Donate or receive? Social hyperscanning application with fNIRS

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Abstract

Recent research in social neuroscience has shown how prosocial behavior can increase perceived self-efficacy, perception of cognitive abilitites and social interactions. The present research explored the effect of prosocial behavior, that is giving a gift during an interpersonal exchange, measuring the hyperscanning among two brains. The experiment aimed to analyze the behavioral performance and the brain-to-brain prefrontal neural activity of 16 dyads during a joint action consisting in a cooperative game, which took place in a laboratory setting controlled by an experimenter, to play before and after a gift exchange. Two different types of gift exchange were compared: experiential and material. Functional Near Infrared Spectroscopy (fNIRS) was applied to record brain activity. Inter-brain connectivity was calculated before and after the gift exchange. In behavioral data, a behavioral performance increase was observed after gift exchange, with accuracy improvement and response times decrease. Regarding intra-brain analyses, an increase in oxygenated hemoglobin was detected, especially in the dorsolateral prefrontal cortex (DLPFC) in both donor and receiver; and in the dorsal part of the premotor cortex (DPMC) in the donor. Moreover, as regards the gift type, greater activation in the DPLFC emerged in both the donor and the receiver after receiving an experiential gift. Finally, the results of the inter-brain connectivity analysis showed that after gift exchange, the donor and receiver brain activity was more synchronized in the DPMC and Frontal Eye Fields (FEF) areas. The present study provides a contribution to the identification of inter-brain functional connectivity when prosocial behaviors are played out.

Keywords Prosocial behavior · Hyperscanning · Inter-brain activity · Intra-brain activity · Gift exchange

Introduction

Gratitude and Gift Exchange

Recent contributions from different research fields, such as anthropology, sociology, and psychology, have investigated the topic of gift exchange as the primary context of interpersonal and social relationships. In particular, anthropological studies have examined the economic and social value of gift, while sociological and psychological research has interpreted gift exchange in terms of social responsibilities redefinition and mutual individuals interactions (Caplow 1982, 1984). Moreover, some research focused on the effects related to different type of gifts on human interactions (Belk and Coon 1991, 1993; Chan and Mogilner 2016). Van Boven and Gilovich (2003) defined two categories of gifts: material and experiential ones. Experiential gifts is defined as realized with the primary intention of acquiring a life experience: an event or a series of events that are lived through^, while material ones, on the contrary, can be categorized as those gifts made with the primary intention of acquiring a material good: a tangible object that is held in its possession^ (Van Boven and Gilovich 2003, p.1994). At this regard, other research has investigated the effects of experiential and mate-rial gift exchange on individuals pleasure (Carter and Gilovich 2010) and emotional experiences (Van

Boven and Gilovich 2003), revealing that experiential gifts can increase individuals satisfaction and positive interpersonal relations more than material ones (Caprariello and Reis 2013; Carter and Gilovich 2010; Rosenzweig and Gilovich 2012), thanks to the possibility to sharing an experience. Moreover, it has been shown that experiential gift exchange intensifies individuals' social connection, strengthening of interpersonal relationships (Bazzini et al. 2007; Clark and Finkel 2017; Nummenmaa et al. 2012; Peters and Kashima 2007; Raghunathan and Corfman 2006; Ramanathan and McGill 2006).

Another important aspect that was considered by re-searchers in relation to gift exchange is gratitude, whose social significance and positive valence have been demonstrated by previous studies with regard to subjective well-being increase (Emmons and McCullough 2003; Froh et al. 2008), social relationships modification (Algoe et al. 2008; Gouldner 1960; Lambert et al. 2010) and prosocial behaviors improvement (McCullough et al. 2001; McCullough and Tsang 2012; Peterson and Stewart 1996). Concerning prosocial attitudes, the involvement of gratitude was defined as a trigger of prosocial behaviors when receiving or giving small gifts (Penner et al. 2005). In some cases, this effect was interpreted as depending on a sense of duty towards the gift donor (Cialdini and Goldstein 2004). At the same time, an increase in prosocial attitudes was also observed in gift donors as a result of increased self-efficacy (Bem 1972). Specifically, it has been shown that the empowerment of prosocial behaviors occurs because donors are motivated by the gratitude received from the gift beneficiary that leads to being more available in executing benefits to others (Carey et al. 1976; Clark et al. 1988; McGovern et al. 1975; Rind and Bordia 1995).

These effects were not only explored from a psychosocial point of view, but they were also measured by using a neuroscientific approach. Neuroimaging studies, for example, identified specific brain regions related to gratitude, such as the right anterior temporal cortex (Wood et al. 2008), the posterior medial cortex, but especially the pre-frontal regions (Bechara et al. 2000; Harbaugh et al. 2007; Immordino-Yang et al. 2009; Knutson and Cooper 2005; Van Overwalle 2011), which are also involved in emotion-al, cognitive, and behavioral components of social interactions (Balconi and Canavesio 2013, 2014; Balconi and Vanutelli 2016). In light of this evidence, in the present study we wanted to investigate the subfrontal cortex areas, such as the dorsolateral prefrontal cortex (DLPFC), the dorsolateral pre-motor cortex (DPMC), the frontal eye fields (FEF) and the superior frontal gyrus (SFG) which are mainly involved in emotional and cooperative processes (Balconi and Pagani 2014, 2015; Chiao et al. 2009) and in the actions planning (Marsh et al. 2009).

Moreover, other studies have observed that when individuals help someone or perform a prosocial action the reward system is significantly involved (Balconi and Bortolotti 2012a, b; Balconi and Canavesio 2013; Harbaugh et al. 2007).

Another important topic that has been considered in relation to gift and gratitude is cooperation. In fact, previous research already underlined that helping and cooperating with others represent an important social reward, even in the absence of a concrete and material repayment (Vanutelli et al. 2016).

Moreover, cooperation induces specific effects linked to the social meaning that lead the inter-agents to perceive themselves as immersed within intersubjective contexts and allow them to confront on a social level (Balconi and Vanutelli 2016). Finally, cooperation reinforces the sense of being part of a whole, the sense of joint actions, the sense of perceived self-efficacy and interpersonal cohesion (Balconi and Pagani 2015; Balconi and Vanutelli 2017; Chung et al. 2015; Cui et al. 2012).

Cooperation and Intercerebral Syncronization

Previous research has revealed that cooperating with others can lead to a sort of synchronization between two inter-agents, triggering a deeper and mutual understanding between the individuals involved.

