Framing a Trust Game as a Power Game Greatly affects Interbrain Synchronicity between Trustor and Trustee

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Abstract

We used dual electroencephalography (EEG) to measure brain activity simultaneously in pairs of trustors and trustees playing a 15-round economic game framed as a "trust game" versus a "power game". Four major findings resulted: first, earnings in each round were higher in the trust than in the power game. Second, in the trust game, reaction time for strategic deliberations was significantly longer for the trustee than the trustor. In the power game, however, the trustee took longer to think about how much money to repay, whereas the trustor took longer to think about how much money to invest. Third, prediction accuracy for the amount exchanged was higher in the trust game than in the power game. Fourth, interbrain synchronicity gauged with the phase-locking value of alpha bands in the brain – especially the frontal and central regions – was higher in the power game than in the trust game. From this latter finding we infer that it reflects an elevated mutual strategic deliberation in the power game. These behavioral and neuroscience-based findings give a better understanding of the framing effects of a trust game on the strategic deliberations of both trustor and trustee seeking to attain wealth.

Keywords: Dual electroencephalography, interbrain synchronicity, trust game, power game, alpha bands, framing

1. Introduction

Social interaction and the formation of relationships is of crucial importance for human survival and the collective creation of wealth (Beckes and Coan, 2011; Lieberman, 2007; 2013). Rather than studying persons engaged in tasks in isolation, such as passively watching visual expressions of facial pictures of conspecifics or interacting with a computer during an economic game, researchers have begun taking a social neuroscience perspective by investigating how individuals interact with each other (Cacioppo, et al., 2003; Hasson et al., 2012). When people interact with other people as opposed to making decisions alone, they essentially react thoughtfully and purposively to another person's behavior. This is reflected in the relationship arising between the subject and the person interacting with each other. For neuroscientists interested in electroencephalography (EEG), this requires direct observation of the "interaction" emerging between the brains of different subjects which only can be obtained by measuring brain activity of the subjects simultaneously during tasks (Babiloni and Astolfi, 2014, p. 77). Hence researchers use dual EEG or hyperscanning EEG (e.g., Mu et al., 2016; Keller et al., 2012; Schilbach et al., 2013) when studying the degree of interbrain synchronicity during social tasks. For similar developments have been taking placed within fMRI-based research e.g., King-Casas et al., (2005).

Most studies on dual EEG focus on simple coordination tasks, especially motor tasks such as button pressing, temporal synchronicity during music production, transmitting gestural words or emotions by facial expression, and synchronicity of hand movements (see Babiloni and Astolfi, 2014: Dumas et al., 2010; Kawasaki et al., 2013). It is apparent that during coordination tasks interbrain synchronicity occurs mainly between prefrontal cortices as these regions are involved in perspective-taking and theory of mind (e.g., Cui et al., 2012; Sanfey et al., 2003; Ruby and Decety, 2004) and for social tasks the alpha bands are discerned (Tognoli et al., 2007; Astolfi et al., 2010). Here different patterns of alpha band interbrain synchronicity (e.g., high versus low interbrain synchronicity) are associated with the temporal dynamics of interpersonal coordination such as found in cooperation versus competition tasks. We focus on a coordination task involving strategic decision-making, during which the value associated with the action of one agent depends critically on the changing actions and mental states of other social agents.

We focus specifically on interbrain synchronicity of pairs engaged in a game framed as either a "trust game" or a "power game" (e.g., Johnson and Mislin, 2011; Burnham, et al., 2000). In both versions of the game, the rules are identical: the trustor decides how much of his endowment to invest in the trustee, who receives this amount in each round. The invested amount is then tripled, after which the trustee decides how much to repay the trustor. This game is played for 15 rounds, and the profits from both trustor and trustee are added up for every round. Hereunder we discuss how framing this economic game as a trust versus power game affects the strategic deliberations of both trustor and trustee. Their deliberations involve making predictions about each other exchanges, perspective-taking and theory of mind inferences about one another (Babiloni and Astolfi, 2014). Research in economic games has shown that small changes in the experimental protocols, such as framing effects, can have an impact on the behavior of both players in the lab (Johnson and Mislin, 2011, p. 866). For instance Burnham et al. (2000) created frames for the two participants in a trust game using the primes "partner" versus "opponent" and found that the trustworthiness was higher in the participant framed as the partner. We add to this literature by studying how framing the game as a trust versus power game not only affects the strategic deliberation of both players but also affects their interbrain synchronicity. The insights gained allow us to obtain a deeper understanding of how the framing effects of a trust game affects how people create personal and common wealth. Such finding might extend our understanding about how economic actors operating within economic systems or institutions create wealth.

Researchers suggest that when two players play a trust game, both players undertake two kinds of strategic deliberation. The first is based on the idea that the trustor faces investment risk. He sends an amount of money from his endowment to the trustee in every round and hopes that the trustee will honor his trust. Whether or not the trustee honors his trust becomes apparent when the trustee makes the initial repayment (e.g., Ruff and Fehr, 2014). Both trustor and trustee learn from their reciprocal actions, meaning they learn to predict how much the other person will invest or repay. Based on this learning, they decide how much to invest or repay, and the iterative money exchanges result in mutual wealth creation. When the trustee honors the risk taken by the trustor, indicated by the size of trustee's repayments, the striatum in the trustor's brain might be thought to become activated (Ruff and Fehr, 2014). This type of activation is known to be related to rewarding experiences and arises here perhaps because the trustor has made an accurate prediction or has noticed that his expectations have been exceeded. This consequently motivates the trustor to invest even bigger amounts from his endowments, leading to substantial earnings for each round of this trust game.

The second strategic deliberation is based on the idea that the two players make two complementary strategic decisions (Hardin, 2003). The first deliberation is *trusting*, defined as being "willing to show his or her vulnerability by taking a risk; e.g., the trustee will not benefit from me." The other is *appraising someone's trustworthiness*, defined as the willingness of a person (the trustee) to act favorably toward the other person (the trustor) (Ben-Ner and Halldorsson, 2010, p.

65). It is the trustee's responsibility to demonstrate high trustworthiness through his benevolence, social competence, sense of obligation to reciprocate the money being invested in him, reputation management, and consistency, all of which is signaled behaviorally by his repaying an amount of money that is balances or is greater than what the trustor expects to receive (Hardin, 2003). Here, however, the trustee is never sure how much the trustor appraises his trustworthiness. Based on viewing the trustee's behavioral signals (repayments), the trustor can learn to trust the trustee through a "lens of trustworthiness" (Hardin, 2003). We argue that this dimension of trust acquired through the lens of trustworthiness affects the trustor's willingness to rely on the trustee. Ultimately this means that it takes the trustor less effort to make strategic deliberations which motives or allows him to invest more in the trustee. Again, this leads to substantial increases in earnings for each round of the trust game.

