Tapping trust task (TTT):

Investigating the mechanisms of interpersonal synchrony in the trust game

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Layman's summary

Trust plays an important role in human social relationships. We usually trust people close to us, such as our friends and family, people with whom we have a social bond. Moving at the same time at the same place together with someone else such as drumming or dancing, a phenomenon called interpersonal synchrony, has been shown to increase these bonds. For example, previous studies have found that people who tap a rhythm at the same time as someone else afterwards like that person more and feel more close to that person. Also, people are more inclined to help a person with whom they performed that synchronous action. In this study, we investigated whether participants also showed more trust towards a person with whom they tapped a rhythm in synchrony. Also, we investigated what happened in the brain during trust using functional MRI. Participants first tapped a rhythm with three tapping partners (in different rounds): with one of them, they tapped in synchrony, with the other one, they tapped out-of-sync, and the third tapping partner did not tap along with participants (control condition). After this tapping task, participants rated the tapping partners on similarity and closeness, and finally, they played a trust game with all three tapping partners (in different rounds). In the trust game, participants had to choose how many coins they wanted to give to the tapping partner in that round. The amount they gave to the tapping partner was tripled, and then the tapping partner could decide how many coins he/she wanted to give back to the participant. We expected that participants would give more coins to the tapping partner with whom they had tapped in synchrony, and that brain regions related to reward processing would be associated with playing the trust game with this partner. However, participants did not give significantly more coins to the tapping partner with whom they had tapped in synchrony than to the other two tapping partners. Also, we did not find differences in brain activation between the different conditions. The lack of these differences could have been caused by multiple factors. One of the female tapping partners was found less attractive and similar and was trusted less than the other two, irrespective of which condition she was in. Also, participants did not see how many coins were reciprocated by the tapping partners in the trust game. As time passed during the trust game, participants may have stopped differentiating between the different tapping partners, realizing that there were no consequences to their actions in the game. Finally, participants may not have considered the tapping interaction realistic since it was all on-screen and not in real-life. This was the first study to investigate the effect of interpersonal synchrony on trust and brain activation. We encourage new research concerning this topic to be carried out with a better controlled and more realistic tapping task, and a regular version of the trust game.

Abstract

Interpersonal synchrony has repeatedly been shown to increase affiliation, similarity, and prosocial decision making. As yet, however, the effect of interpersonal synchrony on trust and its neural mechanisms have not been investigated. The current study therefore investigated the behavioral and neural mechanisms of trust as a function of interpersonal synchrony in a tapping task. Participants performed three finger-tapping rounds, each with a different age- and sex-matched partner, of which one tapped in synchrony, another tapped out-of-sync and a third one did not tap (control condition). After tapping, participants played a trust game in the MRI-scanner with all three tapping partners. Participants could choose how many coins to invest in each of the tapping partners. The invested amount was tripled and participants were told that the tapping partner would later decide how many coins he/she would reciprocate. We hypothesized that playing the trust game with synchronous partners would elicit higher trust than playing with the asynchronous or control partners. Higher trust was expected to be associated with ventral striatum and ventromedial prefrontal cortex activation. Also, we expected that trusting asynchronous and control partners would be associated with regions implicated in cognitive control and mentalizing. The results show no significant differences between conditions in both trust and neural activation. These null-results may be explained by multiple factors, such as the tapping task not being realistic and controlled enough, or lack of feedback during the trust game. In the future we plan to look into the role of these factors more closely.

Keywords: interpersonal synchrony, trust, prosocial behavior, fMRI, trust game, tapping task

Introduction

Prosocial behavior is a basic element of human behavior aimed at benefiting others, either with or without costs for the self (Luo, 2018; van IJzendoorn & Bakermans-Kranenburg, 2014; Berg, Dickhaut, & McCabe, 1995; Fehr & Camerer, 2007). One aspect of prosocial behavior is trust. Trust is often studied using the Trust Game (TG; Berg et al., 1995), a two-player economic game. In this game, the first player (trustor) gets a certain amount of money or tokens that he can divide between himself and the second player (trustee). The amount given to the trustee is multiplied (usually tripled), and the trustee can then decide how much of that amount to give back (reciprocate) to the trustor. This way, trust may result in a higher payoff, but also involves a risk of non-reciprocation or betrayal (Rousseau, Sitkin, Burt, & Camerer, 1998). Despite this risk, trust is a widespread phenomenon in human relationships that plays an important role in promoting both psychological and economic wellbeing (Layous, Nelson, Oberle, Schonert-Reichl, & Lyubomirsky, 2012; Telzer, Fuligni, Lieberman, & Galván, 2014; Stallen & Sanfey, 2013; Luo, 2018).

Familiarity or closeness to the trustee plays a critical role in trust. People are generally more likely to cooperate with in-group members or those who are similar or close to them (Stallen & Sanfey, 2013; Eckel & Grossman, 1996; Fareri, Chang, & Delgado, 2015; Hughes, Ambady, & Zaki, 2016), even if they have been randomly assigned to such in-groups (Goette, Huffman, & Meier, 2006). Responses in the ventral striatum and ventromedial prefrontal cortex (vmPFC) are higher when contributing to in-group members that people feel close to, such as fellow compatriots (Telzer, Ichien, & Qu, 2015), family members (Telzer, Masten, Berkman, Lieberman, & Fuligni, 2010), friends (Fareri, Niznikiewicz, Lee, & Delgado, 2012; Fareri et al., 2015), or fellow students (Hughes et al., 2016), than to out-group members that they do not. These regions have been implicated in (social) reward reception and prediction (O'Doherty et al., 2004; Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004; King-Casas, Tomlin, Anen, Camerer, Quartz, & Montague, 2005) and in integrating costs and benefits for (social) decision making (Fehr & Camerer, 2007; Koenigs & Tranel, 2007; Moretto, Sellitto, & di Pellegrino, 2013), respectively. In-group members also elicit greater empathic responses than out-group members (Hein, Silani, Preuschoff, Batson, & Singer, 2010). Finally, whereas acting prosocially towards in-group members generally elicits activation in reward regions, doing so towards out-group members may require cognitive control as reflected by increased activation in the lateral PFC and the anterior cingulate cortex (ACC; Telzer et al., 2015; Hughes et al., 2016) and possibly more effortful mentalizing as reflected by increased temporoparietal junction (TPJ) and dorsomedial PFC (dmPFC) activation (Telzer et al., 2015).

One way in which familiarity and closeness may be naturally stimulated, even in the absence of pre-existing ties, is through interpersonal synchrony, i.e., the temporal alignment of actions between individuals, such as clapping, finger tapping, or dancing (Rabinowitch & Knafo-Noam, 2015; Hove & Risen, 2009). Previous research has shown that, in both children and adults, interpersonal synchrony has a positive effect on interpersonal feelings, such as similarity and closeness, affiliation, and empathy towards the person with whom participants were in synchrony (Valdesolo & DeSteno, 2011; Rabinowitch & Knafo-Noam, 2015; Hove & Risen, 2009; Tarr, Launay, Cohen, & Dunbar, 2015; Miles, Nind, & Macrae, 2009; Koehne, Hatri, Cacioppo, & Dziobek, 2016; Cacioppo et al., 2014). Importantly, these positive psychological influences may in turn lead to increased prosocial behaviors, such as cooperation (Wiltermuth & Heath, 2009; Valdesolo, Ouyang, & DeSteno, 2010; Rabinowitch & Meltzoff, 2017), helping (Cirelli, Einarson, & Trainor, 2014; Kokal, Engel, Kirschner, & Keysers, 2011; Tunçgenç & Cohen, 2018), and generalized prosociality (Reddish, Bulbulia, & Fisher, 2014). However, as of yet, it is unknown whether these positive effects of interpersonal synchrony also extend to trust.

Current study

The current study investigated the behavioral and neural mechanisms of interpersonal synchrony in the context of trust, thereby contributing to existing literature on the effects of interpersonal synchrony and extending this literature in investigating its neural mechanisms. Participants performed three finger-tapping rounds with three different age- and sex-matched tapping partners; with one of them, finger-tapping was synchronous, with another one, it was asynchronous, and with a third partner, there was no interaction (only the participant tapped, control condition). After tapping, participants played a trust game in the MRI scanner in the role of trustor, with all three tapping partners as trustees in separate rounds. We hypothesized that participants would perceive peers with whom tapping was synchronized as more similar and more trustworthy than peers with whom tapping was not synchronized. Playing with synchronized partners was therefore expected to elicit increased trust in the trust game as shown previously for other prosocial behaviors (e.g., Wiltermuth & Heath, 2009; Valdesolo et al., 2010; Rabinowitch & Meltzoff, 2017). Also, we expected that asynchronous tapping partners would receive more trust than control tapping partners, possibly because of fewer feelings of closeness for control compared to asynchronous partners (see Rabinowitch & Knafo-Noam, 2015).

The amount trusted to the tapping partner was expected to be positively associated with activation in the ventral striatum (e.g., Bellucci, Chernyak, Goodyear, Eickhoff, & Krueger, 2017; Delgado, Frank, & Phelps, 2005; Rilling et al., 2004; Van den Bos, van Dijk, Westenberg, Rombouts, & Crone, 2009) and the vmPFC (Luo, 2018; Wang, Li, Yin, Li, & Wei, 2016; Haas, Ishak, Anderson, & Filkowski, 2015). Such activation was expected to be greater when trusting synchronous partners compared to when trusting asynchronous and control partners, making synchronous partners comparable to friends or in-group members (see Telzer et al., 2015; Telzer et al., 2010; Fareri, Chang, & Delgado, 2012; Fareri et al., 2015; Hughes et al., 2016). Anterior insula (AI) activation has been previously found to be elicited by social norm violation (Delgado et al., 2005; Van den Bos et al., 2009; Belfi, Koscik, & Tranel, 2015), possibly signaling the anticipation of feelings of guilt (Bellucci et al., 2017; Chang, Smith, Dufwenberg, & Sanfey, 2011; Fehr & Camerer, 2007). Therefore, trusting synchronous partners was hypothesized to be negatively associated with activation in the anterior insula (AI). When trusting peers with whom tapping was not synchronized, cognitive control and mentalizing regions, such as the lateral PFC, ACC, and TPJ, were expected to exhibit increased activation. These regions have been shown to be implicated in controlling impulses to defect in one’s own benefit (Fehr & Camerer, 2007; Knoch, Schneider, Schunk, Hohmann, & Fehr, 2009; Stallen & Sanfey, 2013; Van den Bos et al., 2009; Chang et al., 2011), signaling conflict between self-interest and prosocial motives (Ernst & Fudge, 2009; Fehr & Camerer, 2007; Stallen & Sanfey, 2013; Van den Bos et al., 2009), and in active perspective taking during economic games (Van den Bos et al., 2009; Chang et al., 2011; Mitchell, 2009), respectively.

Methods

Participants

Twenty-nine young adults (*M* age = 22.2, *SD* = 2.43, range = 19-27, 14 males, all right-handed), recruited over the phone and by means of flyers, participated in the study. Exclusion criteria included vision or hearing problems, psychiatric or neurological disorders, pregnancy, or any magnetic materials in the body. Three participants were excluded because they were familiar with one of the tapping partners. Another five participants were excluded because of technical issues. Finally, one participant moved too much (> 3 mm) during scanning and indicated to not pay attention during the tasks, leaving a total of twenty participants for the final analysis (*M* age = 22.2, *SD* = 2.40, range 19-27, 12 males) for further analysis. Participants' anatomical scans were checked by a neuroradiologist for anatomical abnormalities. This check did not result in any further exclusions. In accordance with the Declaration of Helsinki, all participants gave their written informed consent before participation. Also, they received a financial compensation of €25 afterwards. The study was part of a larger project approved by the Leiden University Medical Center Medical Ethical Committee in the Netherlands.