Specifically, several studies have shown that cooperation involves a greater inter-cerebral synchronization concerning competition, which does not envisage cooperating or matching one's responses. For example, a study by Lindenberger et al. (2009) observed an inter-cerebral oscillatory coherence between pairs of guitarists who played a short melody together, reporting an increased individuals brain responses synchronization in the frontal regions, emphasizing the role of this brain area in the personal and other actions representation and in the creation of a joint model. Greater brain synchronization in the prefrontal cortex during cooperation, with consequent improvement in behavioral performance, and an absence of synchronization in the competition has also been demonstrated by Funane et al. (2011) and Cui et al. (2012). These results were further con-firmed by a subsequent study that used a different paradigm that involved the joint development of a complex piece of music requiring the two couple members to play a different role (leader and follower), observing a desynchronization in individual's movement, perception, and proprioception (Sänger et al. 2012). The evidence of a positive correlation between cooperation and inter-cerebral synchronization has also been reported by other studies that have shown how, when two individuals must produce precisely the same gestures and the same mimic expressions, there is a greater cerebral synchronization in some cortical regions such as the anterior cingulate gyrus, the inferior frontal gyrus, the parahippocampal gyrus, and the post-central gyrus (Dumas et al. 2010; Konvalinka et al. 2014; Yun et al. 2012).

Furthermore, even in the centroparietal areas a two brains responses synchronization was observed during behavioral synchronicity. Finally, also in the voice responses, in addition to the behavioral ones, the presence of inter-cerebral synchrony was observed (Kawasaki et al. 2013). Specifically, it was found that the individual's responses were more synchronized in the articular condition than the individual, with asynchronous response in temporal and lateral parietal regions, which are associated with the understanding of the intentions and actions of others and social cognition (Adolphs 1999). This evidence shows how the
behavior increases the interbrain synchronization of the individuals involved, bringing benefits in the field of higher, more efficient and faster team performance and suggesting the functional role of cerebral synchronization in a general increase in attention in social facilitation (Szymanski et al. 2017).

Hyperscanning Paradigm

Such evidence led over time to reconsider the experimental setting to better explore inter-personal dynamics in their emo-tional and cognitive components. In fact, to obtain a comprehensive model of the phenomena of interest, it is important to move from a single-person perspective aimed at investigating the subjective experience, towards more sophisticated designs meant to capture joint experiences.

Hyperscanning paradigms allow implementing ecological settings where participants can interact naturally and similarly to real-life situations, especially if conducted with portable, easy-to-use devices. At this regard, functional near-infrared spectroscopy (fNIRS) has been proficiently used to investigate complex psychosocial dynamics through hyperscanning paradigms (Balconi and Molteni 2016) proving to be a non-invasive, portable and user-friendly neuroscientific investigation tool which does not impose immobility and is rather robust to movement artifacts. Specifically, previous research with fNIRS-based hyperscanning paradigms has identified the prevalent role of the prefrontal cortex in emotional, behavioral and cognitive processes related to the performance of cooperative tasks (Balconi and Vanutelli 2016; Cui et al. 2012; Liu et al. 2012; Suzuki et al. 2011). Notwithstanding the prevailing role of the prefrontal cortex in emotional processing, as demonstrated by previous studies, other areas and brain structures are involved in emotional regulation, such as: the hippocampus, the insula (Phillips et al. 2003) and the cortex anterior cingulate (ACC), in particular the dorsal anterior cingulate ACC (dACC) and the subgenual anterior cingulate ACC (sgACC) (Beckmann et al. 2009). Furthermore, as demonstrated by Aalto et al. (2005), also the anterior temporal cortex and the activity of the frontal gyrus are involved in the processing of positive and negative emotions. In the present study we decided to investigate the DLPFC, with the use of fNIRS, as it is not a deep structure that results implicated in low-level emotional processes (Watanabe et al. 2015), emotional regulation, control of empathic sensations due to emotional activation and cognitive emotional events reappraisal (Balconi and Bortolotti 2012a, b).

However, despite the evidence showing the presence of a relationship between gift exchange, gratitude, and cooperation, no previous studies considered all these levels at a time. In detail, we thought that sharing a pleasant emotional experience, such as a gift exchange, could enhance the cognitive and emotional tuning of two individuals by increasing their level of cooperation. Thus, the aim of the present study was to measure inter-brain synchrony through a fNIRS-based hyperscanning paradigm during a cooperative game including a specific phase of gift exchange to measure if and how the behaviors and the two neural activities became coupled after the prosocial condition of gift exchange. At this regard, we expected that the activity of the donor and the receiver could be more synchronized after gift exchange. Secondly, the present study wanted to explore the specific significance of the two roles (the donor vs the receiver of a gift) before and after the gift exchange. We hypothesized that the two roles could be associated with different, specific cortical activation. In particular, as shown by some previous research (Balconi and Pagani 2014, 2015; Kalbe et al. 2010), for the donor, unlike the receiver, we expect to observe greater activation in the DMPC area, for synchronization of motor behavior, and in the DLPFC, which has been shown to be activated in the processes of shared attention of the others actions and intentions (Bilek et al. 2015; Saito 2010).

Thirdly, this study sought to observe the cortical localization related to empathic and cooperative brain areas and rewarding networks related to prosocial behavior. We believed that the frontal areas could be more involved in prosocial behaviors and social and interpersonal relationships. In particular, as shown by previous studies, the DLPFC has been implicated in the implementation of cooperative behaviors (Balconi and Pagani 2014, 2015) and in the management of social interactions (Kalbe et al. 2010; Petrican and Schimmack 2008) that are important for an efficient interpersonal exchange (Suzuki et al. 2011; Baker et al. 2016). Indeed, the affective, cognitive and behavioral components of social interactions during cooperative actions are supported by specific neural networks connecting limbic regions and prefrontal cortex (PFC). A key role in this sense is played by the dorsal (DLPFC) and ventral (VLPFC) portions of the lateral PFC that are mainly involved during cooperative behaviors (Balconi and Pagani 2014, 2015; Chiao et al. 2009) supporting adequate actions planning (Marsh et al. 2009). Fourthly, the dif-ference between material and experiential gifts was explored, supposing that the last one could produce a more significant impact on both receivers and donors due to the higher interpersonal value of the experiential condition. Finally, we expected that the effect of this condition could affect the behavioral performance of the dyad during a cooperative task with an increase of accuracy and a decrease of response time after gift exchange.

Methods

Participants

Sixteen dyads, composed of 32 female subjects in total, took part in the research. Recruited participants were university students (Mage = 22,59; SDage = 1,83, years). A history of psychiatric or neurological diseases and the presence of cognitive deficits were all reason for exclusion from recruitment. Each dyad was composed of same-sex individuals with a consolidated friendship. Specifically, one of the members of the dyad (the donor) was asked to hire his best friend (the receiver) to participate in the experiment. All the participants took part in the study after signing the informed consent. No payment was provided for the performance of the subjects, and they gave their consent to participate in the research. The research was conducted in compliance with the principles and guidelines of the Helsinki Declaration and was approved by the local ethics committee of the Department of Psychology of the Catholic University of Milan.