What strategic deliberations would be involved when the two players play the trust game framed as a power game? We conjecture that the following will not be salient deliberations during the power game: a) the trustor showing trust in the trustee, b) the trustee honoring the trust placed in them, and c) the trustee seeking to demonstrate his trustworthiness to the trustor. Rather, we conjecture, both players will seek to outsmart each other so as to create higher wealth for themselves rather than mutual wealth, as occurs for participants in the trust game. Speaking strategically, the trustee has to show some trustworthiness so as to keep the trustor motivated to continue investing. At the same time, however, keeping a guileful eye on potential earnings, the trustee will minimize his strategic efforts to show trustworthiness and thus will show less benevolence, demonstrate less consistency in repayments, and feel a less obliged to reciprocate the money being invested in him. This results in the trustors' reduced ability to predict the amounts received from the trustee as the volatility in sending repayments will be higher than in the trust game. In other words, the trustor has to be constantly on the lookout for the next strategic move of the trustee. He will not have rewarding experiences as a function of the trustee honoring his risk-taking or being able to predict the trustee's repayment decisions. Thus, the trustor focuses on creating his own wealth rather than on mutual wealth. Hence, the earnings of each round in the power game will should be lower than in the trust game.

The main research question of our study is the following: will interbrain synchronicity be higher when the game is framed as a "trust game" compared to a "power game"? High interbrain synchronicity is commonly taken as a sign of mutual synchronized activity of the brains (Astolfi et al., 2010; De Vico Fallani et al., 2010, Toppi et al., 2016). However, the reflexes on behavioral decision of these synchronized brains activity can only be hypothesized. For instance, some authors have shown that coherent and statistically significant interbrain activities were developed during coordinated and supportive behavioral actions between two or more team members (Astolfi et al., 2010; De Vico Fallani et al., 2010, Toppi et al., 2016). When the hypothesis about the predicted activity of the other partner(s) became less stable (e.g not cooperative actions) these interbrain activity significantly fades. The same line of reasoning could be followed for brain processes that subserve tasks that require a close scrutiny of the other partner when compared to other more “independent” behavior. In particular, tit-for-tat task when compared to the “defect” task (De Vico Fallani et al., 2010). Summarizing, evidences from literature suggest that as cooperative behavior or intense scrutiny of the partner could be associated with an increased interbrain activity by using EEG signals, mainly in frontoparietal areas. This underlying hypothesis founded on the previous literature in the area will be adopted to link the neuroelectrical and the behavioral responses in our experiment.

Materials and Method

Participants

The Ethics Commission at the university granted permission to do the study. The trust game was pretested in three pairs, allowing the team to fine-tune the experimental setup. Subsequently the team began collecting data.

As gender and culture differences are known to affect how people engage in the trust game (Buchan et al., 2008; Croson and Buchan, 1999), only Caucasian males living for at least five years in Europe were recruited to participate in this study. We designed flyers which were distributed to students walking on campus or dropped in the mail boxes of students living on campus. In addition, the campus bulletin board system (Euro-system) and Facebook were used as recruitment tools. The flyer mentioned that recruits would be paid €15 for their participation and could earn up to about €40. In total 98 Caucasians, living in Europe for at least five years were recruited.

All participants had normal vision and reported having no history of neurological diseases. Written informed consent was signed by all participants who were told that they could stop with the experiments if they wanted to anytime. They were randomly matched in pairs with one player assigned as the trustor and the other as trustee. Next, both were assigned to one of the two conditions: the game framed as a “trust game” versus framed as a “power game”. Nine pairs were excluded due to excessive artifacts in more than half of the epochs or when it was discovered that they misunderstood the rules of the game (see description hereunder). This resulted in 20 effective pairs per condition (total subjects n=80). The mean age of this sample was 22.76 and s.d. was 3.88.

Design of Experiment

Two people were assigned to be experimenters (A and B) in the study, and another person, experimenter C, was the lead administrator on the computer equipment during the experiment (see Fig. 1A of the experimental setup). Experimenter A always took the lead at the beginning of all the rounds, thus securing standardization for all the pairs.

Place Fig. 1 (A, B, C) about here

Experimenter A invited the participants to be seated in a waiting room and asked them to introduce themselves to each other. This introduction served as a prompt that during the game they were about to interact with a real person rather than a computer. This precaution was taken because some students might have read a bit of game theory and anticipated that subjects could play against a computer and not a real subject. A toss of the coin was used to assign them to roles of trustor or trustee. They were then asked to take a seat in one of two EEG rooms, where experimenters A and B waited to place the caps on their heads. The participants were always taught how to play the game in the same way. Experimenter A visited each participant in their own EEG room and gave both the same detailed explanations about the rules and their respective role. To check if the instructions were understood, experimenter A asked the participants to briefly repeat the rules and also posed specific testing questions. If experimenter A discovered that the participants did not fully understand the rules, he explained them again. But, during the game, when it was observed that the participants did not understand their role in the game, they were allowed to continue but their data were later deleted from the sample. This was done in order to keep the promise that they could earn up to €40. Then, led by experimenter C, they were asked to play three practice rounds on the computer. This step ensured that the participants' mental efforts to learn the game would be kept to a minimum during the actual experiment. After the instruction phase researchers, A and B left the rooms, closing the doors behind them, thus ensuring that the participants were alone and that no one could interfere with their strategic deliberations and actions.

In the trust game condition, participants were told that the game was called the "trust game", and the sentence, "you are entering a TRUST GAME", was shown on the screen before the game started. In the power game condition, the name became, "power game", and the sentence, "you are entering a POWER GAME", was shown on the screen before the game started. Throughout the explanation, experimenter A never deliberately emphasized the name of the game, nor reminded participants to pay extra attention to the name. Before the experiment started, participants were asked to reflect quietly (resting state) by looking at a cross on the screen. This step was designed to make them feel relaxed and prepare themselves for the actual experiment.

Each round began with a 500 ms fixation, then the trustor was given an endowment of € 10 and was asked to decide how much he would like to send to the trustee (from € 0 to € 10). Meanwhile the trustee was prompted to predict how much money the trustor might send. A blank screen was presented for six seconds while both participants deliberated, and it was followed by a decision (or prediction) screen. After the deliberation period, the players typed their answers on a keypad. Reaction time from the onset of decision (or prediction) screen to button press was recorded and used in subsequent analyses. No time limit was imposed. After both participants entered in a value, the trustor's amount was tripled and revealed to both participants for three seconds. The trustee's predictions were recorded but not revealed to the trustor. The trustee then thought how much money to repay and entered this amount. Likewise, the trustor predicted the repayment value (with his reaction time also recorded), but only the repayment amount, not the prediction, was shown to both players for three seconds. The game consisted of 15 rounds, which was referred to vaguely as "several rounds" in the instruction phase (see Fig. 1B & C). Each participant earned € 15 of their promised participation fee and 5% of their total earnings from the game was converted into cash. At the end of the game each participant could see the total accumulated earnings on the screen.