Procedure

Scanning took place at the Leiden University Medical Center in Leiden, the Netherlands. All participants performed finger tapping rounds with three age- and sex-matched peers. This tapping task functioned as manipulation to induce interpersonal synchrony. In between the tapping task and the trust game, participants rated similarity and closeness to the three tapping partners. Previous to the fMRI experiment, participants practiced the tapping task and the trust game outside of the scanner. Total participation in the experiment took ~110 minutes (of which ~50 minutes of scanning time). The different parts of the experiment are explained in more detail below.

Tapping task

During three tapping rounds, participants tapped with three age- and sex-matched peers: in one round, one of the tapping partners tapped in synchrony with the participant, in another round, another tapping partner tapped out of synchrony, and in another round, the third partner did not tap at all. This last round functioned as a control for the tapping itself. There were two tapping frequencies, with inter-onset intervals of either 600 or 800 ms.

Participants practiced tapping each frequency for about 20 seconds in which no responses were recorded. After practicing, the three age- and sex-matched tapping partners introduced themselves in a separate video, naming their name and age, and saying they looked forward to playing a game with the participant later. Participants were told that they would play a coin allocation game (i.e., the trust game) with these tapping partners. For each participant, each of the three tapping partners was randomly coupled to one of the conditions (i.e., synchronous, asynchronous, or control).

There were six tapping partners in total, three males and three females (*M* age = 23, *SD* = 2.76), who did not participate in the experiment itself. Participants who were familiar with one of the tapping partners were excluded. For each tapping partner, four movies were made: one in which they introduced themselves, two in which they tapped (600 and 800 frequencies, see below) and one in which they did not do anything (for the control condition). The introduction video was used in the practice task to familiarize the participants with the tapping partners. The other three movies were used in the tapping task in the scanner. These tapping task videos showed a bouncing ball animation on the left side of the screen, which indicated the to be tapped rhythm each time the ball touched the floor (the floor turned red when the ball touched the floor; images retrieved from Rabinowitch & Knafo-Noam, 2015). The right side of the screen showed the video of one of the three tapping partners tapping from the waist up (see Figure 1, final screen). The videos of the bouncing ball animation and the tapping videos of the tapping partners were combined in such a way so that all three conditions were created for both tapping frequencies and all six tapping partners, thus creating 36 videos that could be used in the tapping task. In the synchrony condition, participants tapped at the same frequency at the same time as the tapping partners, whereas in the asynchrony condition, participants tapped at a different frequency compared to the tapping partner (e.g., 600 vs. 800 ms). In the control condition, the tapping partner did not tap, thus leaving the participant to tap alone.

Participants were instructed to tap according to the rhythm of the animation with their right index finger, while hearing their own tapping and that of the tapping partner (no auditory stimulus accompanied the animation). Participants were not told the different tapping conditions, only that the tapping partners would tap at the same time. The order in which the synchronous, asynchronous and control partners were shown was counterbalanced. Participants tapped two blocks per tapping partner, visualized in Figure 1. In total, the tapping task lasted about 12 minutes.

In order to check synchronicity in all conditions, we used the SPIKE-distance in SPIKY, a reliable, parameter-free and time-resolved measure of dissimilarity between spike trains. The SPIKE-distance varies between 0 (perfect synchrony) and 1 (perfect asynchrony) and is mediated by differences in spike timing (Kreuz, Chicharro, Houghton, Andrzejak, & Mormann, 2013; see also http://wwwold.fi.isc.cnr.it/users/thomas.kreuz/Source-Code/SPIKY.html and Kreuz, Mulansky, & Bozanic, 2015). In our case, each tapping sequence (i.e., that of the participant, that of the tapping partner, and that of the bouncing ball animation) represented a spike train.

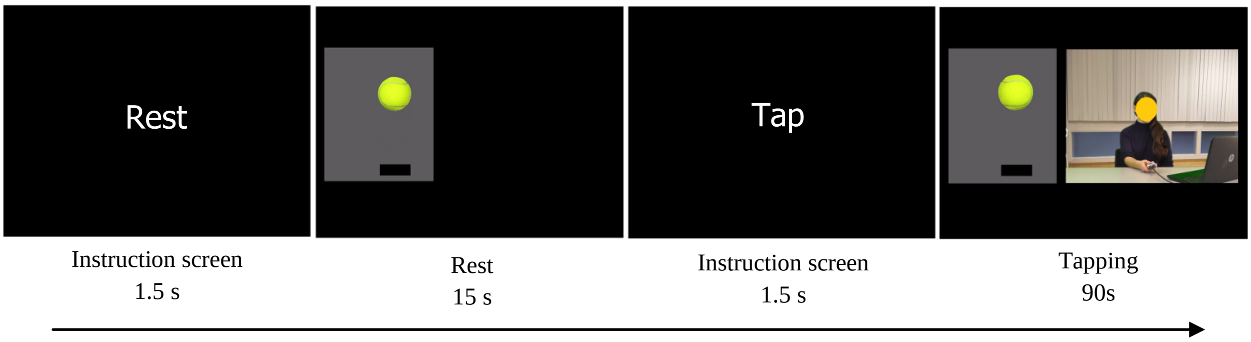

Figure 1. One block of the tapping task. Each block consisted of 15 seconds of rest, which showed the practice animation while the participant was instructed to withhold tapping [in order to be able to analyze the fMRI data from the tapping task as a block design], followed by 90 seconds of tapping (of interest for the current study). Participants tapped two such blocks per tapping partner consecutively (one for each tapping frequency), thus a total of six blocks, during the tapping task. The order of the conditions was counterbalanced and each tapping partner was randomly coupled to each condition.

Similarity and closeness measures

Having finished the tapping task, participants reported similarity and closeness to all three tapping partners. Similarity was assessed using a Dutch translation of the similarity questionnaire used in Rabinowitch and Knafo-Noam (2015). This questionnaire consisted of six questions to be answered on a scale from 1 (not similar at all) to 4 (extremely similar). The questions concerned general similarity (1, 2), similarity in appearance (3), character (4), hobbies (5), and music styles (6). The entire Dutch questionnaire can be found in Appendix A. All questions were repeated three times in a row, once for each tapping partner. Perceived similarity to each partner was operationalized as the average of the six questions about that partner. Internal consistency was satisfactory (Cronbach's alpha: mean = 0.80; synchrony condition = 0.76; asynchrony condition = 0.85; control condition = 0.79).

Closeness was examined with the Inclusion of Other in Self (IOS) scale (Aron, Aron, & Smollan, 1992). This measure presents seven pairs of circles, representing 'self' and 'other' (i.e., the participant and the tapping partner of interest), varying in the degree of overlap between the circles. Participants answered a baseline question asking which pair of circles best represented their closeness to strangers in general. Also, participants were instructed to answer the closeness questions ("How close do you feel to ….?") concerning all three tapping partners.

Trust game

The trust game was played immediately after the tapping task and the questionnaires in the MRI scanner. In this task, participants were instructed to decide how many of 10 or 15 coins they wanted to give to the tapping partner. The amount given to the tapping partner was tripled and the tapping partner could then decide how many coins to reciprocate. We chose two amounts (10 and 15) to make sure that participants could not keep in mind the ratio of coins kept/coins given for each tapping partner, forcing them to choose anew in each trial for each tapping partner. Also, we wanted participants to keep paying attention during the allocation of the coins: the same response button did not correspond to the same amount of coins at all times.

For both amounts (10 or 15 coins), different response options were available. For the 10 coin amount, the eight response options (corresponding to the buttons of the MRI-compatible button boxes) were either 1-8 or 3-10, whereas for the 15 coin amount, the response options were either 1-8 or 8-15. In this way, we were able to create a continuous measure of trust instead of a dichotomous trust choice as often used in fMRI designs of the trust game. The trust game consisted of 96 trials, with 32 trials for each tapping partner. For each tapping partner, 10 coins were to be divided in 16 of the 32 trials (8 low, 8 high response options), and 15 coins were to be divided in the other 16 trials (8 low, 8 high response options). The trials were divided over three blocks of 32 trials, each lasting about 7 minutes. A trust game trial is depicted in Figure 2. Trial order and jitters were optimized using

OptSeq2 (http://surfer.nmr.mgh.harvard.edu/optseq/) and all stimuli (including the tapping videos and questions) were presented using E-prime 2.0.10.356.

Participants played the trust game with each of the three tapping partners in separate rounds. They were told that the amount given to the tapping partner would be tripled, but that they would not see how many coins the tapping partners wished to reciprocate. This way, no partner feedback was needed that could interfere with the effect of the tapping task. Participants were told that at the end of the experiment, a number of rounds would be chosen randomly that would be actually paid to both the participant and the tapping partners. It was therefore emphasized that the choices made would affect both participants' final monetary reward and that of the tapping partners. In reality, all participants received an additional five euros for their participation in the trust game.

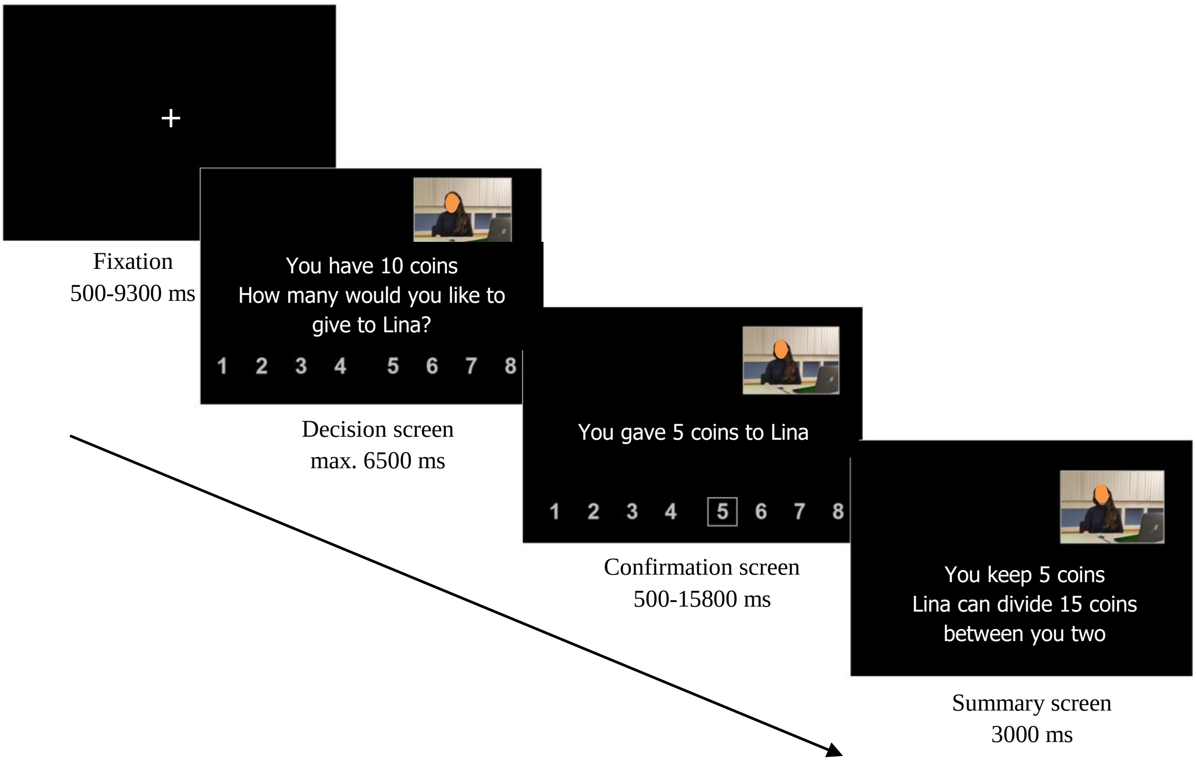

Figure 2. A trust game trial. A trial started with fixation (0.5s + jittered interstimulus interval, min = 0s, max = 8.8s, mean = 1.38s). Then, the response screen followed (max. 6.5s) in which participants had to decide how to divide the amount shown on the screen between themselves and the tapping partner using one of the response options. If a participant took longer than 6.5 seconds to respond, the text 'Too late!' appeared on the screen (1s) and a new trial started. If responding in time, a confirmation screen showed a confirmation of the choice made by the participant (duration 0.5s + (6.5 - response time) + jittered interstimulus interval, min = 0s, max = 8.8s, mean = 0.92s). A summary screen that followed (3s) summarized how many coins the participant had left and how many coins the tapping partner could divide.