Procedure

The participants, coupled in sixteen dyads, were invited to carry out the experiment in a laboratory setting, carefully ar-ranged by an experimenter who provided the indications useful for the task development. Correctly, the participants were seated next to each other in a moderately dark room at a distance of 60 cm from a computer and separated by a black screen in a way to prevent visual contact. Thus, each subject could neither look at her partner nor talk to her. They were asked to participate in a joint social task which comprised a gift exchange during a general cooperative task. Specifically, one of the members of each dyad (the donor) was asked to exchange a gift with the partner (the receiver) at the beginning or half of the task. Therefore, to counterbalance the order effect, the delivery of the gift was randomized within the dyads: for half of the sixteen pairs (8 dyads) it occurred before the beginning of the first block, while for the other half (8 couples) at the end of the first block. Half of the donors (8 dyads) was asked to choose a material gift (objects or accessories) to give to their partner; while the other half was asked to exchange an experiential gift consisting in experiences to share, for example tickets for visiting a museum or a concert.

The cooperative task, instead, consisted of a selective attention game modified from a previous one-person computerized task (Balconi and Pagani 2015). The two members of the dyad had to memorize a target, and to identify it among other different subsequent stimuli by pressing two left/right buttons. The target was a figure that could be a circle or a triangle, colored blue or green. Importantly, however, subjects were not required to perform at their best, but to synchronize their behavioral responses in terms of both speed and accuracy. After every three stimuli (one trial) subjects received a positive feedback about their degree of cooperation, visible through two arrows pointing upwards.

Each stimulus appeared on the screen for 500 msec with an inter-stimulation interval (ISI) of 300 msec. Then, a fixation cross appeared on the screen for 5000 msec followed by other 5000 msec blank appeared on the screen to allow the hemodynamic signal to go back to baseline level. The task consisted of two different blocks, each composed by 25 trials and 25 feedbacks.

At the end of the experiment, a questionnaire was given to the participants to investigate the perception of their partner and the game pair during the first and second blocks tasks, before and after the gift exchange. Specifically, subjects answers to the following open questions: What was the perception of your workmate in the first phase of the game? What was the perception of your workmate in the second phase of the game? What was the perception of relevance of gift for you?^, What was the perception of your cooperation during the game?^. Then, participants' answers have been codified by three expert judges along a Likert scale (from 1 to 4). Partecipants revealed high level of gift relevance, cooperation increasing during the task.

fNIRS Recording and Signal Processing

fNIRS measurements were recorded through a NIRScout System (NIRx Medical Technologies, LLC, Los Angeles, California) using an 8-channel array of optodes (4 emitters and 4 detectors) placed on the frontal and prefrontal areas of each subjects using a fNIRS cap according to the international 10/5 system. Specifically, the emitters were placed on FC3-FC4 and F1-F2, while the detectors were positioned at the following positions (FC1-FC2 and F3-F4) (Fig. 1). A distance of 30 mm for contiguous optodes and a near-infrared light at two wavelengths (760 and 850 nm) were used for the recording. The following channels have been acquired: Ch1 (FC3-F3) and Ch3 (FC4-F4) correspond to the left and right (respectively) DLPFC (Brodmann Area 9). Ch2 (FC3-FC1) and Ch4 (FC4-FC2) correspond to left and right (respectively) Dorsal Pre-motor Cortex (DPMC, Brodmann Area 6). Ch5 (F1-F3) and Ch 7 (F2-F4) corresponding to the left and right (respectively) Frontal Eye Fields (FEF, Brodmann Area 8). Ch6 (F1-FC1) and Ch8 (F2-FC2) correspond to the left and right (respectively) Superior Frontal Gyrus (SFG, Brodmann Area 6) (Koessler et al. 2009).

The recording of changes in the concentration of oxygenated (O2Hb) and deoxygenated (HHb) hemoglobin occurred continuously from the acquisition of a baseline lasting 120 s. The signals obtained from the 8 NIRS channels were acquired with a sampling rate of 6.25 Hz and analyzed and processed with nirsLAB software (v2014.05, NIRx Medical Technologies LLC, 15Cherry Lane, Glen Head, NY, USA) based on their wavelength and position, which led to values for changes in the concentration of oxy and deoxygenated hemoglobin for each channel. The raw O2Hb and HHb data for each channel were digitally band-passed filtered at 0.01– 0.3 Hz.

Data Analysis

Three sets of analyses were performed with respect to behavioral (Accuracy, ACC; Reaction Times, RTs) and neurophys-iological (fNIRS: O2Hb measures) dependent measures.

Behavioral Data By using E-prime Software, ACC and RTs were obtained for each subject during the first (pre) and the second (post) part of the task. Before pre-gift training condition, after the 120-s baseline record, subjects were given a familiarization task. ACC was calculated as the percentage of correct responses on the total responses, while reaction times were computed starting from stimulus presentation. Then, two mixed-model ANOVAs were applied to ACC and RTs with Condition as repeated factor (Cond: baseline, pre-vs. post-gift exchange), and Role (Role: donor vs. receiver) and gift type (Gift: material vs. experiential) as between fac-tors. For all the ANOVA tests, the degrees of freedom were corrected using Greenhouse–Geisser epsilon when appropriate. Post hoc comparisons (contrast analyses) were applied to the data. A Bonferroni test was applied for multiple comparisons. In addition, the normality of the data distribution was preliminary tested (kurtosis and asymmetry tests). The normality assumption of the distribution was supported by these preliminary tests.

Single-Brain Analyses For single-brain analyses, the mean concentration of O2Hb and HHb for each channel was calculated by averaging data across the two blocks, each lasting five minutes. According to the mean concentrations in the time series, the effect size in every block was calculated for each channel and subject as the difference of the means of the block (m2) and the baseline (m1) divided by the standard deviation (sd) of the baseline: d = (m2-m1)/sd (Cohen's d value). The procedure was applied to both O2Hb and HHb variations. Although fNIRS raw data were originally relative values and could not be directly compared across subjects or channels, these normalized indices can now be averaged regardless of the unit since the effect size is not affected by differential pathlength factor (DPF) (Matsuda and Hiraki 2006; Schroeter et al. 2003; Shimada and Hiraki 2006). Then, 4 different regions of interest (ROIs) were calculated by averaging left/right homologous channels: the values obtained from Ch1 and Ch3 were averaged as representative of the activity of the DLPFC area, the values obtained from Ch2 and Ch4 were averaged as representative of the activity of DPMC area, the values obtained from Ch5 and Ch7 were averaged as representative of the activity of FEF and the values obtained from Ch6 and Ch8 were averaged as representative of the activity of SFG area. Subsequently, one mixed-model ANOVA was ap-plied to such indices with Condition (Cond, baseline, pre-, post-gift exchange) and ROI (DLPFC, DPMC, FEF, SFG) as repeated factors, and Role (2) and Gift type as between factors.

Inter-Brain Connectivity Analyses Starting from the raw data-base showing O2Hb and HHb concentration datapoint-per-datapoint, a third step was performed to calculate inter-subjects correlational indices finalized to compute the synchronization between the homologous brain areas (couple of channels) of each dyad of subjects. Such indices (Pearson coefficients, r values) were successively entered as dependent variables into mixed-model ANOVA tests, for O2Hb and HHb, with Cond and ROI as repeated independent factors, and Role and Gift as between factors.