EEG Hyperscanning Setup and Data Acquisition

Simultaneous stimuli presentation and EEG signal recording were manipulated via E-prime port communication (see Fig. 1A). Two BioSemi 32-channel elastic head caps connected with two separate, identical amplifiers (BioSemi Active-Two system AD-box) were used to collect brain signals from both participants. EEG signals were continuously digitized and recorded at a sampling rate of 512 Hz, 24-bit A/D conversion. Two active electrodes attached to the left and right mastoids were selected as reference electrodes. Vertical electro-oculogram (VEOG) and horizontal electro-oculogram (HEOG) were recorded by pasting two active electrodes below and above the left eye, and to the orbital rim of both eyes. Electrode impedance was reduced to a low level (5 kΩ) before the formal experiment began and was maintained for all recordings.

Before the calculation of synchronicity, EEG data were pre-processed adopting BrainVision Analyzer 2 (Brain Products, Gilching, Germany) offline in order to clean the data and remove the artifacts. First, EEG data were filtered with a 0.1-45Hz bandpass filter as well as a 60 Hz notch filter. Next, data were re-referenced to the average of the left and right mastoids. Then, an independent component analysis provided by Brain Vision Analyzer2 was adopted to remove the artifacts caused by ocular movements. Ocular-free EEG data were segmented from 1s before deliberation onset to the end of deliberation period (-1s-6s) in the first and second deliberation period, resulting in 300 epochs per phase per condition. Finally, bad epochs were removed based on the max-min criterion.

In particular, to ensure both roles had the same number of epochs, if the epoch was excluded from trustor EEG dataset, the corresponding epoch was also excluded from the trustee dataset, and vice versa. Consistent with previous hyperscanning research by with Mu et al. (2017), representative electrodes were selected as electrodes of interest in accordance with four ROIs: frontal (F3, Fz, F4), central (C3, Cz, C4), parietal (P3, Pz, P4) and occipital (O1, Oz, O2).

EEG Time-frequency analyses

Similar to EEG hyperscanning studies (e.g., Jahng et al., 2017), time-frequency analyses were conducted to characterize neural activities during the task and test the framing effect on event-related spectral perturbation (ERSP). Artifacts-free epochs from 1s before deliberation onset to 6s after onset were extracted and went into time-frequency analyses. ERSP calculations were done in EEGLAB. Default cycles [3 0.8] was adopted. The frequency range were set from 4 to 40Hz, including all frequency bands we are interested in. 1s prior to the deliberation onset was determined as baseline of calculating spectral power. A bootstrap method with 1000 times replicates was used at every timepoint in every time frequency band in order to compare the ERSP magnitudes in trust game and power game during the whole deliberation period.

Interbrain Synchronicity Calculation

Consistent with previous EEG hyperscanning studies based on epochs, the sample size of this study is adequate to calculate the neural synchronicity (e.g., Jahng et al., 2017; Pérez et al., 2017). The interbrain synchronicity between the trustor and trustee was reflected by phase-locking value (PLV) (Lachaux et al., 1999) for all combinations of the selected electrodes. The trial based PLV of electrode pair (i, j) was defined as (Burgess, 2013; Delaherche et al., 2015; Pérez et al., 2017):

$$PLV_{ij} = \frac{1}{N}\left|\sum_{t=1}^{N} exp^{i(\varphi_i(t)-\varphi_j(t))}\right|$$

where N is the number of time points in each time window. Phase difference at each time point $\varphi_i(t) - \varphi_j(t)$ was estimated using Hilbert Transform in the following four frequency bands: theta (5–7 Hz), alpha (8–13 Hz), beta (14–18 Hz) and gamma (28-40 Hz) at six time ranges of the thinking phase (0–1s, 1–2s, 2–3s, 3–4s, 4–5s and 5–6s). The PLV ranges from 0 to 1, where 0 means no interbrain synchronicity, while 1 indicates perfect synchronicity of the oscillations between two signals. In order to rule out coincidental synchronicity, for each electrode combination (i and j), real PLV_{realij} and 500 $PLV_{surrogateij}$ obtained by surrogating the trials of electrode j and calculating the phase-locking value of i and shuffled j were compared. Phase-locking statistics (PLS) was defined as the sum of shuffled $PLV_{surrogateij}$ exceeding the real PLV_{realij}. If PLS < 5%, the original real PLV was kept, otherwise (PLS ⩾ 5%), PLV was set to 0. Only significant (non-zero) PLVs went into further statistical analyses. PLVs of symmetric electrode pairs were then averaged. Specifically, the average value between PLV_{ij} and PLV_{ji} was calculated as the synchronicity between electrode i and electrode j (Jahng et al., 2017).

Results

Behavioral Results

Earnings Each Round

A 2 (condition: trust game and power game) x 2 (role: trustor and trustee) repeated measures ANOVA was used to explore the framing and role effect on earnings for each round. The salient effects of both factors were found (condition: $F(1,598) = 3.984$, $p = 0.046$; role: $F(1,598) = 8.021$, $p = 0.005$), indicating that participants earned more money in the trust game (M=13.563) than in the power game (M=13.067), and the trustor (M=13.647) earned more money than the trustee (M=12.983). However, no significant interaction between condition and role was observed ($F(1,598) = 1.752$, $p = 0.186$) (Fig. 2).

Place about Fig. 2 here

Reaction Time

Participant's reaction time, defined as the duration from the onset of the answer screen to the button press, after thinking about their predictions and decisions on how much to invest/repay was analyzed to explore the differences between two conditions. Outliers falling outside the range mean ± 2*standard deviation were excluded before the 2 (phase: invest phase and repay phase) x 2 (role: trustor and trustee) repeated measures ANOVA was conducted in two conditions. In the trust game, the statistical result confirmed a significant phase x role interaction effect ($F(1,265) = 8.884$, $p = 0.003$). Specifically, in both phases, the trustee had a longer reaction time than the trustor (invest phase: Mtrustor-trustee = -859.177, $t = -5.477$, $p < 0.001$; repay phase: Mtrustor-trustee = -1409.951, $t = -10.040$, $p < 0.001$) (Fig. 3A). The results indicated that it always took the trustee longer to answer, no matter whether he was asked to decide or predict. In the power game, a significant phase x role interaction effect ($F(1,260) = 38.327$, $p < 0.001$) on reaction time was also revealed. Unlike in the trust game, the trustor in the power game spent longer deciding on the amount of money to invest than the trustee spent predicting how much he would receive (Mtrustor-trustee = 431.394, $t = 2.779$, $p = 0.006$), while in the repay phase, it took the trustee longer to decide how much to repay than the trustor to predict how much to receive (Mtrustor-trustee = -1322.364, $t = -5.163$, $p < 0.001$) (Fig. 3B).

