and a single value for investments and expectations of returns from the PGG for each dyad.

We found that heart rate synchrony was positively associated with expectations of returns ($\beta = .449$, $t(19) = 2.13$, $p = .047$), but not of investments ($\beta = .334$, $t(19) = 1.51$, $p = .150$) (see Fig. 4).[4] No other predictors were significant (all $p > .399$).

3.5. PGG investments and expectations

Participants' performance in the PGG was generally close to ceiling: During each game, participants could freely decide to invest between 0 and 80 DKK. The average investment was 71.70 DKK ($SD = 17.00$), the median was 80.00 DKK. Similarly, expectations of returns were generally very high among participants: The average expectation that regarding the investment of the other player was 70.15 DKK ($SD = 16.48$), with the median expectation being 80.00 DKK, that is maximal reciprocity.

4. Discussion

The physiological processes underlying and mediating trust, have been a subject of investigation within the behavioral sciences [61]. For example, there has been an increasing evidence that oxytocin plays an important role in the regulation of social behavior, such as bonding,

[4] As can be seen in Fig. 4, investment and expectation ratings were close to or at ceiling for many of the dyads. When those data points were removed (i.e., values of 80 for investments or expectations, respectively), the results of the regression analysis relating heart rate synchrony to the PGG were corroborated: There was still no effect of investments ($\beta = .469$, $t(9) = 1.57$, $p = .171$), but a marginal effect for expectations ($\beta = .334$, $t(9) = 1.51$, $p = .057$). Note, however, that the removal of these values also resulted in a loss of at about half of the sample size.

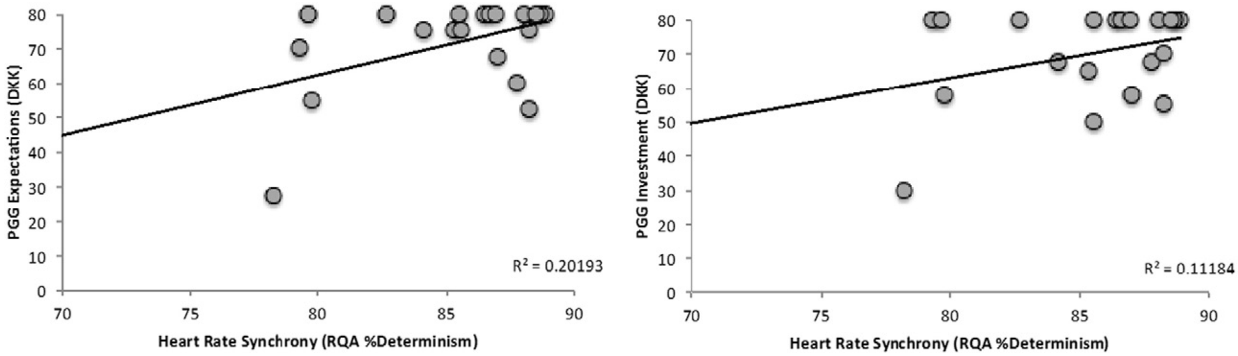

Fig. 4. The degree of heart rate synchrony significantly predicts expectations of returns (left panel), but not investments (right panel) during the PGG.

trust and affective regulation [62–68]. Although, over the last few years much research has been done on the hormonal basis of trust, little research has been done on the autonomic arousal as indicated by physiological responses (i.e. heart rate). Kéri and Kiss (2011) showed that trust-related oxytocin level is positively associated to autonomic arousal habituation. In situations where increased social interaction occurs and where trust conditions may follow, we would assume a higher heart rate arousal as a result of the psychological tension of keeping the interaction alive while attempting to earn the trust of others.

In line with this, research on joint action has repeatedly shown that degree of coupling between people is a key factor in shaping their experience of an action episode [30]. As predicted, participants' heart-rate profiles were more coordinated during the TC. Research on joint action regarding synchrony and autonomic physiology in groups is suggestive in relation to the optimal experience of collective activity, where synchrony in autonomic physiology has been shown to be an indicator of rapport, affiliation, and the improvement of group dynamics [57,69].

The level of heart rate synchrony was a significant predictor of expectations in the PGG. The fact that higher levels of heart rates synchrony led to higher expectations suggests that this measure of interpersonal physiological synchrony may be a marker of interpersonal trust. Expectations are an indication of preferences and beliefs about the behavior of others: an actor undertakes an action that involves the risk of trust only if she believes that this choice will be reciprocated by the other actor.

Economic experiments have shown that in order to build trust one needs to signal the positive externality of being trustworthy [2,4,17,24,31,58]. Even those who have little motive to exercise trust may end up doing so if they expect that the other participant is likely to be trustworthy in return. Expectations about one another's behavior can lead participants to exercise trust (thus cultivating reputation) with the goal of gaining the trust of the other, so that they are willing to engage in cooperative activities [5,13]. Our findings complement those of previous studies that reported that heart rate, a marker of arousal, is an indication of positive excitement [59]. We speculate that the participant's increased heart rates demonstrate an amplified awareness of the other participant [70], while the interpersonal synchrony of heart rate may be an important marker of this reciprocation. Based on this experiment, we cannot tell apart whether this 'falling in synch' simply follows from a coordination of internal states between the individuals or whether it is a more direct signaling mechanism, confirming a 'handshake' between the individuals. However, we speculate that the synchrony may be a way to communicate mutual coupling and trustworthiness in a situation caught between an opportunity for cooperation and a risk of free-riding.

A major research issue is how to operationalize a continuous proxy of trust. Usually, trust is measured by using questionnaires and economic games [9–11,14,16,32,38,51]. However, these measures do not lend themselves particularly well to quantify the time-course of trust in a particular situation [27–29]. Available continuous, physiological measures (e.g. motion capture, FMRI, eye-movements, skin conductance, response time or heart-rate) are not straightforward measures of trust or at least their validity as such is unknown. Those measures have been used to reveal the cognitive and emotional mechanisms underlying different aspects of decision-making [1,28,29,44,45,48]. Our findings suggest that interpersonal heart rate coordination may be a potential proxy for trust building process.

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Authors declare no conflicts of interest.

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