Results

Behavioral Data

For ACC measurement, ANOVA revealed a significant effect for Cond (F[1,28] = 11.63; $p < 0.001$; η2 = 0.34), with a better performance (higher percentages) after (post M = 0.77; SD = 0.03) than before (baseline M = 0.61; SD = 0.04; pre- M =
0.62; SD = 0.07) gift exchange. Concerning RTs, ANOVA showed a significant effect for Cond (F[1,28] = 17.69, $p < 0.0001$, η2 = 0.39), with faster RTs after (post M = 239; SD = 8.23) than before (baseline M = 263; SD = 7.29; pre-M = 273; SD = 10.11) gift exchange (Fig. 2a, b).

Single-Brain Analyses

The statistical analyses were applied to d indices for O2Hb and HHb-concentrations. The analysis on HHb did not reveal significant effects, and for this reason we reported only results for O2Hb-values. As shown by ANOVA applied to O2Hb data, Role effect was significant (F[1,28] = 9.34, $p < 0.01$, η2 = 0.33), with a general increased brain activity for donor than receiver, and ROI (F[3,28] = 8.89, $p < 0.01$, η2 = 0.31), with increased DLPFC and DPMC than other areas (all comparison $p \leq .001$). In addition Cond * ROI * Role * Gift inter-action effect was significant (F[3,72] = 7.09, $p < 0.05$, η2 = 0.28). Specifically, as revealed by post-hoc comparisons, there was an increase of activation in DLPFC area mainly for donor after experiential gift exchange in post- condition more than baseline and pre- condition (respectively F[1,28] = 8.90, $p < 0.01$, η2 = 0.30; F[1,28] = 8.16, $p < 0.01$, η2 =

0.30). Similarly, for receiver an increase of activation was observed in DLPFC and DPMC after experiential gift exchange in post condition more than baseline and pre- condition (respectively $F[1,28] = 6.77$, $p < 0.05$, $\eta 2 = 0.27$; $F[1,28] = 8.05$, $p < 0.01$, $\eta 2 = 0.30$) (Fig. 3a).

Inter-Brain Connectivity Analyses

The analysis on HHb values did not reveal significant effects, and for this reason we report only results for O2Hb-values. For what concerns O2Hb, as shown by the ANOVA, the ROI Gift effect was significant ($F[1,72] = 6.78$, $p < 0.05$, $\eta 2 =$

0.27). Pairwise post-hoc comparisons revealed significant higher values of O2Hb in the DPMC for material gift ($F[1,28] = 7.90$, $p < 0.01$, $\eta 2 = 0.29$) compared to experiential one (Fig. 3b). In contrast experiential gift showed a higher response in FEF than material one ($F[1,28] = 9.04$, $p < 0.01$, $\eta 2 = 0.33$) (Fig. 4a, b).

Discussion

The present research study analyzed behavioral performances and brain activity (intra- and inter-brain analyses) during a joint action consisting in carrying out a cooperation task developed before or after the exchange of two different types of gifts: experiential and material. The modulation of several variables before (pre) and after (post) donations, such as accuracy, RTs, intra-brain activity and inter-brain functional connectivity was considered.

Firstly, as expected, improved behavioral performance emerged after gift exchange. Specifically, after the exchange, higher accuracy rates and a decrease in response times were found. We hypothesized that such effect could be due to an increase in prosocial behavior and a broader social/affective bond among the members of the dyad. This result, as reported by previous studies (Balconi and Vanutelli 2017; Balconi et al. 2017a, b, c), shows that a greater interpersonal engagement between two individuals can lead to a significant gain for the coordination of behavioral activities. Significantly, the in-crease of behavioral performance emerged only after gift ex-change compared to the pre-gift and baseline condition, in which subjects carried out a familiarization test. For this rea-son, we could limit a mere learning effect due to the sequence of experimental tasks. In contrast the gift effect could have improved the cooperative significance of the task, with direct effect on the behavioral performance, as demonstrated by an increase in cognitive skills in terms of attention, memorization and speed response during the course of the task.

Considering the neurophysiological level, instead, the pos-sible differences in the cortical activity of donor and receiver were explored following the gift exchange. Specifically, firstly we found greater cortical activation for the donor than the receiver, especially in the DLPFC and DPMC area. Such a result highlights the presence of a double process from the participants implying a visuomotor (DPMC) and a more social (DLPFC) strategy. The first can be referred to the involvement of a visuomotor network to synchronize the motor response and the behavior which is, nonetheless, informed by social cues (from the feedbacks) and involves a higher-order net-work implied in social cognition (Balconi and Pagani 2014, 2015; Kalbe et al. 2010). In other words, we suppose that the gift exchange might facilitate the visuomotor performance mainly in donor, since this actor could benefit from the more active role during the prosocial behavior. Specifically, the activation of the DLPFC in the donor and the receiver could be due to the implementation of empathic mechanisms and emotional engagement due to the cooperative behavior with one's partner (Balconi and Pagani 2014, 2015; Kalbe et al. 2010). Instead, the activation of DPMC only in the donor may be due to the fact that social cognition is a process that takes place between two or more individuals and requires coordination of the actions of the agents involved in space and time in order to cause modifications in the environment (Sebanz et al. 2006).

With regard to the last brain area, the prevalent involvement of the DLPFC area in social and prosocial processes of exchange and interaction has been demonstrated by some re-searches (Balconi et al. 2018, 2017a, b, c), which have highlighted its implication in perspective and theory of mind (Kalbe et al. 2010) in the suppression of selfish behavior (Baeken et al. 2011) and in the commitment to meaningful relationships and social reinforcement (Petrican and Schimmack 2008). Moreover, this result confirms our hypothesis concerning the role of frontal areas in social processes and interpersonal relationships, highlighting the involvement of the prefrontal cortex in prosocial behaviors and in helping decisions (Balconi and Canavesio 2013) through the adoption of joint strategies and the joint neural network general recruit-ment (Balconi et al. 2017a, b, c).

Also, the result is confirmed by previous evidence showing the involvement of the DLPFC in prosocial exchange (Balconi and Canavesio 2013). In fact, previous research (Balconi and Canavesio 2013, 2014) has shown the implication of DLPFC in the prosocial domain, especially in highly empathic contexts (Adolphs 1999; Greene and Haidt 2002), in decision making implying help and support towards other individuals and in emotional attuning. We believe that its re-cruitment after an interpersonal moment of gift exchange could be significant for a greater emotional and empathic tuning, for the strengthening of the interpersonal bond and social sharing.