Place Fig. 3 (A, B) about here

Prediction Accuracy

Prediction accuracy is reflected by the absolute difference between predicting how much to receive/repay and deciding the amount of money to send/repay, which means that the greater the difference between the predicted amount received/repaid and the real amount sent/repaid, the lower the prediction accuracy. The results of a 2 (condition: trust game and power game) x 2 (phase: invest phase and repay phase) repeated measures ANOVA revealed the pronounced main effects of both condition ($F(1, 1196) = 4.998$, $p = 0.026$) and phase ($F(1, 1196) = 7.825$, $p = 0.005$), indicating that participants predicted more accurately about the exchanged amount of money in the trust game compared to the power game (Mtrust = 1.227; Mpower = 1.557), and trustors did better than trustee in money prediction no matter the condition (Minvest = 1.598; Mrepay = 1.185). No significant interaction effect between condition and phase was observed based on the ANOVA results ($p = 0.095$) (Fig. 4).

Place Fig. 4 about here

EEG Time-frequency Results

In order to gauge interbrain synchronicity we first conduct a time-frequency analysis (Jahng et al. 2017). Significant differences ($p <= 0.001$) were shown with blue, while insignificant ones were shown as yellow (Fig. 5). Greater brain activities of power game versus trust game were found in alpha and gamma band at 1-2s time interval, beta and gamma band at 2-3s time interval as well as 3-4s time interval. Besides, brain activities were observed to be greater only in alpha band at 4-5s time interval. Baseline and 5-6s time interval were cut short after the time-frequency transformation and didn't go into statistical analyses. Based on time-frequency analyses, we aimed to test how framing effect modulated ERSP manipulates in different frequency bands at different time intervals.

Place Fig.5 about here

Interbrain Synchronicity

We calculated the interbrain synchronicity from frequency bands and time intervals which showed significant ERSP magnitude differences between trust game and power game.

PLVs ranged from 0 to 1 were used to measure the connectivity between two brains across time and averaged based on brain regions for further analyses. As the missions in both invest and repay phases were similar, except that the decider in the invest phase turned into a predictor in repay phase, we first ran a t-test for PLVs from the invest and repay phases within a 1-2s time window to test the differences between two phases. The false discovery rate (FDR) procedure was adopted to correct the p-values for multiple comparisons. No significant difference was observed in any of the electrode combinations (corrected $p > 0.05$). PLVs from these two phases were then merged and went into the comparison between conditions. Mixed ANOVA was adopted in all frequency bands, with condition (trust vs. power game) as a between-subject factor and electrode combination (78 combinations) as a within-subject factor. Salient effect of condition ($F(1, 1066) = 4.736$, $p = 0.032$) was observed only in the alpha band (1-2s) (see Table 1). Interaction effect between channels and condition appeared only in beta band at 3-4s time interval. However, further t-test with FDR correction showed almost no significant channel combinations of the interaction effect, so only the salient condition effect in alpha band was plotted and went into discussion. Fig. 6 illustrates that alpha band PLV (1-2s) was substantially higher in the power game than the trust game. Subsequent independent t-test revealed the framing effect in different electrode combinations (FDR corrected). These significant electrode combinations were mainly in the prefrontal and central regions (Fig. 7).

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Discussion

Trust between economic actors is a key factor in society and affects whether and how economic actors can build wealth in a world in which people can compete or cooperate (Ostrom and Walker, 2003). The iterative trust game is a prolifically used tool that exemplifies how participants (two economic actors) learn about each other's economic strategies and build trust accordingly, and how this in turn effects wealth creation. We studied the strategic deliberations that both participants made as well as their interbrain synchronicity which deepens our understanding of how people engage in wealth creation. Based on the knowledge that trust games are sensitive to design factors such as framing effects, we framed the economic experiment as a "trust game" and "power game". We conjectured that this framing effect would substantially affect the strategic deliberations of both the trustor and the trustee and would be associated with differences in EEG time frequency results and in interbrain synchronicity.

Briefly stated: in the trust game the trustor will mainly test the trustee because a) as the trustor faces more risk he needs to study the trustee to predict whether the trustee will repay his investments; b) when his predictions about the trustee are correct or exceeded (more money is repaid than predicted) the trustor will experience feelings of reward; and c) the trustor will view the repayment decisions through the lens of the trustee's trustworthiness. These strategic deliberations affect *his willingness to rely* on the trustee and make investment decisions accordingly, all of which result in creating both his own wealth as well as their collective wealth. The roles substantially change in the power game because now, in their deliberations, both players behave antagonistically as they seek or are required to *outsmart each other* and thus keep a strategic eye on creating their own wealth rather than on collecting mutual wealth.

The experiment delivered three important observations. First, as expected the earnings of each round were higher in the trust game than in the power game. Note that the trustor benefited mostly from wealth creation in either condition and the framing (trust vs. power) of the game had no effect on either the roles taken or wealth creation. In other words, the data show that the trustor was the main beneficiary, no matter the framing condition.

Second, the reaction time taken to ponder about deciding and predicting investments or repayments showed different patterns in both games. In the trust game, the trustee took longer than the trustor to predict both how much money he would receive and how much he would repay. However, in the power game, the trustee only took longer deliberating on how much to repay while the trustor took more time to decide how much to invest in the trustee.

Third, the prediction accuracy was higher in the trust game than the power game. In other words, as we proposed, better prediction brings about more trust and a greater sense of reward, which results in the willingness to make higher investments. Note, however, that in both the trust and power games, the trustor was better at predicting the repayments made. In addition, no interaction effects (condition and role) were found.

All observations (higher earnings for each round of the trust game, longer reaction time for the trustee in the invest/repay phase of the trust game, higher prediction accuracy in the trust game and better prediction accuracy by the trustor no matter what game or condition) lead us to conjecture that in the trust game the trustee takes more responsibility for ensuring that trust builds between the players such that more common wealth can be created. In contrast, in the power game the trustor's longer reaction time for investment decisions and better prediction accuracy for repayments indicates that he might devise a strategic mindset to gain more wealth on the back of the goodwill of the trustee, given that the latter's repayment reaction time was longer than the trustor's prediction reaction time.

In short, these observations lead us to conclude that the economic game framed as a trust game versus power game substantially affects people's strategic deliberations. Importantly, it allows us to understand our findings on the differences in interbrain synchronicity between the two games. In the trust game, the trustee takes longer to think about both the investment received and the repayment sum to be sent to the trustor. Added to that, the trustor's better prediction accuracy about the repayments allow him to rely on the trustee as well to experience the pleasure of having his trust honored and being able to appraise the trustee through the lens of trustworthiness.

