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Praising or keeping silent on partner's ideas: Leading brainstorming in particular ways

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ABSTRACT

This study aimed to investigate how different feedback affect group creative performance, and reveal the underlying interpersonal neural correlates using the functional near-infrared spectroscopy (fNIRS)-based hyperscanning technique. Participants solved one creativity task with two strangers in conditions with positive/negative/no feedback. Results revealed that performance in the negative condition was lower than in the other conditions. Moreover, results showed the highest 'index of convergence'/collective flexibility in the positive/control condition respectively. The fNIRS results demonstrated IBS increment in the frontopolar and bilateral dorsolateral prefrontal cortex, which was stronger in the positive and negative conditions. The IBS increment in the frontopolar and bilateral DLPFC covaried with group creative performance in the positive condition. The findings indicated that negative feedback suppressed the group creative performance; whereas no feedback facilitated collective flexibility and positive feedback promoted interpersonal interaction, these two feedback conditions both benefited group creative performance.

1. Introduction

Creativity, a powerful engine of scientific discoveries and positive social developments, is defined as the ability to produce work that is novel (original and unique) and useful (Runco and Jaeger, 2012; Sternberg and Lubart, 1996). The group creativity is one of the pivotal components of successful scientific researches and business organizations. Brainstorming is supposed to be an effective technique to stimulate group creativity (Osborn, 1953, 1957) and has caught lots of attention in contemporary society (Bittner et al., 2016; Choi et al., 2016; Curşeu and Brink, 2016; Korde and Paulus, 2017; Lebuda et al., 2016).

Four basic principles were developed (Osborn, 1963) and widely applied to guide group brainstorming (i.e., deferment of judgment, quantity breeds quality, free-wheeling is encouraged, and combination and improvement are sought). With regard to 'deferment of judgment' (Korde and Paulus, 2017; Saad et al., 2015; Wang et al., 2015), it suggests that participants should reserve judgments and focus on extending ideas. The occurrence of judgments may increase individuals' evaluation apprehension, or fear for negative evaluations from others. All of this may inhibit individuals' creativity and the motivation to be creative (Camacho and Paulus, 1995; De Dreu et al., 2008; Diehl and Stroebe, 1987). By reserving judgments, individuals will feel free to generate unusual ideas and the creative performance of brainstorming groups will be enhanced.

Judgment or evaluation, as a type of feedback for task performance (Hattie and Timperley, 2007), can be either positive or negative. Considering that negative feedback can exert adverse effects on subsequent individual performance (Cianci et al., 2010; Zhou, 1998), and lead to higher level of individual evaluation apprehension or fear for negative evaluations (Camacho and Paulus, 1995; De Dreu et al., 2008; Diehl and Stroebe, 1987), it may be reasonable to exclude negative feedback in brainstorming groups. However, previous studies have also reported the beneficial effect of positive feedback on individual creative performance (Eisenberger and Aselage, 2009; Selart et al., 2008).

With regard to group creative performance, previous studies have suggested that it is not dependent solely on individual creativity. The effective interaction among team members can contribute to group creative performance (Harvey, 2014; Xue et al., 2018). It was suggested that only if group members not only generate the ideas themselves but also share their own ideas and actively process others' ideas, is group creativity likely to flourish (Gilson and Shalley, 2004; Hargadon and Bechky, 2006; Van Knippberg et al., 2004; Vera and Crossan, 2005). In other words, interpersonal interaction does matter to group creative performance. According to the above review, although positive/negative feedback may exert beneficial/adverse effect on individual creative

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performance, the effect of feedback on group creative performance needs further investigated. Because except individual creative performance, the effect of different feedback on the interpersonal interaction process among team members should also be considered. Meanwhile, the necessity to withhold feedback in brainstorming groups, especially the positive one, needs further considerations.

So far, it is still an open question how different types of feedback affect the interaction process among team members and group creative performance. The present study aimed to investigate whether different types of feedback (i.e., positive, negative, and no feedback) will exert different effects on the creative performance of brainstorming groups and the underlying interpersonal interaction process. We particularly addressed three questions. First, 'How does different feedback affect the creative performance of brainstorming groups and the interpersonal interaction process among individuals engaging in creativity-demanding activity?' Second, 'Does the interpersonal brain synchronization (IBS) between team members show diverse patterns in different feedback conditions?' Third, 'Is there any relationship between IBS and group creative performance or interpersonal interaction process?'