Behavioral data analysis

Behavioral data from the questionnaires and the fMRI tasks were analyzed using the car (Fox & Weisberg, 2011), ez (Lawrence, 2016), nlme (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2017), reshape (Wickham, 2007), multcomp (Hothorn, Bretz, & Westfall, 2008), psy (Falissard, 2012), and MASS (Venables & Ripley, 2002) packages in Rstudio (R Core Team, 2017). Performance on the tapping task was represented by the SPIKE-distance between the participants' own tapping and the bouncing ball animation for each condition. In order to check the manipulation, SPIKE-distances comparing the participants' own tapping and that of the tapping partners were calculated. For all measures of the SPIKE-distance, the tapping sequences ten seconds from the beginning onwards were analyzed to leave room for warming-up time. Perceived similarity to each of the tapping partners was calculated as the mean similarity score for each tapping partner (a score between 1 and 4, the higher, the more similar). Closeness was measured as the number of the figure that participants indicated that best represented their relationship to the tapping partner (the higher, the closer). The amount of trust in the trust game was operationalized as the mean percentage of coins given to each tapping partner. For all behavioral analyses, a significance level of $p < .05$ was employed.

fMRI data acquisition and analysis

fMRI data were acquired with a 3.0T Philips Achieva scanner located at the Leiden University Medical Center, the Netherlands. Via a mirror positioned on top of the head coil, participants viewed a screen presenting the stimuli that was located at the head of the scanner. All participants wore earplugs and MRI compatible headphones (NordicNeuroLab audio system, frequency response 8-35 kHz, ca. 30dB noise attenuation). Participants tapped and responded during the trust game with two four-button fiber optic MRI-compatible response boxes (HHSC-1x4-CL), placed on the participants' left and right upper legs.

A T1 scan was made for each participant at the start of the scanning procedure (voxel size = 1.10 x 1.10 x 1.10 mm, TR = 7.9 s, TE = 3.5 s, FOV = 250 x 196 x 170 mm, 155 1.1 mm transverse slices with 0 mm gap, 228 x 177 matrix). Functional scanning for the trust game consisted of three functional runs of 571 (run 1: 183; run 2: 183; run 3: 205) volumes in total, obtaining T2*-weighted EPI images (voxel size = 2.75 x 2.84 x 2.75 mm, TR = 2.2 s, TE = 30 ms, FOV = 220 x 220 x 115 mm, 38 2.75 mm transverse slices with 0.28 mm gap, 80 x 80 matrix).

fMRI data of the trust game were analyzed with SPM8 (Wellcome Department of Cognitive Neurology, London) implemented in Matlab R2012B. Preprocessing steps included realignment, slice timing correction, coregistration, segmentation, normalization, and smoothing (6 mm kernel). The individual functional images were statistically analyzed using the general linear model in SPM8. The decision-making times from onset of the decision screen (see Figure 2) until response were modeled as zero-duration events by a series of events convolved with a canonical hemodynamic response function (HRF). Images for each contrast (Sync-Baseline, Async-Baseline, Control-Baseline, Sync-Async, Sync-Control, Sync-Async & Control, Sync & Async-Control and their reverses) were computed on an individual (first-level) basis which were then submitted to the second level analysis. For the second level analyses, we conducted whole-brain analyses for each contrast, in which a minimum cluster size of 10 and a maximum p-value of $p = .005$ (uncorrected) were employed. We also investigated brain-behavior relationships by entering behavior during the trust game as a covariate of interest.

Results

Because most of the behavioral data did not meet the assumptions of parametric tests such as the repeated measures ANOVA, linear mixed effects models with random intercepts for Subjects nested in either Condition or TappingPartner were used to analyze most of the behavioral data. For all models, the maximum likelihood fitting method was used. A main effect was considered significant when the model containing only the independent variable of interest showed a significant improvement in the Aikaike's Information Criterion (AIC) compared to the model containing only the random intercepts.

Tapping task

In order to check whether the manipulation of synchrony versus asynchrony was induced, the SPIKE-distances of participants' own tapping compared with those of the tapping partners were computed. A linear mixed effects model was constructed, with a random effect for Condition (*SD* = 0.00, 95% CI: $2.93 \cdot 10^{-19}$-$2.55 \cdot 10^{12}$) nested in Subjects (*SD* = 0.01, 95% CI: 0.00-0.11), and fixed effects for both Condition (Sync or Async) and Frequency (600 or 800). There was a significant main effect of Condition in this model, $\chi^2(1) = 52.56$, $p < .001$, but no main effect of Frequency, $\chi^2(1) = 0.36$, $p = .55$. The final model, containing both the main effects and interaction between Condition and Frequency, showed a significant difference between the synchrony and asynchrony condition ($b = 0.13$, $t(19) = 7.68$, $p < .001$, $r = 0.87$), no difference between the 600 and 800 frequencies ($b = 0.01$, $t(38) = 0.87$, $p = .39$, $r = 0.14$), and no interaction between Condition and Frequency ($b = -0.02$, $t(38) = -0.63$, $p = .53$, $r = 0.10$). Thus, tapping in the Async condition was significantly more asynchronous than in the Sync condition, see Table 1 (Self vs. Tapping partner).

Participants' ability to tap along with the animation irrespective of the tapping partner's behavior was also assessed. This was done by comparing participants' own tapping with the 'taps' of the bouncing ball animation with which they tapped along. Another linear mixed effects model was constructed with a random effect for Condition (*SD* = 0.00, 95% CI: $2.74 \cdot 10^{-54}$-$3.94 \cdot 10^{45}$) nested in Subjects (*SD* = 0.05, 95% CI: 0.03-0.07). There was no main effect of Condition ($\chi^2(1) = 1.01$, $p = .60$), no main effect of Frequency ($\chi^2(1) = 2.74$, $p = .10$), and no Condition x Frequency effect ($\chi^2(2)$

=1.18, p = .56, compared to the model containing only the main effects of Condition and Frequency). Thus, participants seemed to have performed equally well in all three conditions for both frequencies, see Table 1 (Self vs. Animation).

Table 1

Mean (SD) SPIKE-distances in all conditions and for both frequencies

	Self vs. Tapping partner		**Self vs. Animation**	
	Frequency		Frequency	
Condition	600	800	600	800
Sync	0.13 (0.10)	0.14 (0.05)	0.12 (0.10)	0.10 (0.04)
Async	0.26 (0.00)	0.26 (0.00)	0.11 (0.04)	0.11 (0.05)
Control	-	-	0.12 (0.06)	0.11 (0.06)

Trust game

In order to test the hypothesis that participants trusted the synchronous partner more than the asynchronous and the control partners, a linear mixed effects model was again constructed. In this model, Condition was added as a fixed effect predicting the percentage of coins given to the tapping partner, with random intercepts for Condition (SD = 6.46, 95% CI: $2.41 \cdot 10^{-60}$-$1.73 \cdot 10^{61}$) nested in Subjects (SD = 11.30, 95% CI: 7.93-16.09). Note that there was significant individual variation in intercepts in this model. There was no main effect of Condition ($\chi^2(2)$ = 0.20, p = .91). Thus, there were no significant differences in the percentage of coins given to the tapping partners (Sync vs. Async: b = -0.89, $t(38)$ = -0.38, p = .71, r = 0.06; Sync vs. Control: b = -0.87, $t(38)$ = -0.37, p = .71, r = 0.06). Table 2 and Figure 3a show the mean percentage of coins given to each of the tapping partners.

Table 2

Descriptive statistics of behavior during the Trust Game (TG), the similarity and closeness questionnaires, and three exit interview variables (liked, attractive, and reported trust)

	Sync	**Async**	**Control**	**Difference**
	M (SD)	*M (SD)*	*M (SD)*	
Given TG	55.64 (12.31)	54.76 (13.32)	54.78 (15.47)	none, p = .91
Similarity	1.89 (0.50)	2.00 (0.60)	1.83 (0.52)	none, p = .45
Closeness	2.95 (1.19)	2.90 (1.08)	2.95 (1.15)	none, p = .98
Liked	4.35 (0.88)	4.45 (0.94)	4.05 (1.05)	none, p = .19
Attractive	3.85 (1.09)	3.45 (1.43)	3.60 (1.47)	none, p = .47
Rep. trust	4.90 (0.97)	4.65 (1.23)	4.20 (1.32)	none, p = .15

Note: Maximum attainable scores: TG: 100%; Similarity: 4; Closeness, Liked, Attractive, and Reported trust: 7. p-values of the main effects are reported.

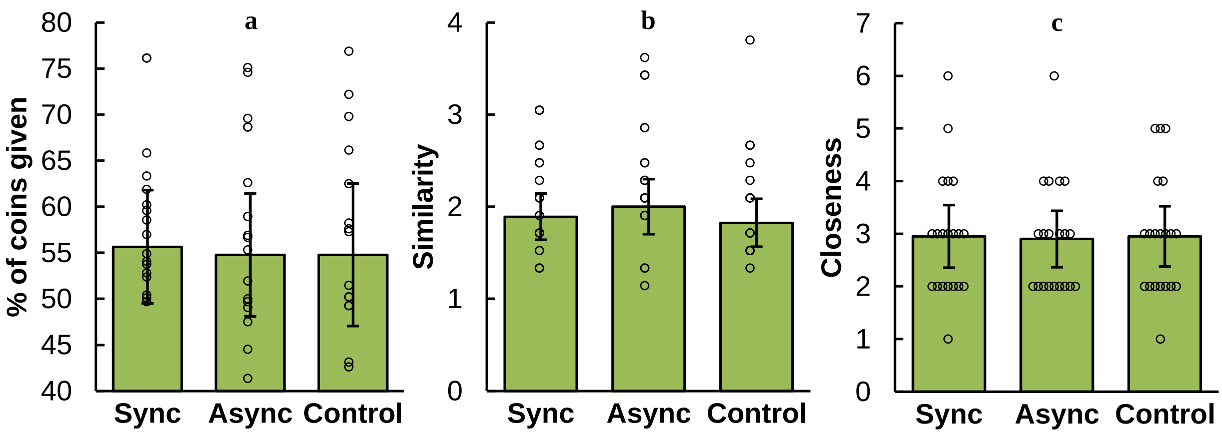

Figure 3. Results of the trust game (a), the similarity (b), and the closeness questionnaires (c). Error bars depict one between-participant standard deviation around the mean. Dots represent separate participants.

Similarity and closeness: differences between conditions

In order to examine whether the tapping manipulation influenced similarity and closeness towards the tapping partners, differences in similarity and closeness between the three conditions were investigated using a linear mixed effects model with a random effect for Condition (*SD* = 0.42, 95% CI: $4.97 \cdot 10^{-21}$-$3.52 \cdot 10^{19}$) nested in Subjects (*SD* = 0.29, 95% CI: 0.16-0.52). No main effect of Condition was present in predicting Similarity ($\chi^2(2) = 1.58$, $p = .45$). For closeness (Intercepts: Subject: *SD* = 0.75, 95% CI: 0.48-1.17; Condition: *SD* = 0.75, 95% CI: $2.00 \cdot 10^{-8}$-$2.81 \cdot 10^{7}$), no significant differences between conditions were found either, $\chi^2(2) = 0.05$, $p = .98$, see Figure 3b and 3c. The same analysis with closeness corrected for baseline closeness (Intercepts: Subject: *SD* = 0.49, 95% CI: 0.26-0.92; Condition: *SD* = 0.76, 95% CI: 0.00-570.72) also showed no significant differences between conditions, $\chi^2(2) = 0.05$, $p = .98$.