Furthermore, another objective of our study was to investigate the effects of the type of gift on both the components of couples (donor and receiver). In particular, as expected, fol-lowing the exchange of an experiential gift, a significant in-crease emerged in the DLPFC and DPMC areas activity for both the donor and the receiver. Considering the involvement of the DLPFC in the social and interpersonal relationship processes, the increase of cortical activity in this area, after receiving an experiential gift, demonstrates how this type of gift is connected to the representation of the possibility to share an experience with another individual, activating the areas involved in social and sharing processes. As for the material gift, however, a greater cortical activation has emerged in the DPMC area which, as shown by previous studies (Schubotz and Von Cramon 2001), can be activated by the visual dimension of the familiar objects. Previous studies have shown the involvement of this area in sensorial processes related above all to the objects spatial information and the expectations of the latter (Shulman et al. 2010). This result demonstrates that the material gift activates motor networks linked to the act of giving or a metaphoric version of this act of giving; while, the experiential gift activates highest level networks linked to social sharing, empathic and emotional attunement. At this regard the DLPFC activation will be a direct response to the prosocial value of an experiential and shared gift.

Finally, considering inter-brain connectivity within the dyads, the results showed higher coherence after gift ex-change. Indeed, there has been a greater cerebral synchronization between donor and receiver in the DPMC after the exchange of a material gift and in the FEF after the exchange of an experiential gift. This result showed that after gift ex-change there is a greater cerebral synchronization between the components of the single dyads, increasing their ability to bind with other individuals. Recent research (Vanutelli et al. 2017) has shown that strengthening interpersonal bonding im-proves attentive and behavioral synchronization between two or more individuals (Butler and Randall 2013; Feldman 2012; Vanutelli et al. 2017), providing a somatosensory structure that facilitates the understanding of their intentions and actions (Balconi and Canavesio 2014, 2016; Keysers et al. 2010).

On the other hand, as regards the greater synchronization in the FEF following the exchange of an experiential gift, recent research has shown that this area is activated when individuals experience greater excitement towards social interaction. Previous research (Centelles et al. 2011) has shown that when the characteristics of social interaction are perceived as more exciting, entertaining and salient, the regions involved in sustained attention are activated (Szymański et al. 2017; Walker et al. 2009). Specifically, the eye movements reflected by the activity of the FEF are made to direct our attention in order to provide salient points to our ongoing behavior (Walker et al. 2009).

However, some limitations should be reported for the present study. First, future research could include a higher number of dyads to improve the comparisons between all the variables of interest. Secondly, in future studies, one could propose the experiment in pairs formed by unknown individuals to see if sharing a pleasant experience increases prosocial behavior and the synchrony between two individuals without a consolidated bond. Thirdly, pairs of male gender individuals could be included in the sample to see if gender-related effects occur. Fourth, other neurophysiological measures could be recorded, such as electrophysiological and autonomic activity, foreseeing the use of a multimethodological approach. Fifth, although when dealing with hemodynamic time-domain data correlational analyses are often chosen (Balconi et al. 2017b; Crivelli and Balconi 2017), more complex analyses related to coherence could also be performed, al already proposed in previous work (Cui et al. 2012). Finally, future studies should consider entering a non-gift condition in order to control the learning of the dyad synchronization strategy for the whole task. Furthermore, future studies could investigate, in addition to the prefrontal cortex, the role of other brain areas that are involved in emotional processing (Beckmann et al. 2009; Phillips et al. 2003).

References

Aalto, S., Brück, A., Laine, M., Någren, K., & Rinne, J. O. (2005). Frontal and temporal dopamine release during working memory and attention tasks in healthy humans: A positron emission tomog-raphy study using the high-affinity dopamine D2 receptor ligand [11C] FLB 457. Journal of Neuroscience, 25(10), 2471–2477. https://doi.org/10.1523/JNEUROSCI.2097-04.2005.

Adolphs, R. (1999). Social cognition and human brain. Trends in Cognitive Sciences, 3(12), 469–479. https://doi.org/10.1016/ S1364-6613(99)01399-6.

Algoe, S. B., Haidt, J., & Gable, S. L. (2008). Beyond reciprocity: Gratitude and relationships in everyday life. Emotion, 8(3), 425–429. https://doi.org/10.1037/1528-3542.8.3.425.

Baeken, C., Van Schuerbeek, P., De Raedt, R., De Mey, J., Vanderhasselt, M. A., Bossuyt, A., & Luypaert, R. (2011). The effect of one left-sided dorsolateral prefrontal sham-controlled HF-rTMS session on approach and withdrawal related emotional neuronal processes. Clinical Neurophysiology, 122(11), 2217–2226. https://doi.org/10. 1016/j.clinph.2011.04.009.

Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. Quarterly Journal of Economics, 131(4), 1593– 1636. https://doi.org/10.1093/qje/qjw024.

Balconi, M., & Bortolotti, A. (2012a). Detection of the facial expression of emotion and self-report measures in empathic situations are in-fluenced by sensorimotor circuit inhibition by low-frequency rTMS. Brain Stimulation, 5(3), 330–336. https://doi.org/10.1016/j.brs. 2011.05.004.

Balconi, M., & Bortolotti, A. (2012b). Resonance mechanism in empath-ic behavior: BEES, BIS/BAS and psychophysiological contribution. Physiology & Behavior, 105(2), 298–304. https://doi.org/10.1016/j.physbeh.2011.08.002.

Balconi, M., & Canavesio, Y. (2013). Emotional contagion and trait em-pathy in prosocial behavior in young people: The contribution of autonomic (facial feedback) and Balanced Emotional Empathy Scale (BEES) measures. Journal of Clinical and Experimental Neuropsychology, 35(1), 41–48. https://doi.org/10.1080/13803395. 2012.742492.

Balconi, M., & Canavesio, Y. (2014). High-frequency rTMS on DLPFC increases prosocial attitude in case of decision to support people. Social Neuroscience, 9(1), 82–93. https://doi.org/10.1080/17470919.2013.861361.

Balconi, M., & Canavesio, Y. (2016). Is empathy necessary to compre-hend the emotional faces? The empathic effect on attentional mech-anisms (eye movements), cortical correlates (N200 event-related potentials) and facial behaviour (electromyography) in face process-ing. Cognition and Emotion, 30(2), 210–224. https://doi.org/10. 1080/02699931.2014.993306.

Balconi, M., & Molteni, E. (2016). Past and future of near-infrared spec-troscopy in studies of emotion and social neuroscience. Journal of Cognitive Psychology, 28(2), 129–146. https://doi.org/10.1080/20445911.2015.1102919.

Balconi, M., & Pagani, S. (2014). Personality correlates (BAS-BIS), self-perception of social ranking, and cortical (alpha frequency band) modulation in peer-group comparison. Physiology and Behavior, 133, 207–215. https://doi.org/10.1016/j.physbeh.2014.05.043.

Balconi, M., & Pagani, S. (2015). Social hierarchies and emotions: Cortical prefrontal activity, facial feedback (EMG), and cogni-tive performance in a dynamic interaction. Social Neuroscience, 10(2), 166–178. https://doi.org/10.1080/17470919.2014. 977403.