Recently, hyperscanning has been widely used in the field of social interactions (Cheng et al., 2015; Cui et al., 2012; Jiang et al., 2012; Nozawa et al., 2016). Hyperscanning studies can be conducted with fMRI (Chiu et al., 2008; Li et al., 2009), EEG (Lindenberger et al., 2009), and fNIRS (Tang et al., 2016). Previous hyperscanning studies have successfully identified interpersonal synchronized neural activities during social interactions in some cerebral regions. In this study, considering that the fNIRS offers an advantage of higher tolerance for motor artifacts, we used the fNIRS-based hyperscanning technique to measure the interpersonal brain interactions between group members while engaging in tasks demanding creativity.

Neuroscience studies have confirmed that the prefrontal cortex (PFC) is quite pivotal to cognitive processing during creativity tasks (Beaty et al., 2016; Kleibeuker et al., 2013; Wu et al., 2015). The PFC is involved in various cognitive functions such as cognitive control and goal maintenance (Miller and Cohen, 2001; Sanfey et al., 2003; Knoch et al., 2009), cognitive top-down inhibition of pre-potent responses (Mansouri et al., 2007, 2009), monitoring responses and inhibiting task-irrelevant stimulus (Jahanshahi et al., 2000; Petrides, 2000; Nachev et al., 2008; Anticevic et al., 2012). In addition, the PFC is recruited during tasks involving relation integration, task-set switching (Heinonen et al., 2016; Seeley et al., 2007), and idea evaluation (Beaty et al., 2016). In brief, the PFC plays important roles in the generation of novel ideas as well as the elaboration and modification of these ideas.

Moreover, previous studies have identified the PFC, orbito-frontal cortex, and r-DLPFC as parts of the brain regions where activities are important for tasks involving interpersonal cooperative interaction (Chaminade et al., 2012; Decety et al., 2004; McCabe et al., 2001; Suzuki et al., 2011). Recent hyperscanning studies observed IBS increments in medial prefrontal cortex, DLPFC, and superior frontal cortex between individuals while they were engaging in cooperative interactions (Cheng et al., 2015; Cui et al., 2012; Dommer et al., 2012; Funane et al., 2011). Similar IBS increment in the PFC was also reported in other types of social interaction processes, including face-to-face dialogs between partners (Jiang et al., 2012; Liu et al., 2017), group humming (Osaka et al., 2014), teaching-learning interactions (Dikker et al., 2017; Holper et al., 2013), model-imitation interactions (Holper et al., 2012), and coordinated walking (Ikeda et al., 2017). These studies observed significant IBS increments in the PFC between individuals in the cooperative interaction state. In addition, Schoot et al. (2016) suggested that IBS increment may indicate a state of mutual understanding between individuals. All of this may suggest that the IBS increment in the prefrontal cortex assessed using the hyperscanning technique can provide evidence for the interpersonal neural correlates between individuals underly the collective creativity activity.

In the present study, we expected to reveal the effects of different types of feedback on the creative performance of brainstorming groups as well as the underlying interpersonal interaction process and interpersonal neural correlates by using the fNIRS-based hyperscanning technique. This could allow us to reconsider the appropriateness of the brainstorming rule 'deferment of judgment'. Moreover, the design of the 'Non-target' participant was introduced in this study, whereby we could explore the effect of feedback on the creative performance of the team member who merely witnessed the feedback process. Further, given that openness has been found to affect creativity (Charyton and Snelbecker, 2007; Prabhu et al., 2008), we measured participants' openness using scores on the openness subscale of NEO-PI-R (Costa and McCrae, 1992). Because group preference also influences performance on teamwork (Campion et al., 1993; Tekleab and Quigley, 2014), we measured participants' preference for group work by using the Group Preference Scale (Larey and Paulus, 1999). Therefore, we could check whether the effect of feedback on creative performance of brainstorming groups was independent from the aforementioned factors. In addition, to rule out the potential contaminative effect of individual creativity on group creative performance, participants' creativity quotients were measured using the scores on the Runco Ideational Behaviour Scale (RIBS) (Runco et al., 2016).

2. Method

2.1. Participants

One hundred and eighteen college students (102 females, age: 20.72 ± 2.47 years old) took part in the study. Participants were all right handed, with normal or corrected-to-normal vision. They were randomly assigned as pairs to work in brainstorming group. Participants in each group were typically unknown to each other. A total of 59 groups were finally created. Informed consent was obtained from each participant prior to the experiment. Each participant was paid ¥ 35 for the participation. The study procedure was approved by the University Committee on Human Research Protection (UCHRP) of East China Normal University.