Exit interview data: differences between conditions

In the exit interview, participants were asked about their opinion of the tapping partners. Specifically, we asked them how nice and attractive they found the tapping partners before tapping, and to what extent they trusted each tapping partner. Because these factors could have influenced how much participants trusted the tapping partners during the trust game, we decided to explore these variables further. Multiple linear mixed effects models suggested that there were no significant differences between conditions in either reported likeability ($\chi^2(2) = 3.28$, $p = .19$; Intercepts: Subject: *SD* = 0.61, 95% CI: 0.38-0.96; Condition: *SD* = 0.66, 95% CI: $6.03 \cdot 10^{-5}$-$7.15 \cdot 10^{3}$), reported attractiveness ($\chi^2(2) = 1.51$, $p = .47$; Intercepts: Subject: *SD* = 0.80, 95% CI: 0.49-1.32; Condition: *SD* = 0.95, 95% CI: 0.10-8.74), and reported trust ($\chi^2(2) =3.69$, $p = .15$; Intercepts: Subject: *SD* = 0.01, 95% CI: $8.92 \cdot 10^{-44}$-$1.74 \cdot 10^{39}$; Condition: *SD* = 1.18, 95% CI: 0.65-2.16), see Figure 4.

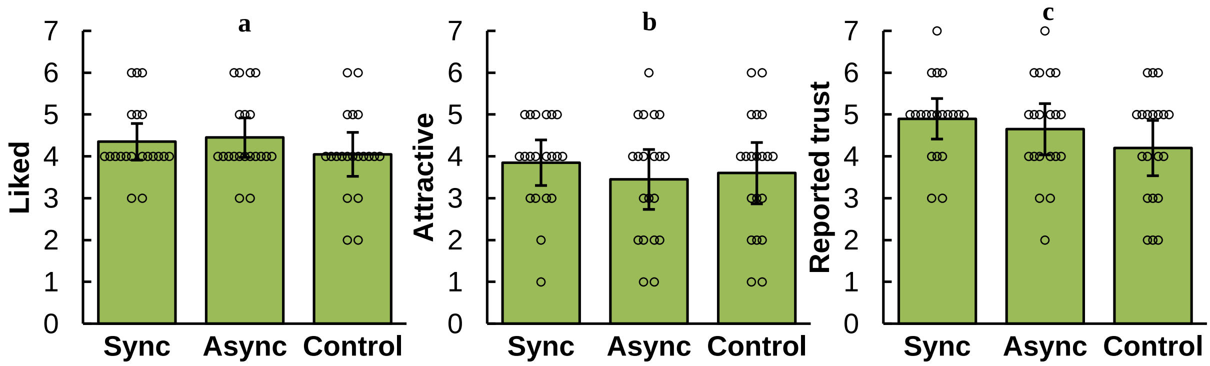

Figure 4. Mean results of the exit interview data: likeability (a), attractiveness (b), and reported trust (c). Error bars depict one between-participant standard deviation around the mean. Dots represent separate participants.

Investigating the predictors of trust game behavior

The above described results suggested that the tapping manipulation did not have a significant effect on trust, similarity, and closeness. However, we still wished to investigate which variables may have played a role in the percentage of coins given to the tapping partners. Because each variable (trust, similarity, closeness, likeability, attractiveness, and reported trust), contained repeated measures, we correlated *difference* scores (Sync-Async, Sync-Control, and Async-Control) of these variables with one another in order to investigate this. Because most variables did not follow a normal distribution and/or contained outliers (Field, Miles, & Field, 2012), Spearman rank correlations were used. As can be seen in Table 3, most variables appeared to be associated in some way with trust.

Table 3

Spearman rank correlations between difference scores of trust and predictor variables

		Trust Sync-Async	**Trust Sync-Control**	**Trust Async-Control**
Similarity	Sync-Async	$r_s = 0.26$, $S = 983.46$		
	Sync-Control		$r_s = 0.54$*, $S = 606.91$	
	Async-Control			$r_s = 0.49$*, $S = 680.04$
Closeness	Sync-Async	$r_s = 0.26$, $S = 981.36$		
	Sync-Control		$r_s = 0.30$, $S = 936.96$	
	Async-Control			$r_s = 0.54$*, $S = 609.75$
Attractive	Sync-Async	$r_s = 0.64$**, $S = 474.76$		
	Sync-Control		$r_s = 0.53$*, $S = 626.79$	
	Async-Control			$r_s = 0.70$***, $S = 405.19$
Liked	Sync-Async	$r_s = -0.23$, $S = 1640.30$		
	Sync-Control		$r_s = 0.70$***, $S = 398.93$	
	Async-Control			$r_s = 0.16$, $S = 1119.10$
Rep. trust	Sync-Async	$r_s = 0.46$*, $S = 715.97$		
	Sync-Control		$r_s = 0.86$***, $S = 185.59$	
	Async-Control			$r_s = 0.73$***, $S = 355.70$

Note: * $p < .05$, ** $p < .01$, *** $p < .001$.

In order to explore the exact relationships between these variables and trust further, multiple regression models were constructed for all three contrasts. These analyses can be found in Appendix

B. In summary, differences in similarity, attractiveness, and reported trust significantly predicted differences in trust between the Sync and the Async conditions. Differences in similarity, attractiveness, likeability and reported trust predicted differences in trust between the Sync and Control conditions. Lastly, differences in similarity, attractiveness, and reported trust predicted differences in trust between the Async and the Control conditions. These results suggest that especially similarity and attractiveness seemed to have played a role in the amount of trust given to each tapping partner. Also, there seems to be good agreement between reported trust and the percentage of coins giving during the trust game, suggesting that the trust game may be considered a fairly valid measure of trust.

Differences between tapping-partners

Because no significant differences in trust during the trust game between conditions arose, the presumption was explored that differences in trust arose because of characteristics of the tapping partners themselves instead of differences between the conditions during the tapping task. Table 4 shows the descriptive statistics of all variables of interest for each of the six tapping partners (independent of which condition they were coupled to).

Table 4

Descriptive statistics for each tapping partner of behavior during the Trust Game (TG), the similarity and closeness questionnaires, and three exit interview variables (liked, attractive, and reported trust)

	Female A	**Female B**	**Female C**	**Male A**	**Male B**	**Male C**	**Difference**
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	
Given TG	54.81 (13.66)	53.30 (10.27)	50.87 (13.38)	58.32 (15.40)	54.99 (14.28)	55.97 (14.64)	fem A > C* fem B > C*
Similarity	1.81 (0.37)	1.94 (0.47)	1.56 (0.34)	2.29 (0.66)	1.88 (0.60)	1.82 (0.43)	fem B > C* male A > C*
Closeness	3.25 (1.16)	3.13 (1.55)	2.50 (0.53)	3.25 (1.54)	2.67 (0.65)	2.83 (0.94)	
Liked	4.63 (1.41)	4.38 (0.92)	4.63 (0.92)	4.42 (0.90)	4.17 (0.72)	3.75 (0.87)	male A > C**
Attractive	4.75 (0.71)	4.25 (0.71)	3.25 (0.89)	3.83 (1.64)	3.17 (1.19)	3.00 (1.48)	fem A > C*** fem B > C**
Rep. trust	4.75 (0.71)	4.88 (0.64)	3.88 (0.99)	5.08 (1.38)	4.42 (1.38)	4.42 (1.38)	fem A > C* fem B > C*

Note: Maximum attainable scores: TG: 100%; Similarity: 4; Closeness, Liked, Attractive, and Reported trust: 7. * $p < .05$, ** $p < .01$, *** $p < .001$. P-values of paired comparisons are shown.

The full analysis can be found in Appendix C. In summary, female participants trusted female C significantly less than females A and B. Participants felt significantly less similar to female C than to female B, and found female C less attractive and also reported to trust her less than females A and B. For males, participants felt significantly less similar to male C compared to male A, and also liked male C less than male A. No significant differences arose for the other variables.

fMRI results

In order to investigate differences in neural activation between conditions related to trusting decisions, whole-brain analyses were conducted. With a FWE-corrected p-threshold, only conditions contrasted with baseline activation showed significant activation. For every other contrast investigated, no significant activations arose. Therefore, as a further exploration of these data, uncorrected results are reported for these contrasts.

Baseline contrasts

In all three baseline contrasts (Sync-Baseline, Async-Baseline, and Control-Baseline), the fusiform gyrus, inferior occipital gyrus, middle cingulate gyrus, insula, superior frontal gyrus, precentral gyrus, and thalamus were significantly activated ($p < .05$, FWE-corrected). A full list of the activated areas can be found in Appendix D.

Contrasts between conditions

Sync-Async. The right inferior frontal gyrus, and a cluster of the right olfactory cortex and the right rectal gyrus in the vicinity of the putamen were more activated in the Sync condition than in the Async condition ($p < .005$, uncorrected), see Table 5 and Figure 5.

Sync-Control. The right superior frontal gyrus was more activated when playing the trust game against the Sync partner compared to the Control partner ($p < .005$, uncorrected), see Table 6 and Figure 6.

Sync-Async & Control. In determining the regions activated specifically in the Sync condition, the contrast Sync vs. Async & Control showed activation in the left superior frontal gyrus and the right anterior cingulate cortex ($p < .005$, uncorrected), see table 7 and Figure 7.

Table 5

Results of the Sync-Async contrast

Size	Hem	Area	Coordinates	t
18	R	inferior frontal gyrus	42 35 4	4.45
34	R	olfactory cortex	24 11 -17	4.18
	R	rectal gyrus	18 14 -11	3.27
13	R	inferior frontal gyrus	36 29 25	3.19

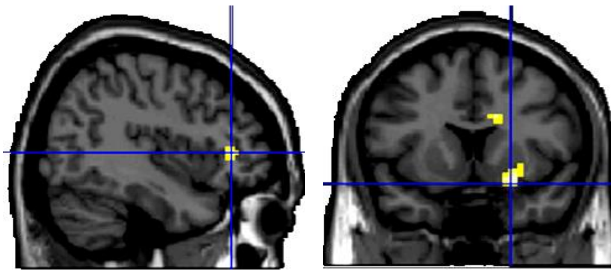

Figure 5. Areas that were more activated during the Sync than during the Async condition: right inferior frontal gyrus, [42 35 4] and [36 29 25] (a), and a cluster of the right olfactory cortex [24 11 -17] and right rectal gyrus [18 14 -11] (b), $p < .005$, uncorrected. All coordinates are in MNI space. Clusters are superimposed on the MNI template.

Table 6

Results of the Sync-Control contrast

Size	Hem	Area	Coordinates	t
10	R	superior frontal gyrus	30 53 10	3.33
	R	superior frontal gyrus	30 56 19	3.18

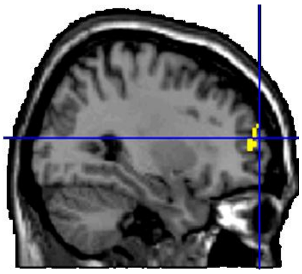

Figure 6. The right superior frontal gyrus [30 53 10] was found to be more activated during the Sync than during the Control condition, $p < .005$, uncorrected. All coordinates are in MNI space. Clusters are superimposed on the MNI template.

Table 7

Result of the Sync-Async & Control contrast

Size	Hem	Area	Coordinates	t
13	L	superior frontal gyrus	-21 35 49	3.85
10	R	ACC	12 38 10	3.35

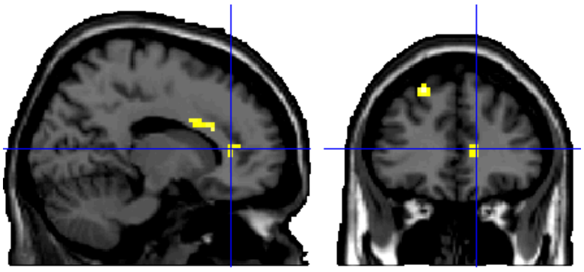

Figure 7. Results of the Sync-AsyncControl contrast ($p < .005$, uncorrected): the left superior frontal gyrus [-21 35 49] and the right anterior cingulate cortex [12 38 10]. All coordinates are in MNI space. Clusters are superimposed on the MNI template.