Balconi, M., & Vanutelli, M. E. (2016). Competition in the brain. The contribution of EEG and fNIRS modulation and personality effects in social ranking. Frontiers in Psychology, 7, 1587. https://doi.org/10.3389/fpsyg.2016.01587.

Balconi, M., & Vanutelli, E. (2017). Empathy in negative and positive interpersonal interactions. What is the relationship between central (EEG, fNIRS) and peripheral (autonomic) neurophysiological re-sponses? Advances in Cognitive Psychology, 13(1), 105–120. https://doi.org/10.5709/acp-0211-0.

Balconi, M., Crivelli, D., & Vanutelli, M. E. (2017a). Why to cooperate is better than to compete: Brain and personality components. BMC Neuroscience, 18(1), 1–15. https://doi.org/10.1186/s12868-017-0386-8.

Balconi, M., Pezard, L., Nandrino, J. L., & Vanutelli, M. E. (2017b). Two is better than one: The effects of strategic cooperation on intra- and inter-brain connectivity by fNIRS. PLoS One, 12(11), 1–17. https://doi.org/10.1371/journal.pone.0187652.

Balconi, M., Vanutelli, M. E., & Grippa, E. (2017c). Resting state and personality component (BIS/BAS) predict the brain activity (EEG and fNIRS measure) in response to emotional cues. Brain and Behavior, 7(5), e00686. https://doi.org/10.1002/brb3.686.

Balconi, M., Gatti, L., & Vanutelli, M. E. (2018). Cooperate or not coop-erate EEG , autonomic , and behavioral correlates of ineffective joint strategies. Brain and Behavior, 8(2), e00902. https://doi.org/10. 1002/brb3.902.

Bazzini, D. G., Stack, E. R., Martincin, P. D., & Davis, C. P. (2007). The effect of reminiscing about laughter on relationship satisfaction. Motivation and Emotion, 31(1), 25–34. https://doi.org/10.1007/ s11031-006-9045-6.

Bechara, A., Tranel, D., & Damasio, H. (2000). Characterization of the decision-making deficit of patients with ventromedial prefrontal cor-tex lesions. Brain, 123(11), 2189–2202. https://doi.org/10.1093/brain/123.11.2189.

Beckmann, M., Johansen-Berg, H., & Rushworth, M. F. (2009). Connectivity-based parcellation of human cingulate cortex and its relation to functional specialization. Journal of Neuroscience, 29(4), 1175–1190. https://doi.org/10.1523/JNEUROSCI.3328-08.2009.

Belk, R. W., & Coon, G. S. (1991). Can't buy me love: Dating, money, and gifts. Advances in Consumer Research. https://doi.org/10.1109/ ICACT.2016.7423268.

Belk, R. W., & Coon, G. S. (1993). Gift giving as Agapic love - an alternative to the exchange paradigm based on dating experiences. Journal of Consumer Research, 20(3), 393–417. https://doi.org/10. 1086/209357.

Bem, D. J. (1972). Self-perception theory. Advances in Experimental Social Psychology, 6, 1–62. https://doi.org/10.1016/S0065-2601(08)60024-6.

Bilek, E., Ruf, M., Schäfer, A., Akdeniz, C., Calhoun, V. D., Schmahl, C., Demanuele, C., Tost, H., Kirsch, P., & Meyer-Lindenberg, A.

(2015). Information flow between interacting human brains: Identification, validation, and relationship to social expertise. Proceedings of the National Academy of Sciences, 112(16), 5207– 5212. https://doi.org/10.1073/pnas.1421831112.

Butler, E. A., & Randall, A. (2013). Emotional coregulation in close relationships. Emotion Review, 5(2), 202–210. https://doi.org/10. 1177/1754073912451630.

Caplow, T. (1982). Christmas gifts and kin networks. The Sociological Review, 47, 383–392. https://doi.org/10.2307/2094994.

Caplow, T. (1984). Rule enforcement without visible means: Christmas gift giving in Middletown. American Journal of Sociology, 89(6), 1306–1323. https://doi.org/10.1086/228017.

Caprariello, P. A., & Reis, H. T. (2013). To do, to have, or to share? Valuing experiences over material possessions depends on the in-volvement of others. Journal of Personality and Social Psychology, 104(2), 199–215. https://doi.org/10.1037/a0030953.

Carey, J. R., Clicque, S. H., Leighton, B. A., & Milton, F. (1976). A test of positive reinforcement of customers. Journal of Marketing, 40(4), 98–100. https://doi.org/10.2307/1251075.

Carter, T. J., & Gilovich, T. (2010). The relative relativity of material and experiential purchases. Journal of Personality and Social Psychology, 98(1), 146–159. https://doi.org/10.1037/a0017145.

Centelles, L., Assaiante, C., Nazarian, B., Anton, J. L., & Schmitz, C. (2011). Recruitment of both the mirror and the mentalizing networks when observing social interactions depicted by point-lights: A neu-roimaging study. PLoS One, 6(1), e15749. https://doi.org/10.1371/ journal.pone.0015749.

Chan, C., & Mogilner, C. (2016). Experiential gifts foster stronger social relationships than material gifts. Journal of Consumer Research, 43(6), 913–931. https://doi.org/10.1093/jcr/ucw067.

Chiao, J. Y., Harada, T., Komeda, H., Li, Z., Mano, Y., Saito, D., Parrish, T. B., Sadato, N., & Iidaka, T. (2009). Neural basis of individualistic and collectivistic views of self. Human Brain Mapping, 30(9), 2813–2820. https://doi.org/10.1002/hbm.20707.

Chung, D., Yun, K., & Jeong, J. (2015). Decoding covert motivations of free riding and cooperation from multi-feature pattern analysis of EEG signals. Social Cognitive and Affective Neuroscience, 10(9), 1210–1218. https://doi.org/10.1093/scan/nsv006.

Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: Compliance and conformity. Annual Review of Psychology, 55, 591–621. https:// doi.org/10.1146/annurev.psych.55.090902.142015.

Clark, M. S., & Finkel, E. J. (2017). Does expressing emotion promote well-being? It depends on relationship context. The Social Life of Emotions, 105–126. https://doi.org/10.1017/CBO9780511819568. 007.

Clark, H. B., Northrop, J. T., & Barkshire, C. T. (1988). The effects of contingent thank-you notes on case managers' visiting residential clients. Education and Treatment of Children, 11, 45–51.

Crivelli, D., & Balconi, M. (2017). The agent brain: A review of non-invasive brain stimulation studies on sensing agency. Frontiers in Behavioral Neuroscience, 11, 229. https://doi.org/10.3389/fnbeh. 2017.00229.

Cui, X., Bryant, D. M., & Reiss, A. L. (2012). NIRS-based hyperscanning reveals increased interpersonal coherence in superior frontal cortex during cooperation. NeuroImage, 59(3), 2430–2437. https://doi.org/10.1016/j.neuroimage.2011.09.003.