However, when framed as a power game, the way in which both players deliberated strategically changed substantially: the trustor spent more time deciding how much to invest so as attain higher earnings himself while the trustee had to keep the game going, in terms of both wondering "how much will I get?" to a certain extent, due to the trustor's intense strategizing, and in thinking strategically about how much to repay. This showed up especially in the lower prediction accuracy in the power game as opposed to the trust game. Both accounts of strategic deliberations the trust and power games help us explain why interbrain synchronicity was higher in the power game than in the trust game. This finding, we believe, is our contribution to the literature on interbrain synchronicity which has become an important stream of research today given that the human base line has a rich social foundation rather than merely reflecting individuality in an observer or appraiser of facial expressions of conspecifics (e.g., Babiloni and Astolfi, 2014; Dumas et al., 2010).

As discussed, the strategic deliberations of trustor and trustee performed key roles in the trust game and so these periods were chosen to measure interbrain synchronicity. A closer look at the differences in interbrain synchronicity between the two conditions shows that they occurred especially between the electrodes in frontal and central regions. These regions are associated with prefrontal activation, and this in turn is known to be involved in human decision-making (Miller and Cohen, 2001; Tang et al., 2015). Several authors have proposed that when people deliberate strategically in economic games, their prefrontal cortex activations play key roles (e.g., Sanfey, 2003). Concretely, these strategic deliberations involve perspective-taking or theory of mind inferences, when predicting how much money to receive or, particularly applicable to the trustee, the suppression of overly selfish behavior (Balconi and Pagani, 2014; Ruby and Decety, 2004).

Apparently these strategic deliberations are more synchronous during the power game than in the trust game. Again, during the power game both participants were seeking to outsmart each other, which requires intense perspective-taking efforts, while in the trust game the trustor can rely on the trustworthiness of the trustee, whom we believe undertook more effort to show his trustworthiness or refrain from being opportunistic. Hence these interbrain synchronicity findings match well with the main conjectures made in our paper. Finally, it is important to note that interbrain synchronicity takes place at the alpha bands which are known to be related to social strategic deliberations (e.g., Tognoli et al., 2007; Astolfi et al., 2010).

It may seem counter-intuitive that interbrain synchronicity is higher in the power game than the trust game. After all, friendships and other relationships between people are known to show high interbrain synchronicity (Goldstein et al., 2018). Note, however, that interpersonal relationships function to provide all partners in the relationship affection, pleasure, and stress relief. Here we must emphasize that in the economic game under study both players face high opportunity costs if their strategic deliberations do not benefit each other. One or both face a loss of money if they do not learn about the other person's strategy, or whether they can rely on the other person's trust, which is especially the case for the trustor. Concretely, in our experiment they can lose or earn about €40, a significant amount for most students, especially given the short period of time needed to complete the experiment and their low student budget. Of course, beyond monetary gain, pride and reputation are also rewarding.

Although this may be a leap of faith, we cannot refrain from pondering that the trustee in the trust game also functions much like a banker who has to take responsibility for his customers' trust that his bank is a reliable place to invest their money in. Ultimately, trustworthiness between economic actors, such as two individuals or an individual's interaction with an institution, and the consequent effort to demonstrate trustworthiness by individuals, firms or institutions are what foster common wealth creation in society (Fukuyama, 1995). Again, our conclusions are inferred especially from our study of interbrain synchronicity: in the power game both players work to outsmart each other and thus show high interbrain synchronicity, while in the trust game the trustee allows the trustor to rely on him (i.e., trust him) and this shows up in lower interbrain synchronicity.

Limitations of the Study

This study focused on two related questions: does framing an economic game influence how trustor and trustee engage in strategic deliberations and how in turn does this relate to differences in interbrain synchronicity based on hyper EEG. Other hyperscanning techniques are available these days, such as hyperscanning fMRI (e.g., Hasson et al., 2012). This study could be replicated using the latter neuroscientific method. Indeed, we could have chosen to use hyperscanning fMRI or even both methods to study whether the trustor has higher activation in his striatum when the trustee honors his investments or matches his predictions in the trust game. Indeed, while EEG has much to offer in studies of temporal resolution it has less value in spatial resolution, whereas fMRI offers just the opposite benefits. EEG, however, is more convenient and less expensive to implement.

Second, in this study the participants were seated in two different rooms and could not see each other's faces. Yet facial expression is known to affect people's strategic deliberations (e.g., Scharlemann et al., 2001). These days, with the availability of mobile hyper EEG (e.g., EMOTIV), it is in principle possible to study economic games when people are in close proximity with each other (Babiloni and Astolfi, 2014 for an overview).

Third, the participants in the experiment were limited to Caucasian males and excluded females and people from other ethnic backgrounds (e.g., Asians, blacks) or cultural backgrounds (North/South America, East Europe). Actually, these variables could significantly influence strategic deliberations during the game (Ben-Ner and Halldorsson, 2010). Future replications should create a variety of strategically chosen stratified samples (e.g., placing a male and female together or placing people from different cultural backgrounds together) in order to check whether these variables could influence the effect of framing on strategic deliberation and interbrain synchronicity found in our research.

Fourth, as it becomes more easy to use biomarkers such as hormones or genetic markers we could have studied whether e.g., participants produce more testosterone in the power game as opposed to the trust game (e.g., Zak, et al., 2009) or whether individual genetic makeup matters (e.g., Cesarini et al., 2008). Most importantly, we could have studied whether the endocrine or genetic variables are associated with interbrain synchronicity.

Conclusions

Our study focused on how framing an economic game as a "trust game" versus "power game" affects the strategic deliberations of trustor and trustee and how this in turn is associated with differences in interbrain synchronicity. While cooperation is intuitively associated with higher interbrain synchronicity, here we find that when people play the economic game framed as a power game, interbrain synchronicity is higher than when framed as a trust game. The main lesson that can be drawn from this finding is that the trust emerging between players in a trust game, indicated by higher earnings for each round, is due to the fact that the trustee engages in more intense strategic deliberation efforts to imbue trust in the game, and the trustor is able to rely on this trust with less need for ongoing monitoring reflected in additional synchronicity. This especially benefits the trustor who, as he can rely on the trustee will therefore attain better prediction accuracy about repayments. It also motivates him to invest (more) in the trustee; hence the occurrence of lower interbrain synchronicity. In the power game, however, both actors seek to outsmart each other which paradoxically affects their interbrain synchronicity positively, largely due to greater need for joint vigilance concerning each other.