Control-Sync & Async

The following regions were more activated during the Control condition than during the Sync and Async conditions ($p < .005$, uncorrected): right paracentral lobule, right supplementary motor area, left precuneus, left superior temporal gyrus, right inferior temporal gyrus, and right fusiform gyrus, see Table 8 and Figure 8.

Table 8

Result of the Control-SyncAsync contrast

Size	Hem	Area	Coordinates	t-value
30	R	paracentral lobule	6 -31 61	3.95
	R	SMA	3 -25 55	3.50
15	L	precuneus	-12 -37 70	3.88
19	L	superior temporal gyrus	-48 -37 22	3.77
	L	superior temporal gyrus	-42 -34 16	3.50
11	R	inferior temporal gyrus	45 -55 -5	3.33
	R	fusiform gyrus	36 -58 -11	3.10

Note: $p < .005$, uncorrected. All coordinates are in MNI space.

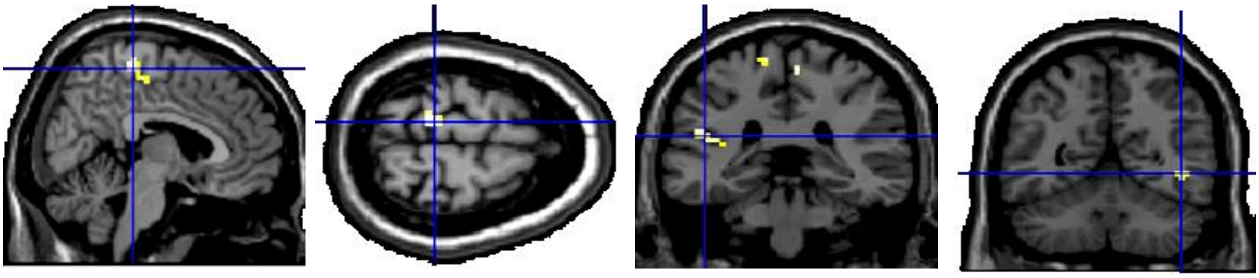

Figure 8. Results of the Control-SyncAsync contrast ($p < .005$, uncorrected): the right paracentral lobule [6 -31 61] and SMA [3 -25 55] (first picture), the left precuneus [-12 -37 70] (second picture), the left superior temporal gyrus [-48 -37 22] (third picture), and the right inferior temporal gyrus [45 -55 -5] and fusiform gyrus [36 -58 -11] (fourth picture). All coordinates are in MNI space. Clusters are superimposed on the MNI template.

Correlations with trust game behavior

There was large variation in trust game behavior and in the amount of differentiation participants made between tapping partners. We figured that this variation may be associated with differences in neural activation. Therefore, we investigated whether individual differences in the trust game covaried with neural activation by including behavior as a covariate of interest in the whole brain analyses. For the only Sync-Async contrast, we found that differences in activation in the left inferior frontal gyrus and the left Heschl's gyrus covaried positively with the difference in the percentage of coins given between the Sync and Async condition, i.e., the greater the positive difference in neural activation in these regions, the more coins participants gave to the Sync partner compared to the Async partner, see Table 9. In order to visualize this, we extracted the parameter estimates of the activation cluster for all participants and plotted the associations in Figure 9 and 10.

Table 9

Result of the Sync-Async contrast with Sync-Async given as positive covariate

Size	**Hem**	**Area**	**Coordinates**	**t-value**
13	L	inferior frontal gyrus	-30 35 7	4.07
17	L	Heschl's gyrus	-33 -28 -8	3.88

Note: $p < .005$, uncorrected. All coordinates are in MNI space.

There was also a negative correlation between the difference scores Sync-Async in activation and that of trust game behavior: the greater the activation in the right postcentral gyrus cluster in the Sync condition as opposed to the Async condition, the smaller the positive difference in the percentage of coins participants gave to the Sync compared to the Async partner, see Table 10. This association is visualized as well, see Figure 11.

Table 10

Result of the Sync-Async contrast with Sync-Async given as negative covariate

Size	Hem	Area	Coordinates	t-value
61	R	postcentral gyrus	57 -25 52	4.07
	R	postcentral gyrus	42 -31 55	3.68
	R	precentral gyrus	39 -22 58	3.32

Note: $p < .005$, uncorrected. All coordinates are in MNI space.

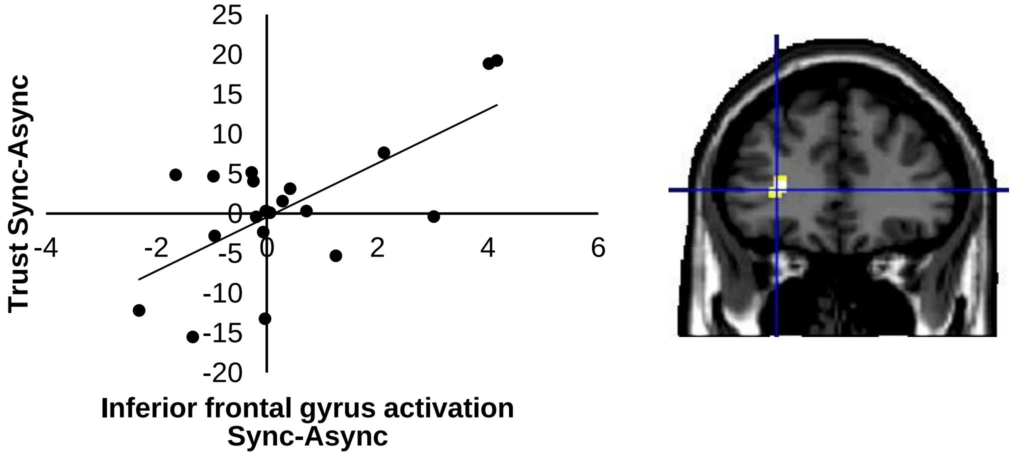

Figure 9. Positive association between differences in activation in the left inferior frontal gyrus [-30 35 7] and differences in trust game behavior between the Sync and Async condition ($p < .005$, uncorrected). Clusters are superimposed on the MNI template.

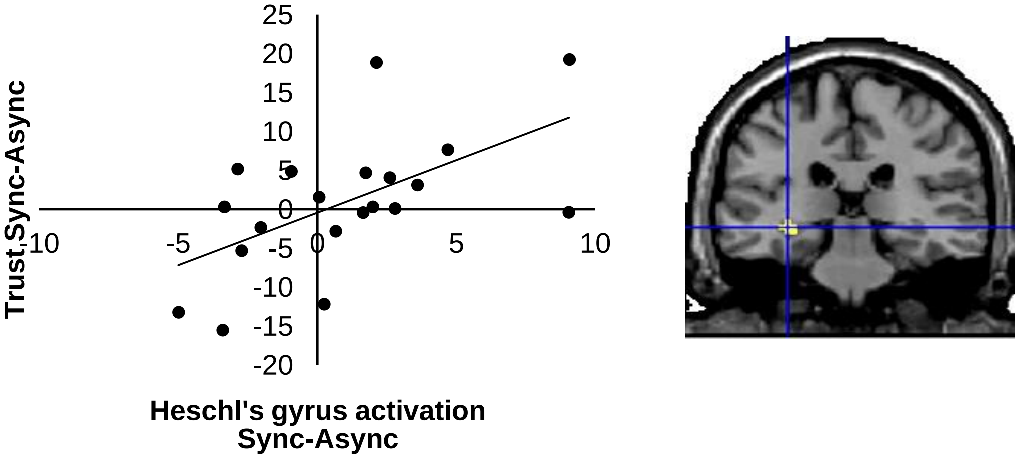

Figure 10. Positive association between differences in activation in the left Heschl's gyrus (near the insula) [-33- 28 -8] and differences in trust game behavior between the Sync and Async condition ($p < .005$, uncorrected). Clusters are superimposed on the MNI template.

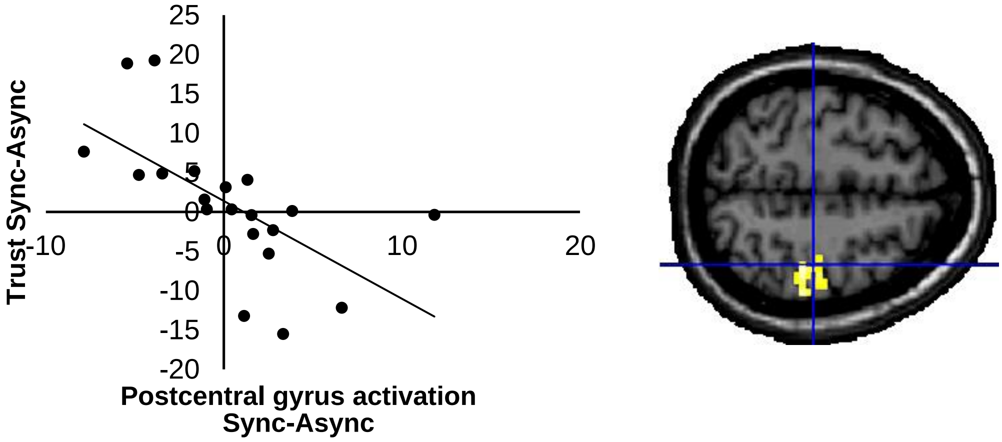

Figure 11. Negative association between differences in activation in the right postcentral gyrus [57 -25 52] and differences in trust game behavior between the Sync and Async condition ($p < .005$, uncorrected). Clusters are superimposed on the MNI template.

Discussion

The current study investigated the behavioral and neural effects of interpersonal synchrony on trust. We tested for the first time whether the positive effect of interpersonal synchrony extends beyond affiliation and helping to trust. Moreover, the neural mechanisms of the effect of interpersonal synchrony have not been investigated as such. The current study therefore contributes to the growing literature on the neural mechanisms of prosocial behavior and the role of interpersonal synchrony in such behavior.

Our results show no effect of interpersonal synchrony on trust, nor was there an effect on perceived similarity or closeness. These results do not seem to be in line with existing literature showing that interpersonal synchrony is associated with increased similarity, closeness, affiliation, empathy (Rabinowitch & Knafo-Noam, 2015; Valdesolo & DeSteno, 2011; Hove & Risen, 2009; Tarr et al., 2015; Miles et al., 2009; Koehne et al., 2016; Cacioppo et al., 2014), and forms of prosocial behavior such as cooperation and helping (Wiltermuth & Heath, 2009; Valdesolo et al., 2010; Rabinowitch & Meltzoff, 2017; Cirelli et al., 2014; Kokal et al., 2011; Tunçgenç & Cohen, 2018; Reddish et al., 2014). On the other hand, our results show that similarity and attractiveness played an important role in determining trust. Moreover, reported trust was associated with the percentage of coins given to each tapping partner in the trust game, confirming the validity of the trust game in measuring interpersonal trust.

We did not find any significant differences in neural activation between conditions. In contrast to our hypotheses, in the synchrony condition, compared to the asynchrony and control conditions, we found (non-significant) activations in the inferior and superior frontal gyri, and the anterior cingulate cortex. These regions have been associated with mentalizing, cognitive control, and emotional empathy (Yordanova, Duffau, & Herbet, 2017; Luo, 2018; McAdams, Harper, & Van Enkevort, 2018; Shamay-Tsoory, Aharon-Peretz, & Perry, 2009; Lavagnino et al., 2016; Li et al., 2013; Cutini et al., 2008; Aron, Robbins, & Poldrack, 2014), suggesting that trust in the synchrony condition was not, as hypothesized, associated with increased reward processing compared to the other two conditions. Future studies may point out which exact roles these regions play in trust.