Dumas, G., Nadel, J., Soussignan, R., Martinerie, J., & Garnero, L. (2010). Inter-brain synchronization during social interaction. PLoS One, 5(8), e12166. https://doi.org/10.1371/journal.pone.0012166.

Emmons, R. A., & McCullough, M. E. (2003). Counting blessings versus burdens: An experimental investigation of gratitude and subjective well-being in daily life. Journal of Personality and Social Psychology, 84(2), 377–389. https://doi.org/10.1037/0022-3514. 84.2.377.

Feldman, R. (2012). Parent-infant synchrony: A biobehavioral model of mutual influences in the formation of affiliative bonds. Monographs of the Society for Research in Child Development Series, 77(2), 42–51.

Froh, J. J., Sefick, W. J., & Emmons, R. A. (2008). Counting blessings in early adolescents: An experimental study of gratitude and subjective well-being. Journal of School Psychology, 46(2), 213–233. https://doi.org/10.1016/j.jsp.2007.03.005.

Funane, T., Kiguchi, M., Atsumori, H., Sato, H., Kubota, K., & Koizumi, H. (2011). Synchronous activity of two people's prefrontal cortices during a cooperative task measured by simultaneous near-infrared spectroscopy. Journal of Biomedical Optics, 16(7), 077011. https:// doi.org/10.1117/1.3602853.

Gouldner, A. W. (1960). The norm of reciprocity: A preliminary state-ment. American Sociological Review, 25, 161–178. https://doi.org/ 10.2307/2092623.

Greene, J., & Haidt, J. (2002). How and where does moral judgment work? Trends in Cognitive Sciences, 6(12), 517–523.

Harbaugh, W. T., Mayr, U., & Burghart, D. R. (2007). Neural responses to taxation and voluntary giving reveal motives for charitable dona-tions. Science, 316(5831), 1622–1625. https://doi.org/10.1126/science.1140738.

Immordino-Yang, M. H., McColl, A., Damasio, H., & Damasio, A. (2009). Neural correlates of admiration and compassion. Proceedings of the National Academy of Sciences, 0810363106, 8021–8026. https://doi.org/10.1073/pnas.0810363106.

Kalbe, E., Schlegel, M., Sack, A. T., Nowak, D. A., Dafotakis, M., Bangard, C., Brand, M., Shamay-Tsoory, S., Onur, O. A., & Kessler, J. (2010). Dissociating cognitive from affective theory of mind: A TMS study. Cortex, 46(6), 769–780. https://doi.org/10. 1016/j.cortex.2009.07.010.

Kawasaki, M., Yamada, Y., Ushiku, Y., Miyauchi, E., & Yamaguchi, Y. (2013). Inter-brain synchronization during coordination of speech rhythm in human- to-human social interaction. Scientific Reports, 3, 1–8. https://doi.org/10.1038/srep01692.

Keysers, C., Kaas, J. H., & Gazzola, V. (2010). Somatosensation in social perception. Nature Reviews Neuroscience, 11(6), 417–428. https:// doi.org/10.1038/nrn2833.

Knutson, B., & Cooper, J. C. (2005). Functional magnetic resonance imaging of reward prediction. Current Opinion in Neurology, 18(4), 411–417. https://doi.org/10.1097/01.wco.0000173463. 24758.f6.

Koessler, L., Maillard, L., Benhadid, A., Vignal, J. P., Felblinger, J., Vespignani, H., & Braun, M. (2009). Automated cortical projection of EEG sensors: Anatomical correlation via the international 10-10 system. NeuroImage, 46(1), 64–72. https://doi.org/10.1016/j. neuroimage.2009.02.006.

Konvalinka, I., Bauer, M., Stahlhut, C., Hansen, L. K., Roepstorff, A., & Frith, C. D. (2014). Frontal alpha oscillations distinguish leaders from followers: Multivariate decoding of mutually interacting brains. Neuroimage, 94, 79–88. https://doi.org/10.1016/j. neuroimage.2014.03.003.

Lambert, N. M., Clark, M. S., Durtschi, J., Fincham, F. D., & Graham, S. M. (2010). Benefits of expressing gratitude: Expressing gratitude to a partner changes one’s view of the relationship. Psychological Science, 21(4), 574–580. https://doi.org/10.1177/0956797610364003.

Lindenberger, U., Li, S. C., Gruber, W., & Müller, V. (2009). Brains swinging in concert: Cortical phase synchronization while playing guitar. BMC Neuroscience, 10(1), 22. https://doi.org/10.1186/1471-2202-10-22.

Liu, T., Saito, H., & Oi, M. (2012). Distinctive activation patterns under intrinsically versus extrinsically driven cognitive loads in prefrontal cortex: A near-infrared spectroscopy study using a driving video game. Neuroscience Letters, 506(2), 220–224. https://doi.org/10. 1016/j.neulet.2011.11.009.

Marsh, A. A., Blair, K. S., Jones, M. M., Soliman, N., & Blair, R. J. R. (2009). Dominance and submission: The ventrolateral prefrontal cortex and responses to status cues. Journal of Cognitive Neuroscience, 21(4), 713–724. https://doi.org/10.1162/jocn_a_ 00553.

Matsuda, G., & Hiraki, K. (2006). Sustained decrease in oxygenated hemoglobin during video games in the dorsal prefrontal cortex: A NIRS study of children. NeuroImage, 29(3), 706–711. https://doi.org/10.1016/j.neuroimage.2005.08.019.

McCullough, M. E., & Tsang, J. A. (2012). Parent of the virtues?: The prosocial contours of gratitude. In The psychology of gratitude (pp. 123–141). https://doi.org/10.1093/acprof:oso/9780195150100.003. 0007.

McCullough, M. E., Emmons, R. A., Kilpatrick, S. D., & Larson, D. B. (2001). Is gratitude a moral affect? Psychological Bulletin, 127(2), 249–266. https://doi.org/10.1037/0033-2909.127.2.249.

McGovern, L. P., Ditzian, J. L., & Taylor, S. P. (1975). The effect of one positive reinforcement on helping with cost. Bulletin of the

Psychonomic Society, 5(5), 421–423. https://doi.org/10.3758/ BF03333287.

Nummenmaa, L., Glerean, E., Viinikainen, M., Jaaskelainen, I. P., Hari, R., & Sams, M. (2012). Emotions promote social interaction by synchronizing brain activity across individuals. Proceedings of the National Academy of Sciences, 109(24), 9599–9604. https://doi.org/ 10.1073/pnas.1206095109.

Penner, L. A., Dovidio, J. F., Piliavin, J. A., & Schroeder, D. A. (2005). Prosocial behavior: Multilevel perspectives. Annual Review of Psychology, 56(1), 365–392. https://doi.org/10.1146/annurev. psych.56.091103.070141.