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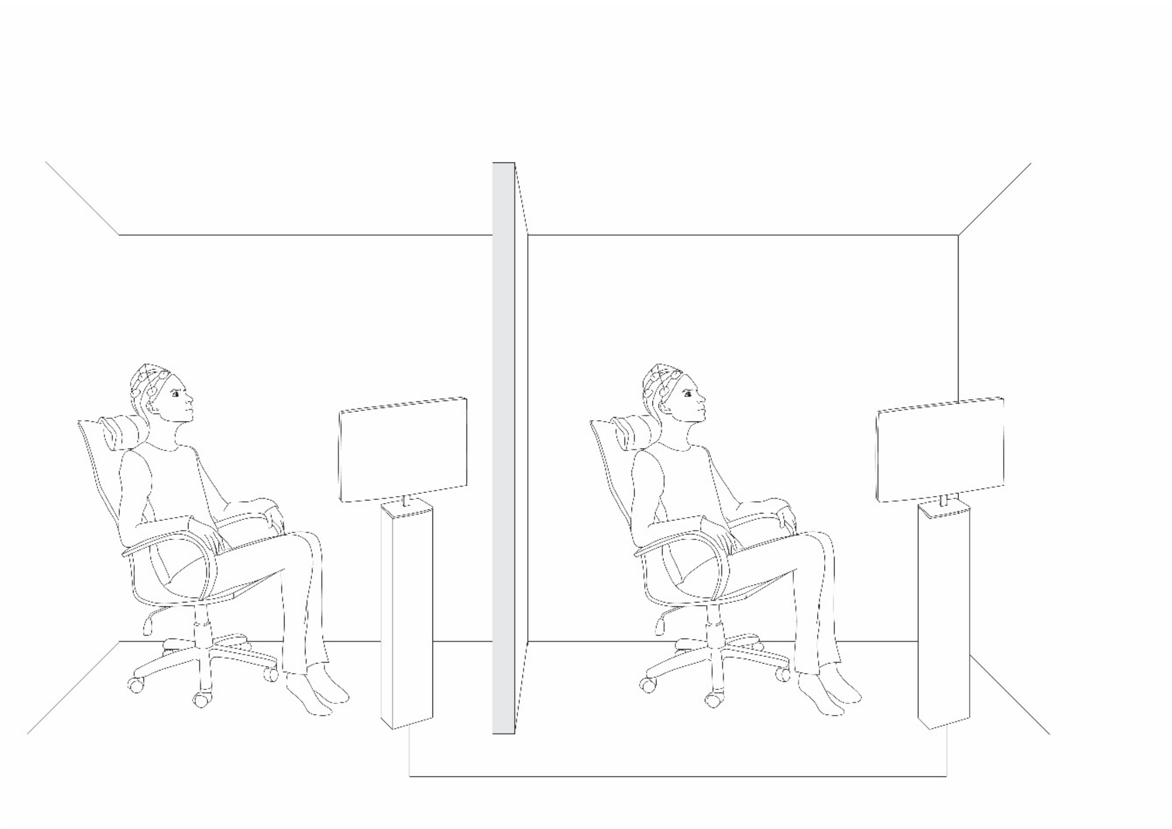
List of tables.

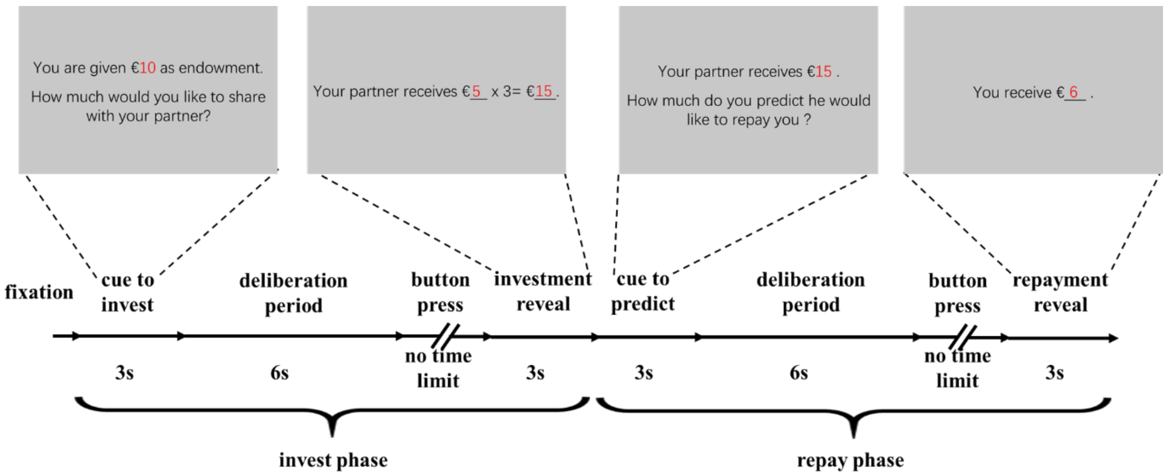
Frequency band	Time interval	Between-subject effects	Interactions of condition × electrode
alpha (8–13 Hz)	1-2s	p = 0.032 (*)	p = 0.717
	4-5s	p = 0.666	p = 0.172
beta (14–18 Hz)	2-3s	p = 0.155	p = 0.661
	3-4s	p = 0.145	p = 0.001(*)
gamma (28-40 Hz)	1-2s	p = 0.306	p = 0.583
	2-3s	p = 0.846	p = 0.494
	3-4s	p = 0.968	p = 0.465

Table 1. Between-subject effects and interactions of condition × electrode pair in all frequency rounds within 1-2s time window (*p < 0.05; **p < 0.01; ***p < 0.001).

List of Figures



A



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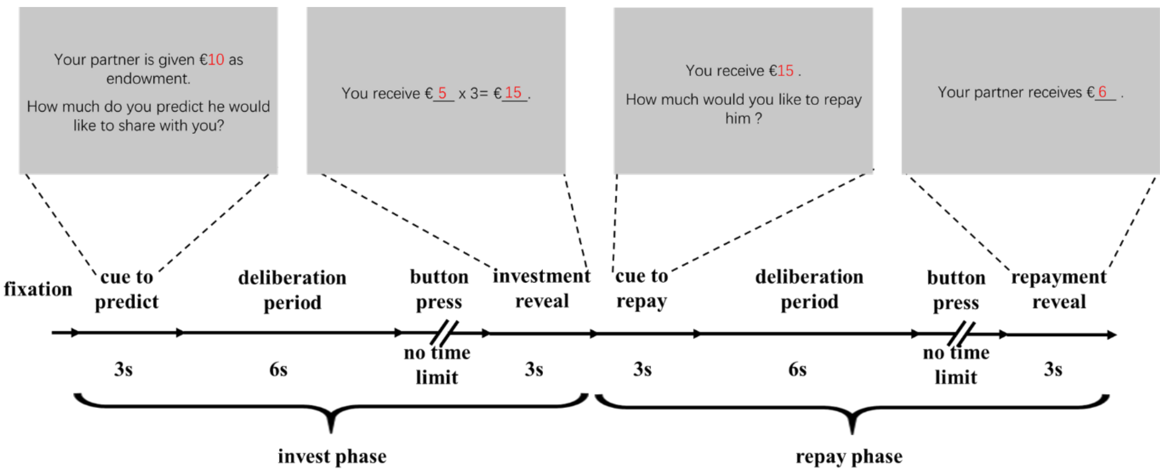


Fig. 1. (A) Setup of the experiment; (B) Timeline of one round for the trustor; (C) Timeline of one round for the trustee.