In the control condition, compared to the synchrony and asynchrony conditions, there was (non-significantly) increased activation in the precuneus, paracentral lobule, and superior and inferior temporal gyri. The precuneus has been associated with self-other distinction, imagery, episodic memory, and mental state attribution (Cavanna & Trimble, 2006; Luo, 2018; Farrow et al., 2001). The paracentral lobule has been implicated in motor control (Sumner et al., 2007). The superior temporal gyrus has been associated with semantics, auditory association, and mentalizing (e.g., Friederici, Rueschemeyer, Hahne, & Fiebach, 2003; Yordanova et al., 2017), and finally, the inferior temporal gyrus is part of the visual object recognition pathway (Miller, Li, & Desimone, 1991). Together, increased activation in these regions could point to a recognition of the control partner and a memory of the tapping task, together with increased effort of planning a response in the control condition. However, as we did not measure these processes explicitly, and since none of the described activations survived FWE-correction, they should be interpreted with great caution.

Our results suggest that interpersonal synchrony as operationalized in our finger tapping task did not influence trust. The effect of interpersonal synchrony may be limited to less complex prosocial behaviors such as spontaneous helping. Building a trusting relationship depends on both parties' behaviors that may be in play for a longer period of time and that determine the strength of the relationship (Rousseau et al., 1998). As Rousseau et al. (1998, p. 395) stated it: "Trust is not a behavior (e.g., cooperation), or a choice (e.g., taking a risk), but an underlying psychological condition that can cause or result from such actions." Thus, more time to interact and greater certainty may be required in order to decide whether or not to trust someone, as compared to, for example, deciding whether or not to help someone spontaneously, the latter option lacking expectations about or interdependence on the other party's behavior (Rousseau et al., 1998). Three minutes of simple synchronous finger tapping may simply not be sufficient to establish such a psychological condition.

Limitations and future directions

The lack of a significant effect of interpersonal synchrony on trust may also be partly explained by factors in our experimental design. Firstly, there were differences between the tapping partners irrespective of which condition they were assigned to, preventing us from determining the effect of the tapping manipulation properly. Specifically, one of the females (female C) was trusted less and found less attractive and less similar than the other two. One explanation for these differences may be that this female was never coupled to the synchrony condition (as opposed to three times for female A and five times for female B). The differences we found could thus be a consequence of this unfair division of conditions across tapping partners, leading female C, the asynchronous or control partner, to be trusted less. One the other hand, however, if the differences were pre-existing, one may expect an added effect of the interpersonal synchrony manipulation on top of these baseline differences. However, since we did not measure baseline trust, we cannot disentangle these explanations. In order to properly measure the effect of interpersonal synchrony, our future experiments will aim to make sure that each tapping partner is coupled to each condition the same amount of times and to control for pre-existing differences between the tapping partners. For example, the tapping partners' physical characteristics and behaviors during the tapping task should be held constant as much as possible. Also, the tapping partners' tapping could be simulated in order to control for differences in tapping performance between tapping partners (i.e., instead of using their actual tapping performances, see Kokal et al., 2011).

In future studies, we also aim to create a more realistic experience for participants. Our design did not involve real-life interaction between the participants and the tapping partners, but on-screen interaction only. Despite the fact that the synchrony manipulation was induced, as shown by synchronous vs. asynchronous tapping, participants may not have considered the tapping task a realistic interaction, which may have affected the strength of our manipulation negatively. Therefore, another possibility is to use a real-life interpersonal synchrony interaction, for example by having participants tap next to each other (e.g., see Rabinowitch & Knafo-Noam, 2015).

The lack of feedback of the tapping partners' behavior in the trust game could also explain why we did not find an effect of interpersonal synchrony on trust. Because participants did not see any immediate consequences for their decisions, they may have stopped differentiating between the different partners at a certain point during the task. Perhaps the feedback component of the regular trust game (Berg et al., 1995; Luo, 2018) would have made the trust game more realistic and would elicit different behaviors. On the other hand, because the trust game was a time consuming task, participants' engagement in the task may also have decreased as the task progressed. Moreover, trust in the trust game was associated with self-reported trust, suggesting some degree of validity of our trust game.

Our sample showed a great amount of variation in all measures used, which may have caused the main effect of interpersonal synchrony to be cancelled out. For example, some participants differentiated between the tapping partners, whereas others did not, or did so in a different direction. Research is now moving more towards individual differences approaches that take such differences into account (Rosenberg, Casey, & Holmes, 2018; Foulkes & Blakemore, 2018). Such an approach could also reveal sources of this individual variation. However, modeling individual trajectories would require a much larger sample size than the current one permits. Apart from the individual differences approach, a greater study sample could also provide more robust results, both in behavior and in neural activation.

Finally, for the current dataset, we consider it highly interesting to investigate differences in neural activation between the different female and male tapping partners (as opposed to conditions), who were randomly assigned to a condition for each participant. That is, the behavioral differences between the tapping partners may be associated with differences in neural activation. Moreover, we aim to analyze differences in neural activation between the conditions during the tapping task itself. This way, we will be able to investigate whether activation during the tapping task can predict or explain neural activation during the trust game.

Conclusion

In sum, our study was the first to investigate the effect of interpersonal synchrony on trust and neural activation during trust, using a continuous, instead of a dichotomous, measure of trust. We did not find any significant effects of interpersonal synchrony on both behavior and neural activation. However, multiple factors may explain the lack of the experimental effect, such as differences between the tapping partners, irrespective of which condition they were assigned to, a lack of tapping partner feedback during the trust game, and lack of realism of the tapping interaction. We encourage future investigations that can take care of these factors, for example by running the experiment with a more realistic and controlled tapping task, a greater study sample and a feedback version of the trust game. Perhaps such an adjusted experimental design will show different results, providing more accurate information on the mechanisms of trust in the context of interpersonal synchrony.

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Appendix A

Dutch translation of the similarity questionnaire as used in Rabinowitch & Knafo-Noam (2015)

Hoe vergelijkbaar vind je dat jij en <name> over het algemeen zijn?

1. Helemaal niet vergelijkbaar
2. Een beetje vergelijkbaar
3. Vergelijkbaar
4. Zeer vergelijkbaar

Doet <name> je op een bepaalde manier aan jezelf denken?

1. Doet me helemaal niet aan mezelf denken
2. Doet me een beetje aan mezelf denken
3. Doet me aan mezelf denken
4. Doet me heel erg aan mezelf denken

Vind je dat jij en <name> qua uiterlijk op elkaar lijken?

1. Lijkt qua uiterlijk helemaal niet op mij
2. Lijkt qua uiterlijk een beetje op mij
3. Lijkt qua uiterlijk op mij
4. Lijkt qua uiterlijk heel erg op mij

Vind je dat jij en <name> een vergelijkbaar karakter hebben?

1. Helemaal geen vergelijkbaar karakter
2. Een beetje vergelijkbaar karakter
3. Een vergelijkbaar karakter
4. Een zeer vergelijkbaar karakter

Denk je dat jij en <name> vergelijkbare hobby's hebben?

1. Geen vergelijkbare hobby's
2. Een paar vergelijkbare hobby's
3. Vergelijkbare hobby's
4. Veel vergelijkbare hobby's

Denk je dat jij en <name> een vergelijkbare muzieksmaak hebben?

1. Geen vergelijkbare muzieksmaak
2. Een beetje vergelijkbare muzieksmaak
3. Een vergelijkbare muzieksmaak
4. Een zeer vergelijkbare muzieksmaak

Appendix B

Multiple regression analyses to determine the predictors of trust

Despite the fact that we could not find a significant effect of interpersonal synchrony on trust, we still wished to investigate which variables (similarity, closeness, and three exit interview variables: attractiveness, likeability, and reported trust) played a role in predicting trust. Therefore, we conducted multiple regression analyses on the difference scores between these variables (Sync-Async, Sync-Control, and Async-Control). The difference scores of all variables were entered in each multiple linear regression model in the following order: Similarity, Closeness, Attractiveness, Likeability, and Reported trust. Below the results of the three linear regression models, one for each behavioral contrast, can be found.

Sync-Async. The Sync-Async model, containing the difference scores between the Sync and the Async condition of all five variables was significant ($F(5,14) = 4.78$, $p = .009$, adjusted $R^2 = 0.50$). In this model, there were main effects of Similarity ($F(1,14) = 8.16$, $p = .013$) and Attractiveness ($F(1,14) = 7.32$, $p = .017$), with the main effects of Closeness ($F(1,14) = 3.90$, $p = .068$) and Reported trust ($F(1,14) = 4.39$, $p = .0549$) approaching significance. The marginal effects, however, did not reach significance in this model, see Table B1. When using a forward-backward selection procedure, the model of best fit (i.e., the model with the lowest Aikaike's Information Criterion, $F(2,17) = 13.15$, $p < .001$, adjusted $R^2 = 0.56$) was that containing only Attractiveness ($F(1,17) = 21.09$, $p < .001$; marginal: $b = 2.88$, $t = 2.01$, $p = .0604$, $r = 0.44$) and Reported trust ($F(1,17) = 5.21$, $p = .036$; marginal: $b = 3.21$, $t = 2.28$, $p = .036$, $r = 0.48$) as predictors of the difference in trust between the Sync and Async conditions.

Table B1

Regression table of the marginal effects of each variable predicting trust (Sync-Async)

	b	*SE*	*t*	*p*	*r*
Intercept	-1.48	1.62	-0.91	.38	0.24
Similarity	-3.72	4.18	-0.89	.39	0.23
Closeness	1.50	2.01	0.75	.47	0.20
Attractiveness	2.14	1.82	1.18	.26	0.30
Liked	0.24	2.00	0.12	.91	0.03
Reported trust	4.24	2.02	2.09	.0549	0.49

Note: All predictors and the dependent variable are difference scores Sync-Async. Underlined variables remain when using forward-backward selection for the multiple regression model.

Sync-Control. The Sync-Control model, containing the difference scores between the Sync and the Control condition of all five variables, was significant ($F(5,14) = 14.55$, $p < .001$, adjusted $R^2 = 0.78$). There were main effects of Similarity ($F(1,14) = 21.64$, $p < .001$), Attractiveness ($F(1,14) = 7.20$, $p =$

.018), Likeability (F(1,14) = 8.47, p = .01), and Reported trust (F(1,14) = 35.38, p < .001) in predicting the difference in trust between the Sync and Control condition. For the marginal effects, however, only Reported trust remained significant, see Table B2. When using a forward-backward selection procedure, the model of best fit (F(2,17) = 41.91, p < .001, adjusted R^2 = 0.81) was that containing Likeability (F(1,17) = 33.53, p < .001; marginal: b = -2.43, t = -1.49, p = .16, r = 0.34) and Reported trust (F(1,17) = 50.29, p < .001; marginal: b = 5.95, t = 7.09, p < .001, r = 0.86) as predictors of the difference in trust between the Sync and Control conditions.

Table B2

Regression table of the marginal effects of each variable predicting trust (Sync-Control)

	b	*SE*	*t*	*p*	*r*
Intercept	-2.61	1.08	-2.41	.03	0.52
Similarity	-0.08	2.78	-0.03	.98	0.01
Closeness	0.12	1.16	0.11	.92	0.03
Attractiveness	-0.98	1.27	-0.78	.45	0.20
<u>Liked</u>	-2.05	1.94	-1.06	.31	0.27
<u>Reported trust</u>	6.21	1.04	5.95	<.001	0.85

Note: All predictors and the dependent variable are difference scores Sync-Control. Underlined variables remain when using forward-backward selection for the multiple regression model.

Async-Control. The Async-Control model, containing the difference scores between the Async and the Control condition of all five variables was significant (F(5,14) = 9.11, p < .001, adjusted R^2 = 0.68). In this model, there were significant main effects of Similarity (F(1,14) = 25.39, p < .001), Attractiveness (F(1,14) = 9.48, p = .008), and Reported trust (F(1,14) = 8.78, p = .01) in predicting the difference in trust between the Async and Control conditions. For the marginal effects, however, only Reported trust remained significant, see Table B3. When using a forward-backward selection procedure, the model of best fit (F(1,18) = 52.56, p < .001, adjusted R^2 = 0.73) was that containing only Reported trust (F(1,18) = 52.57, p < .001; marginal effect: b = 5.64, t = 7.25, p < .001, r = 0.86) as predictor of the difference in trust between the Async and Control conditions.