Peters, K., & Kashima, Y. (2007). From social talk to social action: Shaping the social triad with emotion sharing. Journal of Personality and Social Psychology, 93(5), 780–797. https://doi. org/10.1037/0022-3514.93.5.780.

Peterson, B. E., & Stewart, A. J. (1996). Antecedents and contexts of generativity motivation at midlife. Psychology and Aging, 11(1), 21–33. https://doi.org/10.1037/0882-7974.11.1.21.

Petrican, R., & Schimmack, U. (2008). The role of dorsolateral prefrontal function in relationship commitment. Journal of Research in Personality, 42(4), 1130–1135. https://doi.org/10.1016/j.jrp.2008. 03.001.

Phillips, M. L., Drevets, W. C., Rauch, S. L., & Lane, R. (2003). Neurobiology of emotion perception II: Implications for major psy-chiatric disorders. Biological Psychiatry, 54(5), 515–528. https:// doi.org/10.1016/S0006-3223(03)00171-9.

Raghunathan, R., & Corfman, K. (2006). Is happiness shared doubled and sadness shared halved? Social influence on enjoyment of he-donic experiences. Journal of Marketing Research, 43(3), 386–394. https://doi.org/10.1509/jmkr.43.3.386.

Ramanathan, S., & McGill, A. L. (2006). Consuming with others: Social influences on moment-to-moment and retrospective evaluations of experiences. Journal of Consumer Research, 34(4), 506–524.

Rind, B., & Bordia, P. (1995). Effect of Server's Bthank you^ and per-sonalization on restaurant tipping. Journal of Applied Social Psychology, 25(9), 745–751. https://doi.org/10.1111/j.1559-1816. 1995.tb01772.x.

Rosenzweig, E., & Gilovich, T. (2012). Buyer's remorse or missed op-portunity? Differential regrets for material and experiential pur-chases. Journal of Personality and Social Psychology, 102(2), 215–223. https://doi.org/10.1037/a0024999.

Saito, J. (2010). Subordinates' use of Japanese plain forms: An examina-tion of superior–subordinate interactions in the workplace. Journal of Pragmatics, 42(12), 3271–3282. https://doi.org/10.1016/j. pragma.2010.06.014.

Sänger, J., Müller, V., & Lindenberger, U. (2012). Intra-and interbrain synchronization and network properties when playing guitar in duets. Frontiers in Human Neuroscience, 6, 312. https://doi.org/ 10.3389/fnhum.2012.00312.

Schroeter, M. L., Zysset, S., Kruggel, F., & Von Cramon, D. Y. (2003). Age dependency of the hemodynamic response as measured by functional near-infrared spectroscopy. NeuroImage, 19(3), 555–564. https://doi.org/10.1016/S1053-8119(03)00155-1.

Schubotz, R. I., & Von Cramon, D. Y. (2001). Functional organization of the lateral premotor cortex: fMRI reveals different regions activated by anticipation of object properties, location and speed. Cognitive Brain Research, 11(1), 97–112. https://doi.org/10.1016/S0926-6410(00)00069-0.

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: Bodies and minds moving together. Trends in Cognitive Sciences, 10(2), 70–76. https://doi.org/10.1016/j.tics.2005.12.009.

Shimada, S., & Hiraki, K. (2006). Infant's brain responses to live and televised action. NeuroImage, 32(2), 930–939. https://doi.org/10. 1016/j.neuroimage.2006.03.044.

Shulman, G. L., Pope, D. L. W., Astafiev, S. V., McAvoy, M. P., Snyder, A. Z., & Corbetta, M. (2010). Right hemisphere dominance during

spatial selective attention and target detection occurs outside the dorsal Frontoparietal network. Journal of Neuroscience, 30(10), 3640–3651. https://doi.org/10.1523/JNEUROSCI.4085-09.2010.

Suzuki, S., Niki, K., Fujisaki, S., & Akiyama, E. (2011). Neural basis of conditional cooperation. Social Cognitive and Affective Neuroscience, 6(3), 338–347. https://doi.org/10.1093/scan/nsq042.

Szymanski, C., Pesquita, A., Brennan, A. A., Perdikis, D., Enns, J. T., Brick, T. R., Müller, V., & Lindenberger, U. (2017). Teams on the same wavelength perform better: Inter-brain phase synchronization constitutes a neural substrate for social facilitation. Neuroimage, 152, 425–436. https://doi.org/10.1016/j.neuroimage.2017.03.013.

Szymański, J., Janikiewicz, J., Michalska, B., Patalas-Krawczyk, P., Perrone, M., Ziółkowski, W., Duszyński, J., Pinton, P., Dobrzyń, A., & Więckowski, M. R. (2017). Interaction of mitochondria with the endoplasmic reticulum and plasma membrane in calcium ho-meostasis, lipid trafficking and mitochondrial structure. International Journal of Molecular Sciences, 18(7), 1–24. https:// doi.org/10.3390/ijms18071576.

Van Boven, L., & Gilovich, T. (2003). To do or to have? That is the question. Journal of Personality and Social Psychology, 85(6), 1193–1202. https://doi.org/10.1037/0022-3514.85.6.1193.

Van Overwalle, F. (2011). A dissociation between social mentalizing and general reasoning. NeuroImage, 54(2), 1589–1599. https://doi.org/ 10.1016/j.neuroimage.2010.09.043.

Vanutelli, M. E., Nandrino, J. L., & Balconi, M. (2016). The boundaries of cooperation: Sharing and coupling from ethology to neurosci-ence. Neuropsychological Trends, 19, 83–104. https://doi.org/10. 7358/neur-2016-019-vanu.

Vanutelli, M. E., Gatti, L., Angioletti, L., & Balconi, M. (2017). Affective synchrony and autonomic coupling during cooperation: A hyperscanning study. BioMed Research International, 2017, 1–9. https://doi.org/10.1155/2017/3104564.

Walker, R., Techawachirakul, P., & Haggard, P. (2009). Frontal eye field stimulation modulates the balance of salience between target and distractors. Brain Research, 1270, 54–63. https://doi.org/10.1007/ 978-0-85729-609-2_33.

Watanabe, Y., Sumitani, S., Hosokawa, M., & Ohmori, T. (2015). Prefrontal activation during two Japanese Stroop tasks revealed with multi-channel near-infrared spectroscopy. The Journal of Medical Investigation, 62(1.2), 51–55.

Wood, L., Egger, M., Gluud, L. L., Schulz, K. F., Jüni, P., Altman, D. G., Gluud, C., Martin, R. M., Wood, A. J. G., & Sterne, J. A. C. (2008). Empirical evidence of bias in treatment effect estimates in controlled trials with different interventions and outcomes: Meta-epidemiological study. BMJ, 336(7644), 601–605. https://doi.org/ 10.1136/bmj.39465.451748.AD.

Yun, K., Watanabe, K., & Shimojo, S. (2012). Interpersonal body and neural synchronization as a marker of implicit social interaction. Scientific Reports, 2, 959. https://doi.org/10.1038/srep00959.