2.2. Experimental tasks and procedure

Each pair of participants was going to work with a false participant (i.e., the evaluator) (see Fig. 2B). Participants would not be told that the false participant was an experimental assistant. The false participant is a 25-year-old male student majoring in psychology. He played the role of evaluator among all brainstorming groups.

Participants were randomly assigned into three feedback conditions: positive feedback, negative feedback, no feedback (i.e., control condition). There were 20, 19, 20 brainstorming groups in the positive feedback condition, negative feedback condition and control condition respectively. In the positive feedback condition, the false participant only gave positive feedback to the 'Targets' such as 'Your idea is very original'. Feedback would be given to the 'Targets' in the 2nd, 3rd and 6th cycles, which was constant among all groups (see Fig. 1B, C). This ensured that feedback was given to the 'Targets' in the earlier stage of the task section. In the negative feedback condition, the false participant only gave negative feedback to the 'Targets' such as 'Your idea is bad'. Feedback was given to the 'Targets' in the same way as in the positive feedback condition. In the control condition, the false participant gave no feedback to the 'Targets' and was only asked to report the prepared ideas.

It should be noted that whether the real participants could provide feedback to others or not was not directly and clearly clarified by the experimenter. Hence, it is reasonable to speculate that the real participants might also provide feedback to others, especially in the case that the false participant was providing feedback to others. However, based on our observation, the real participants did not give any oral feedback to others. So, the potentially contaminant effect of the feedback from the real participants was excluded in the study.