Table B3

Regression table of the marginal effects of each variable predicting trust (Async-Control)

	b	*SE*	*t*	*p*	*r*
Intercept	-1.63	2.12	-0.77	.46	0.20
Similarity	-1.81	3.94	-0.46	.65	0.12
Closeness	0.57	2.23	0.25	.80	0.07
Attractiveness	0.46	1.51	0.30	.77	0.08
Liked	-1.43	1.37	-1.04	.32	0.27
<u>Reported trust</u>	5.76	1.94	2.96	.0103	0.62

Note: All predictors and the dependent variable are difference scores Async-Control. Underlined variables remain when using forward-backward selection for the multiple regression model.

Correlations with behavior during the trust game

In order to separate the effects of each of the predictors used in the multiple regressions, separate Spearman rank correlations were conducted with trust game behavior for each condition. For similarity, there was a significant correlation between the percentage of coins given and similarity in the Sync condition (r_s = 0.47, S = 706.77, p = .04) and in the Async condition (r_s = 0.50, S = 669.01, p = .03), but not in the Control condition (r_s = 0.20, S = 1067.5, p = .40). For closeness, there were no significant correlations between the percentage of coins given to each partner and reported closeness to that partner (Sync: r_s = 0.23, S = 1025.3, p = .33; Async: r_s = 0.13, S = 1161.7, p = .59; Control: r_s = 0.21, S = 1050.40, p = .37), as was the case for attractiveness of the tapping partners (Sync: r_s = 0.28, S = 961.54, p = .24; Async: r_s = 0.31, S = 922.04, p = .19; Control: r_s = 0.13, S = 1161.5, p = .59), and reported likeability (Sync: r_s = 0.01, S = 1341.90, p = .97; Async: r_s = 0.08, S = 1228.6, p = .75; Control: r_s = 0.27, S = 974.22, p = .25). Reported trust correlated significantly with the percentage of coins given to the tapping partner in the Sync condition (r_s = 0.50, S = 665.6, p = .03) and in the Control condition (r_s = 0.74, S = 339.52, p < .001), and this correlation approached significance in the Async condition (r_s = 0.39, S = 806.62, p = .09).

Appendix C
Differences between tapping partners

Because there were no differences between conditions in trust, similarity, closeness, and the exit interview variables, the presumption was explored that the reason there were no differences between conditions was that there were differences between the different tapping partners, irrespective of the condition they were coupled to. Below, the results of these analyses can be found.

Differences in trust game behavior. For the females, there was a significant effect of TappingPartner on the percentage of coins given during the trust game ($\chi^2(2) = 8.60$, $p = .01$; Intercepts: TappingPartner: $SD = 2.15$, 95% CI: $2.03\cdot10^{-7}$-$2.28\cdot10^{7}$; nested in Subject: $SD = 12.40$, 95% CI: 7.54-20.40). Posthoc Tukey contrasts revealed that subjects gave significantly fewer coins to female C compared to the other two (female A: $b = -3.93$, $t(14) = -1.58$, $p = .01$, $r = 0.39$; female B: $b = -3.93$, $t(14) = -1.58$, $p = .01$, $r = 0.39$). For the males, the same model (TappingPartner: $SD = 7.65$, 95% CI: $2.43\cdot10^{-7}$-$2.41\cdot10^{8}$; nested in Subject: $SD = 11.42$, 95% CI: 7.09-18.39) yielded no significant effect of TappingPartner on the percentage of coins given, $\chi^2(2) = 1.00$, $p = .61$, see Figure C1.

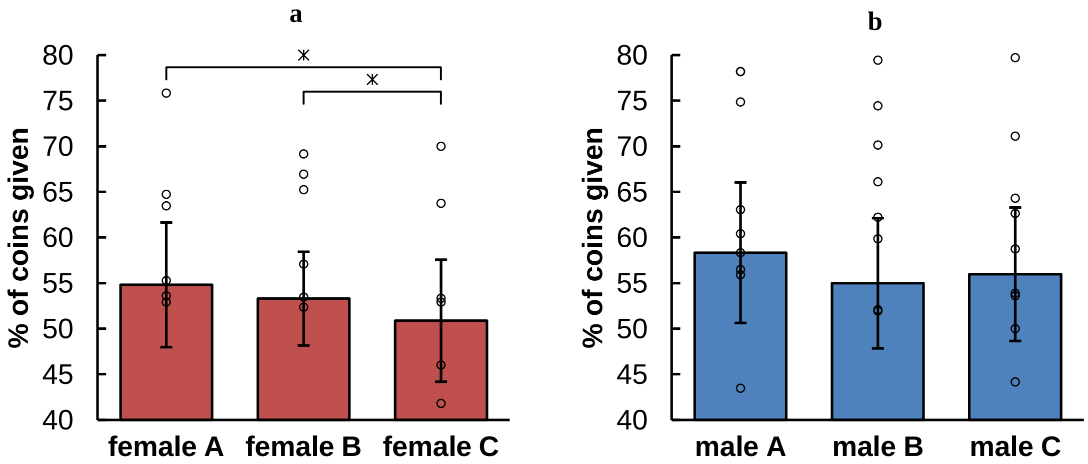

Figure C1. Mean amounts of trust given to each tapping partner (females (a) and males (b)) during the trust game. Error bars represent one between-participant standard deviation around the mean. Dots represent separate participants.

Differences in similarity. In another model built the same way as previously mentioned models (Intercepts: TappingPartner: $SD = 0.26$, 95% CI: $4.52\cdot10^{-12}$-$1.51\cdot10^{10}$; nested in Subject: $SD = 0.24$, 95% CI: 0.12-0.50), there was a significant effect of TappingPartner for females in predicting similarity scores ($\chi^2(2) = 5.98$, $p = .05$), with participants feeling significantly less similar to female C than to female B ($b = -0.38$, $t(14) = -1.90$, $p = .02$, $r = 0.45$). The same model for males (Intercepts: TappingPartner: $SD = 0.47$, 95% CI: $1.76\cdot10^{-38}$-$1.28\cdot10^{37}$; nested in Subject: $SD = 0.29$, 95% CI: 0.12-0.69) indicated that there was a significant effect of TappingPartner on similarity as well, $\chi^2(2) = 7.18$,

p =.03. Specifically, participants felt significantly less similar to male C than to male A (b = -0.47, t(22) = -2.53, p = .02, r = 0.56), see Figure C2. Also, the difference in similarity between male B and male A approached significance (b = -0.42, t(22) = -2.24, p = .0512, r = 0.51).

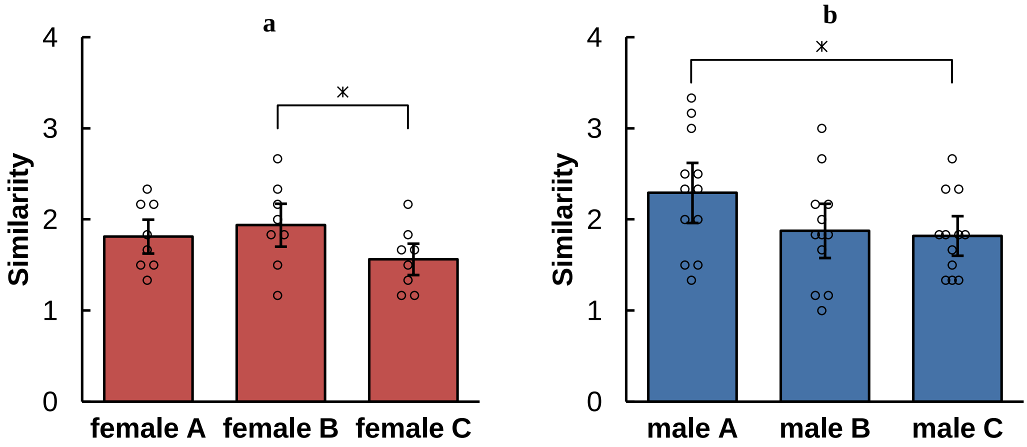

Figure C2. Mean similarity scores for each tapping partner (females (a) and males (b)). Error bars represent one between-participant standard deviation around the mean. Dots represent separate participants.

Differences in closeness. Employing the same methods, we found no differences in closeness for both females ($\chi^2(2)$ = 3.65, p = .16; Intercepts: TappingPartner: SD = 0.82, 95% CI: $9.28 \cdot 10^{-8}$-$7.29 \cdot 10^{6}$; nested in Subjects: SD = 0.70, 95% CI: 0.33-1.53) and males ($\chi^2(2)$ = 4.04, p = .13; Intercepts: TappingPartner: SD = 0.64, 95% CI: $2.58 \cdot 10^{-5}$-$1.59 \cdot 10^{4}$; nested in Subject: SD = 0.80, 95% CI: 0.48-1.32), see Figure C3.

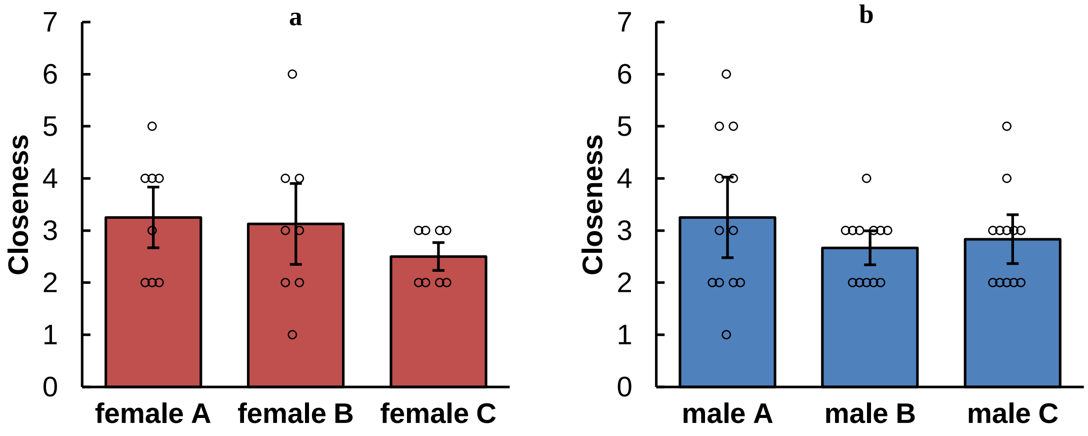

Figure C3. Mean closeness scores for each tapping partner (females (a) and males (b)). Error bars represent one between-participant standard deviation around the mean. Dots represent separate participants.

Differences in exit interview data. There were no significant differences between tapping partners in Likeability for females ($\chi^2(2)$ = 0.45, p = .80; Intercepts: TappingPartner: SD = 0.79; nested in Subject: SD = 0.58), but for males ($\chi^2(2)$ = 7.63, p = .02; Intercepts: TappingPartner: SD = 0.50;

nested in Subject: *SD* = 0.57), participants liked male A significantly more than male C (*b* = -0.67, *t*(22) = -2.84, *p* = .008, *r* = 0.52). For attractiveness, there was a significant difference between female tapping partners ($\chi^2(2) = 14.26$, *p* < .001, Intercepts: TappingPartner: *SD* = 0.61; nested in Subject: *SD* = 0.32): participants found female C significantly less attractive than female A (*b* = -1.50, *t*(14) = -4.35, *p* < .001, *r* = 0.76) and female B (*b* = -1.00, *t*(14) = -2.90, *p* = .006, *r* = 0.61). For males, there were no differences in attractiveness ($\chi^2(2) = 4.38$, *p* = .11, Intercepts: TappingPartner: *SD* = 0.90, 95% CI: $4.19 \cdot 10^{-8}$-$1.95 \cdot 10^{7}$; nested in Subject: *SD* = 0.98, 95% CI: 0.57-1.68). Finally, for reported trust, there was a significant difference between female tapping partners, $\chi^2(2) = 7.37$, *p* = .025 (Intercepts: TappingPartner: *SD* = 0.71, 95% CI: 0.00-168.51; nested in Subject: *SD* = 0.13, 95% CI: $8.77 \cdot 10^{-5}$-178.10): participants reported to trust female C significantly less than female A (*b* = -0.88, *t*(14) = -2.23, *p* = .04, *r* = 0.51) and female B (*b* = -1.00, *t*(14) = -2.55, *p* = .02, *r* = 0.56). For males, there was no such difference, $\chi^2(2) = 2.02$, *p* = .36 (Intercepts: TappingPartner: *SD* = 1.25, 95% CI: 0.00-626.88; nested in Subject: *SD* = 0.24, 95% CI: 0.00-40.14). Figure C4 visualizes these results.