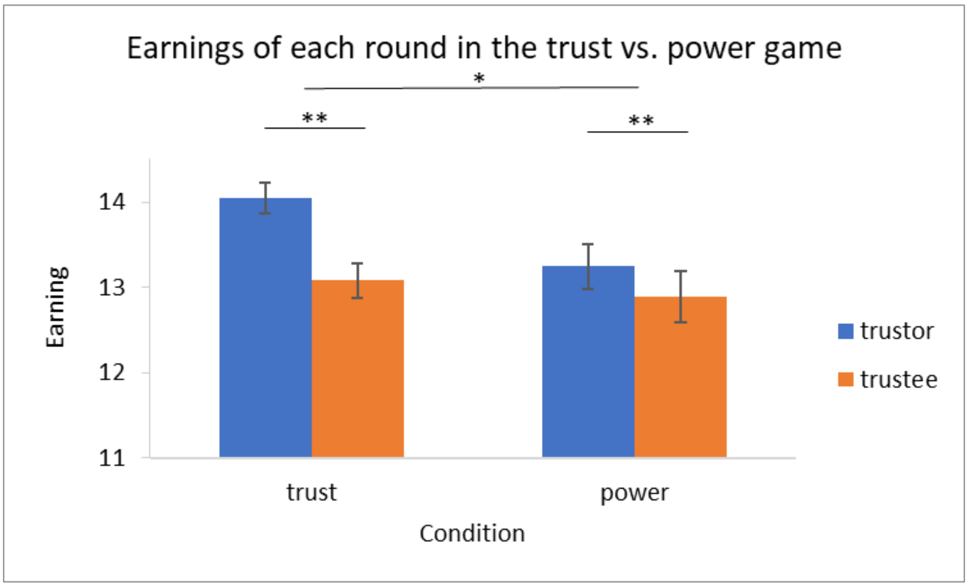
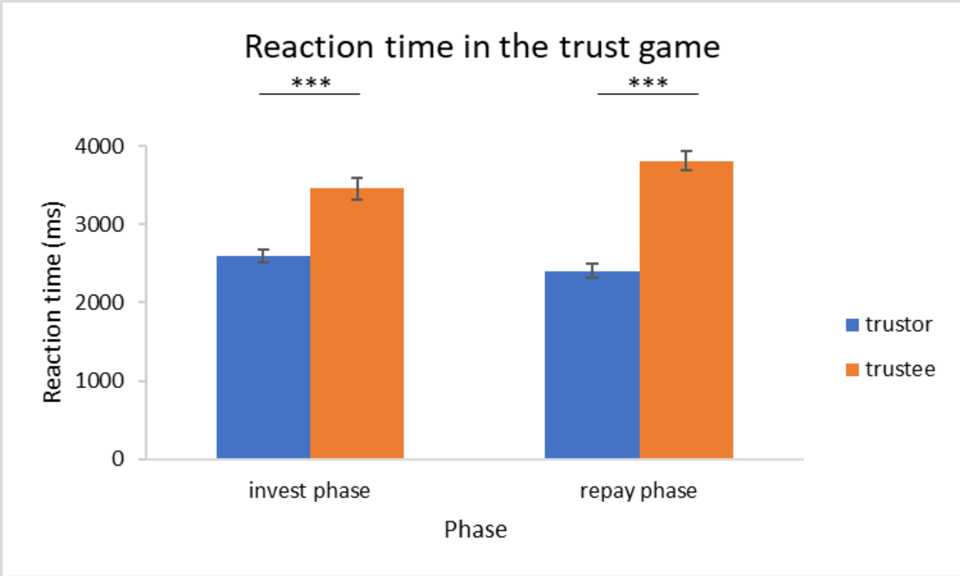
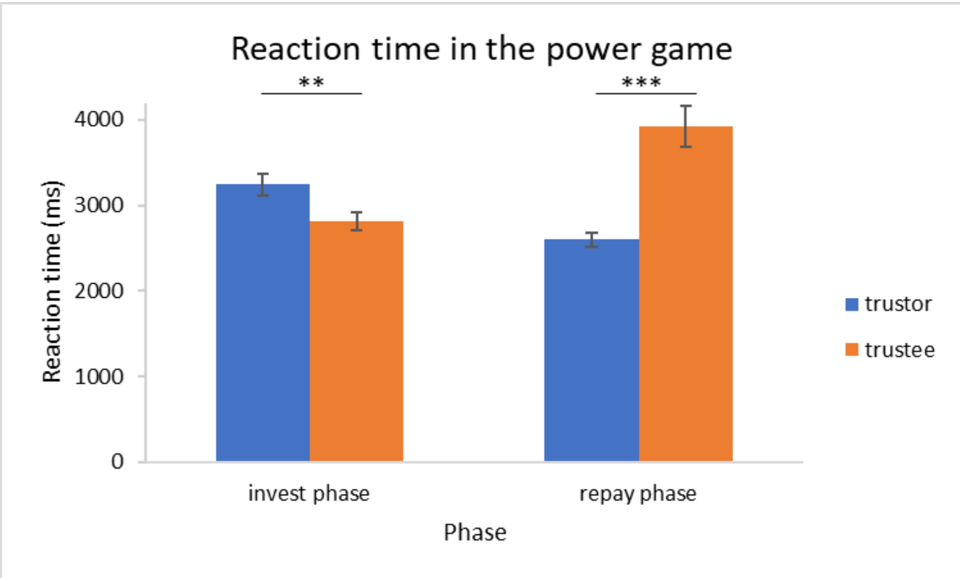


Fig. 2. Earnings of each round in trust vs. power game (*p < 0.05; **p < 0.01; ***p < 0.001).



A



B

Fig. 3. (A) Reaction time of trustor and trustee in the trust game; (B) Reaction time of trustor and trustee in the power game (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$).