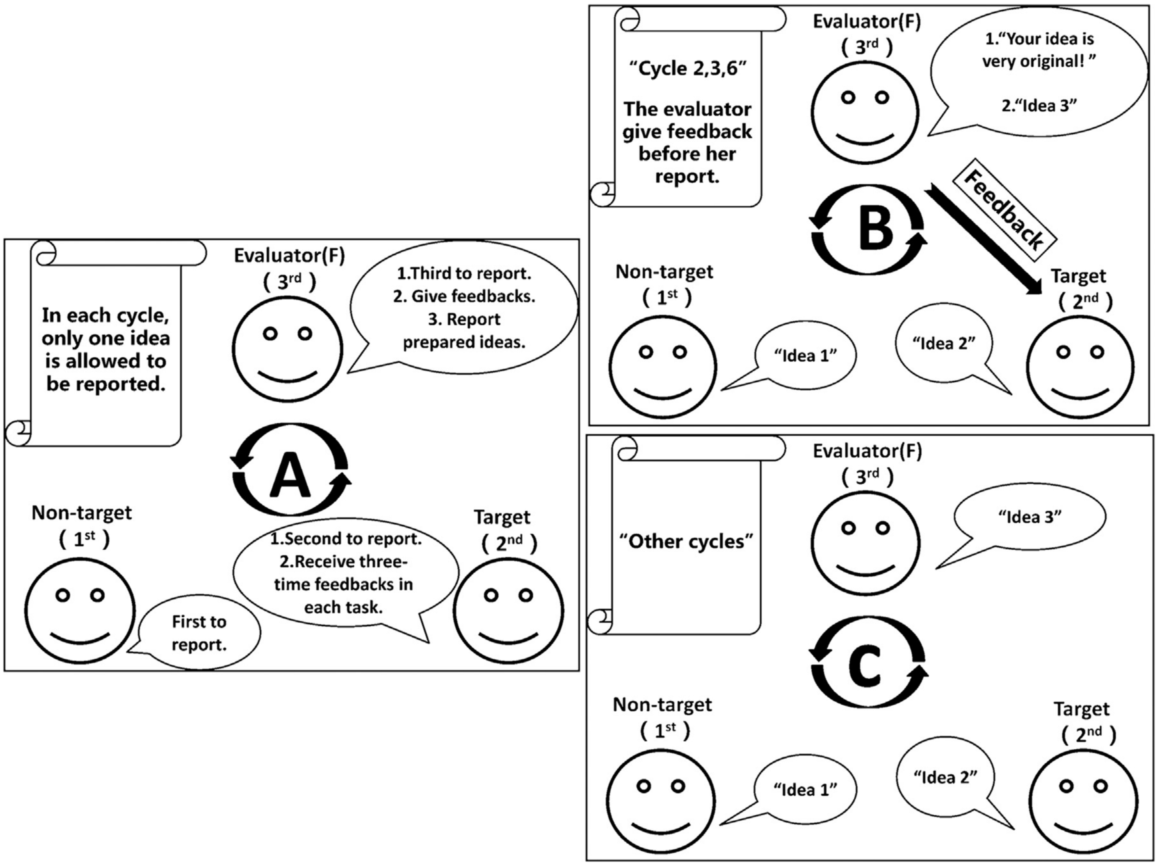

Fig. 1. Brainstorming design. (A) Brainstorming settings. The sequence of reporting was as follows: 'Non-target', 'Target', 'evaluator'. In each cycle, each participant was allowed to report only one idea. (B) Cycles in which the evaluator would give feedback to the 'Target'. In each task, the evaluator would only give feedback to the 'Target' three times. For instances, in cycle 2, after the 'Target' reported his idea, the evaluator would give feedback to him right away. Then, the evaluator reported one of the prepared ideas. If the 'Target' said 'pass' in the feedback cycles (cycle 2, 3, 6), the feedback would be given in the next cycle. (C) Cycles in which the evaluator would give no feedback to the 'Target'. In these cycles, the evaluator only reports the prepared ideas.

After the participants completed the ratings for openness, group preference (see details in the Supplement (S1)), they were asked to sit in a triangle. The distances between participants were equal. The participant who sat in the right side of the evaluator (i.e., the false participant) was marked as the 'Target'. The 'Target' would receive feedback from the evaluator during the creativity task. The other participant was marked as the 'Non-target' who would receive no feedback during the task.

In each group, an initial resting-state session of 2 min (see Fig. 2C) served as a baseline. During this session, participants were required to remain as still as possible, with their eyes closed, and mind relaxed (Lu et al., 2010). Then, the instructions of the creativity task and rules of brainstorming (except 'deferment of judgment') were clarified to them. They were asked to discuss on the following topic for 5 min: 'Your friend Pat sits next to you in class. Pat really likes to talk to you and often bothers you while you are doing your work. Sometimes he distracts you and you miss an important part of the lecture, and many times you don't finish your work because he is bothering you. What should you do? How would you solve this problem?' This is a typical sample of the Realistic Presented Problems (RPP) (Agnoli et al., 2016; Hao et al., 2017; Runco et al., 2016). The RPP is used to assess the ability to solve open-ended realistic problems. Each group was required to generate as many novel ideas as possible. Also, participants were encouraged to improve upon and combine the ideas generated by their partners (Osborn, 1957).

Moreover, during the task, the participants were instructed to answer while taking turns and report one idea at a time. The 'Non-target' was asked to report first. Next, the 'Target' and the false participant were allowed to report successively. The false participant would report a prepared idea (from common ideas prepared by the experimenter). These common ideas were reported frequently for the same task in previous studies. Besides, the prepared ideas were given in a fixed order. Participants were allowed to say 'pass' when they failed to present an idea during their respective turn (see Fig. 1A).

2.3. Assessment of performance on RPP

Participants' performance on the RPP was measured using the fluency and originality of their ideas (Guilford, 1967; Runco, 1991). Fluency was based on the total number of ideas each participant reported. Originality was assessed using an objective method. Generated ideas from all participants were collected into a comprehensive lexicon. Synonyms were identified and ideas collapsed accordingly. If a response was statistically infrequent (namely, if 5% or fewer participants in the sample reported this response), it would be scored '1'. Regardless of the frequency of appearance, all other responses would be scored '0'. Following this scoring procedure, two trained raters independently assessed the originality scores of generated ideas for each participant. The inter-rater agreement of this method (Internal Consistency Coefficient (ICC) = 0.90) was satisfactory. Individual ratings for each participant from these two raters were averaged into a single originality score for each participant. Finally, a total originality/fluency score for each group was calculated by summing the originality/fluency scores of the 'Target' and 'Non-target' in the group.