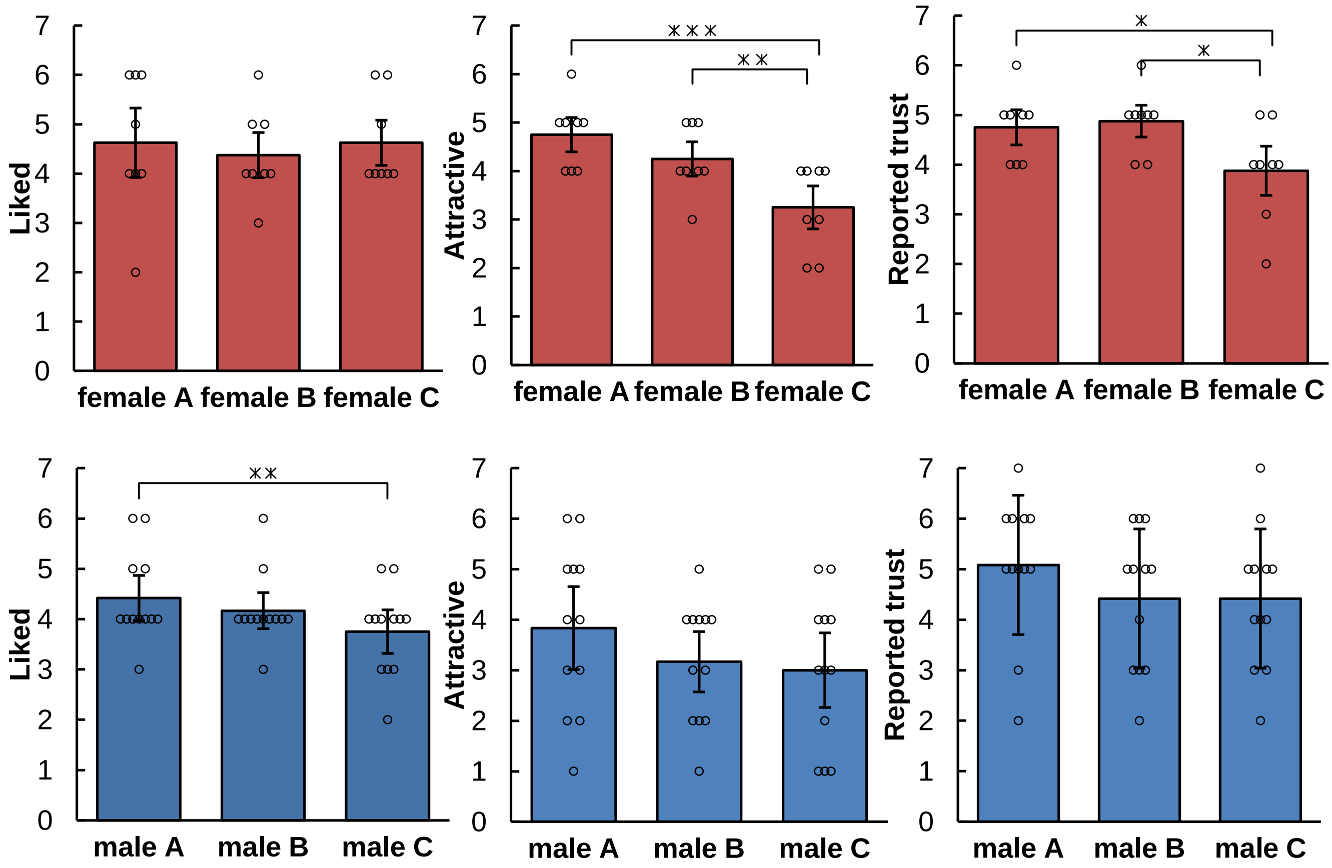

Figure C4. Differences between tapping partners on exit interview data (upper: females; lower: males). Error bars represent one between-participant standard deviation around the mean. Dots represent separate participants.

Correlations between trust and predictor variables

In order to investigate whether similarity, closeness, likeability, attractiveness, and reported trust were related to the amount of trust given to each of the tapping partners, a Spearman correlation analysis was conducted for all tapping partners between the percentage given during the trust game and Similarity, Closeness and the three exit interview variables. The results of this analysis can be seen in Table C1. As can be seen from this table, not many significant correlations were present. Therefore, no further analyses were conducted on the differences between the tapping partners.

Table C1

Spearman rank correlations between trust and predictor variables for each tapping partner

	Trust					
	Female A	Female B	Female C	Male A	Male B	Male C
Similarity	$r_s = 0.34$	$r_s = 0.55$	$r_s = 0.57$	$r_s = 0.65$*	$r_s = 0.40$	$r_s = 0.03$
	$S = 55.66$	$S = 37.45$	$S = 36.43$	$S = 99.37$	$S = 171.80$	$S = 278.81$
Closeness	$r_s = 0.40$	$r_s = 0.34$	$r_s = 0.44$	$r_s = 0.35$	$r_s = -0.36$	$r_s = -0.11$
	$S = 50.36$	$S = 55.32$	$S = 47.34$	$S = 187.06$	$S = 388.37$	$S = 318.35$
Liked	$r_s = 0.15$	$r_s = -0.19$	$r_s = -0.66$	$r_s = 0.23$	$r_s = 0.53$	$r_s = 0.38$
	$S = 71.38$	$S = 100.19$	$S = 139.43$	$S = 221.49$	$S = 133.74$	$S = 178.18$
Attractive	$r_s = 0.17$	$r_s = -0.43$	$r_s = 0.18$	$r_s = 0.39$	$r_s = 0.23$	$r_s = 0.64$*
	$S = 69.76$	$S = 119.82$	$S = 99.12$	$S = 175.25$	$S = 220.05$	$S = 103.81$
Rep. trust	$r_s = 0.57$	$r_s = 0.51$	$r_s = 0.91$**	$r_s = 0.51$	$r_s = 0.49$	$r_s = 0.51$
	$S = 35.80$	$S = 41.2$	$S = 7.84$	$S = 141.47$	$S = 144.47$	$S = 140.12$

Note: $*p < .05$, $**p < .01$, $***p < .001$.

Appendix D

Tables MRI-results for Condition-Baseline contrasts

Table D1

Result of the Sync-Baseline contrast

Size	Hem	Area	Coordinates	t-value
1366	R	fusiform gyrus	30 -64 -14	15.14
	L	inferior occipital gyrus	-45 -76 -8	14.59
	R	fusiform gyrus	30 -79 -11	14.02
190	L	inferior parietal lobule	-39 -31 37	11.67
	L	postcentral gyrus	-48 -34 46	9.76
	L	postcentral gyrus	-45 -34 58	8.02
38	R	calcarine gyrus	12 -67 13	10.99
274	L	middle cingulate cortex	-6 14 40	10.95
	R	suppl. motor area	6 8 49	10
	L	middle cingulate cortex	-9 20 34	8.62
99	L	putamen	-21 14 -2	10.14
	L	insula	-27 26 1	8.33
	L	insula	-30 14 7	7.48
146	R	postcentral gyrus	48 -31 49	10.01
	R	supramarginal gyrus	42 -34 43	9.49
	R	inferior parietal lobule	39 -46 52	8.36
29	L	superior parietal lobule	-15 -70 49	9.34
22	L	rolandic operculum	-45 -1 10	9.13
54	L	superior parietal lobule	-24 -58 52	8.80
27	L	superior frontal gyrus	-24 -10 52	8.70
39	L	calcarine gyrus	-12 -67 4	8.56
19	R	precentral gyrus	63 8 19	8.38
	R	rolandic operculum	54 2 16	7.28
	R	precentral gyrus	60 8 28	7.11
44	R	superior frontal gyrus	30 -10 58	8.31
	R	superior frontal gyrus	21 -4 55	7.54
13	L	postcentral gyrus	-63 -10 28	8.24
	L	postcentral gyrus	-57 -19 25	9.97
14	R	thalamus	15 -13 -2	8.14
13	R	insula	30 23 7	7.96
18	R	precuneus	18 -61 25	7.84
30	R	precuneus	-57 2 31	7.79
	L	inferior frontal gyrus	-48 5 25	7.59
11	R	putamen	24 11 -2	7.33

Note: $p < .05$ (FWE-corrected). All coordinates are in MNI space.

Table D2

Result of the Async-baseline contrast

Size	**Hem**	**Area**	**Coordinates**	**t-value**
1174	R	fusiform gyrus	27 -79 -11	18.24
	L	inferior occipital gyrus	-33 -82 -8	11.90
	R	middle occipital gyrus	30 -88 4	11.37
101	R	calcarine gyrus	12 -67 10	14.42
294	L	middle cingulate cortex	-3 14 43	14.19
	L	anterior cingulate cortex	-9 23 31	9.55
	R	middle cingulate cortex	9 26 31	7.80
121	L	precentral gyrus	-27 -10 52	11.96
	L	precentral gyrus	-24 -10 67	8.57
325	R	angular gyrus	30 -58 49	10.55
	R	supramarginal gyrus	39 -34 43	9.87
305	L	superior parietal lobule	-15 -70 49	10.21
	L	inferior parietal lobule	-45 -37 46	10.10
	L	inferior parietal lobule	-42 -46 43	9.58
64	R	superior frontal gyrus	18 -1 57	9.62
	R	middle frontal gyrus	27 -4 52	8.32
20	R	hippocampus	24 -28 -5	9.36
32	L	calcarine gyrus	-9 -73 10	8.92
12	L	thalamus	-12 -25 10	7.81
23	L	insula	-30 17 7	7.53
	L	insula	-39 11 4	7.17

Note: $p < .05$ (FWE-corrected). All coordinates are in MNI space.

Table D3

Results of the Control-Baseline contrast

Size	Hem	Area	Coordinates	t-value
3569	L	fusiform gyrus	-30 -73 -11	16.05
	L	inferior occipital gyrus	-45 -73 -5	15.81
393	L	middle cingulate gyrus	-3 14 43	13.74
	L	SMA	-3 5 52	11.39
	L	SMA	-12 -4 64	8.43
119	L	precentral gyrus	-30 -10 58	9.94
	L	precentral gyrus	-39 -13 55	7.74
50	L	insula	-42 11 4	10.67
	L	insula	-45 -1 4	8.38
	L	insula	-30 17 7	7.59
39	L	thalamus	-12 -28 10	9.99
	L	thalamus	-9 -10 7	6.89
19	L	rolandic operculum	-45 -22 16	9.66
61	L	putamen	-18 14 -2	9.50
	L	pallidum	-15 -1 -5	9.05
	L	pallidum	-24 -10 4	7.42
86	L	precentral gyrus	-57 5 34	9.12
	L	precentral gyrus	-48 5 37	7.97
	L	inferior frontal gyrus (p. opercularis)	-39 8 28	7.56
27	R	inferior frontal gyrus (p. opercularis)	54 8 28	8.88
	R	inferior frontal gyrus (p. opercularis)	60 11 19	7.16
24	R	insula	36 -4 13	8.81
69	R	superior frontal gyrus	30 -7 58	8.55
		not assigned	18 -7 52	7.46
	R	precentral gyrus	27 -13 64	7.17

Note: $p < .05$ (FWE-corrected). All coordinates are in MNI space.