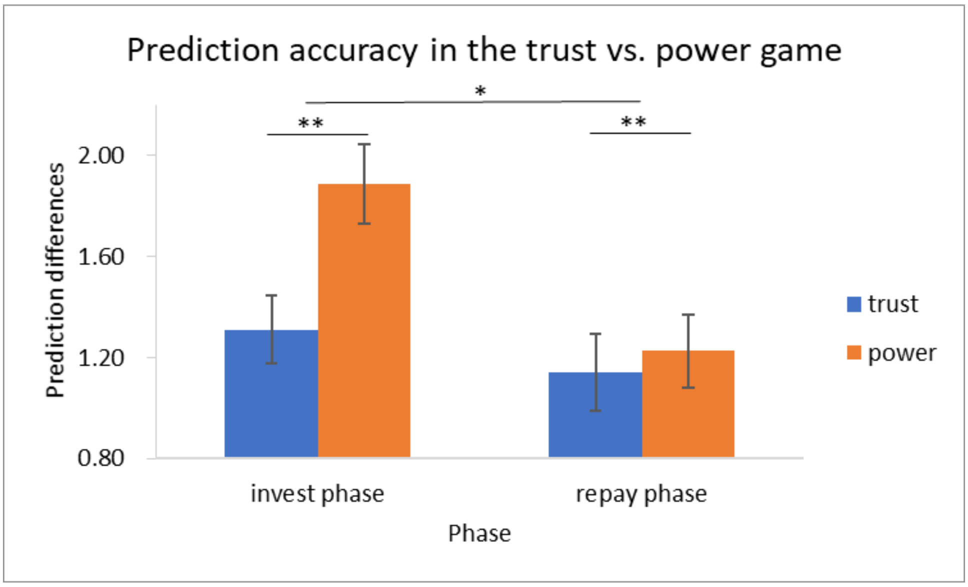


Fig. 4. Prediction accuracy in the trust vs. power game (*p < 0.05; **p < 0.01; ***p < 0.001).

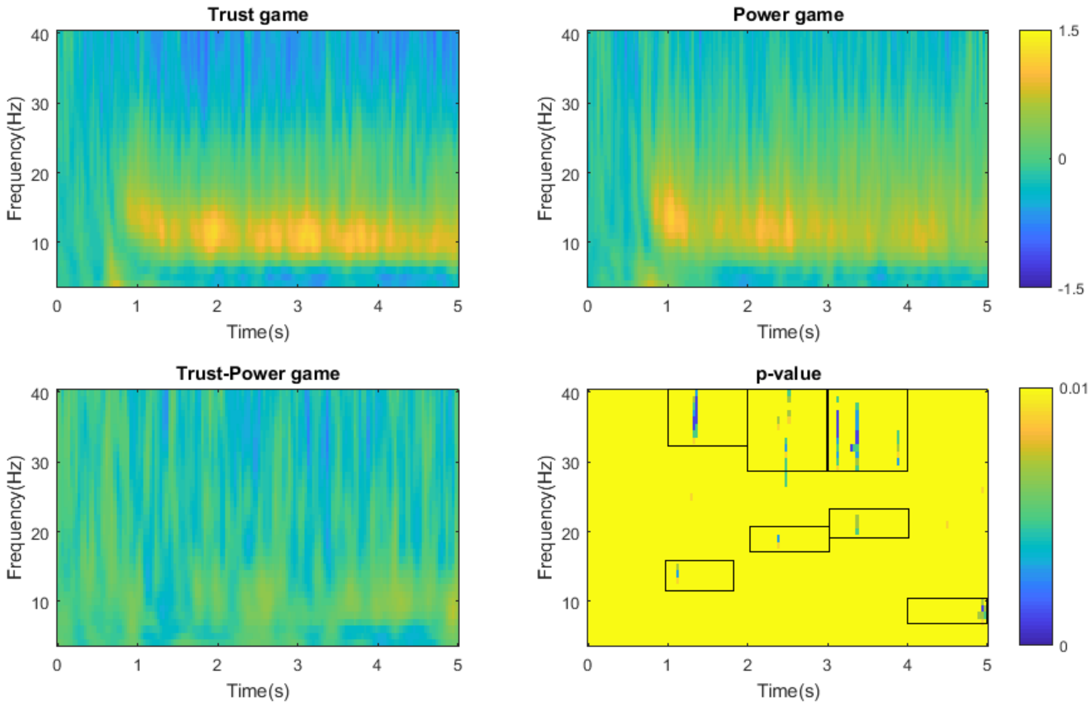


Fig. 5. ERSP magnitudes in trust game vs. power game, separately, differences between two games and significant statistical difference (alpha level 0.001)

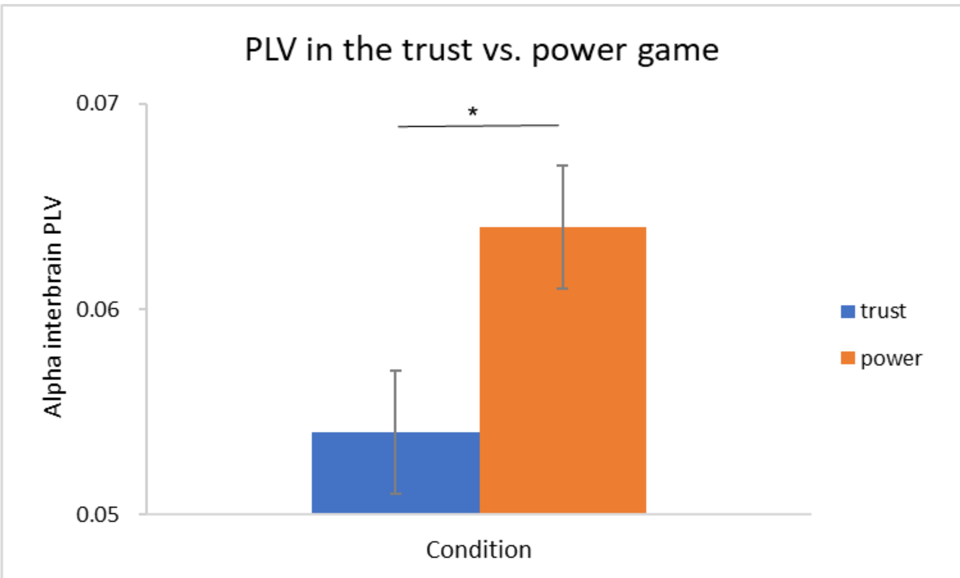


Fig. 6. Average PLV in trust vs. power game (*p < 0.05; **p < 0.01; ***p < 0.001).

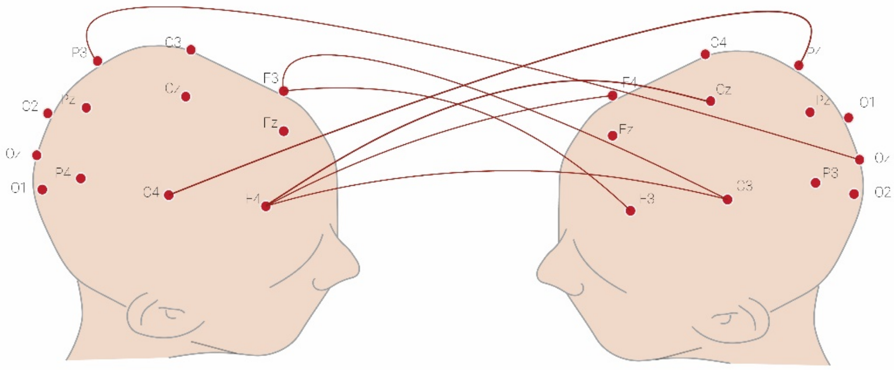


Fig. 7. Differences in alpha band interbrain synchronicity (corrected $p < 0.05$).