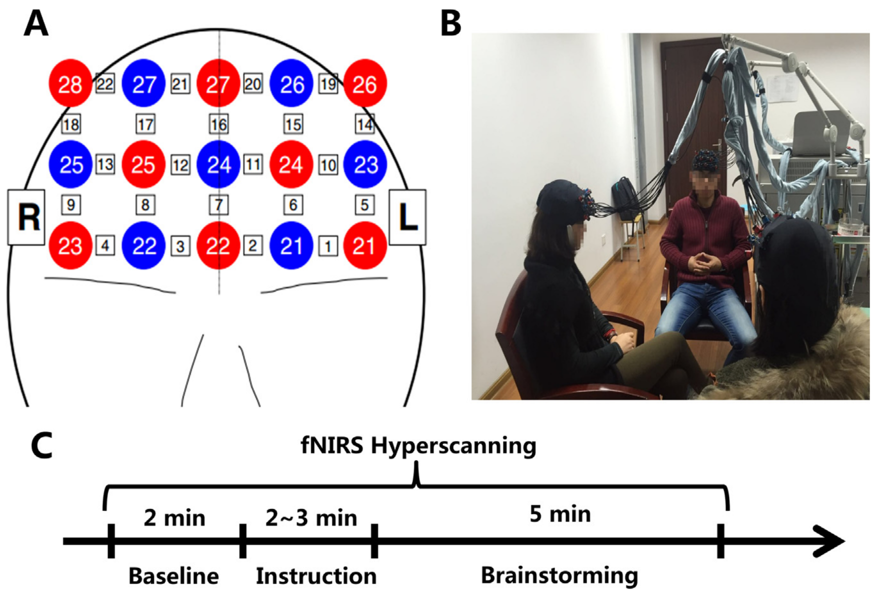

Fig. 2. Experimental design. (A) Optode probe set. The probe patch is placed on the prefrontal cortex. (Note: this picture was cited from Cui et al., 2012). (B) Experimental setup. (C) Hyperscanning design. Baseline: 2-min resting state session; Instruction: (2–3)-min instructions introduction; Brainstorming: 5-min Realistic presented problem task session.

2.4. Collective communication behaviour indices of TN

Primarily, in order to assess the extent to which group members explored ideas belonging to different categories, the collective flexibility was calculated. It was calculated as follows: Two trained raters independently assessed the total number of categories for ideas generated by each group. The inter-rater agreement for this method was satisfactory (ICC = 0.95). The collective flexibility of each dyad was calculated by averaging ratings from the two raters.

Besides, in order to assess the extent to which group members combined their ideas with others, 'Index of Convergence' (IOC) was calculated (Larey and Paulus, 1999). The IOC was calculated based on the value Sum (stay). The Sum (stay) value indicates the occurrence that an idea currently being reported comes from the same category as the previous idea that was reported. The detailed calculation process was illustrated as follow: (1) the ideas from the evaluator were excluded from the analysis; (2) according to the time point, the ideas reported during the whole brainstorming session from two real participants were listed sequentially. Here, the 'previous idea' for the 'Non-target' means idea from the 'Target' (skipping the evaluator), whereas the 'previous idea' for the 'Target' means idea from the 'Non-target'; (3) from the first idea to the last one, if one idea was recognized as an idea from the similar category that the previous idea was pertain to, it was scored '1'. The sum value of ideas scored '1' would then be obtained (Sum (stay)). If there were 7 ideas that were scored '1', the Sum (stay) was '7'; (4) eventually, the IOC value for each group was obtained by the following equation: IOC = Sum (stay)/ [Group fluency − Sum (stay)]. Here, the group fluency indicates the sum of the fluency of two real participants. Two trained raters independently assessed the IOC for each group. The inter-rater agreement for this method was satisfactory (ICC = 0.97). Further, the IOC of each dyad was calculated by averaging ratings from the two raters. It was suggestive of the extent to which the group explored ideas within one single category. Those improved or combinative ideas should be recognized as the responses in the same category. Accordingly, higher IOC score may reflect that the group members showed higher tendency to combine their ideas with others and improve upon other's idea, and indicate to a more effective interpersonal interaction process.

2.5. fNIRS data collection

A NIRS system (ETG-7100, Hitachi Medical Corporation, Japan) was used for the continuous measures of concentrations of oxygenated hemoglobin (HbO) and deoxygenated hemoglobin (HbR). The absorption of near infrared light (wavelengths: 695 and 830 nm) was measured at a sampling rate of 10 Hz. The optode probe set was placed over each participant's forehead, based on previous studies showing creativity tasks and cooperative interaction involved prefrontal regions (Beaty et al., 2016; Cheng et al., 2015; Cui et al., 2012; Kleibeuker et al., 2013; Wu et al., 2015). The 3 × 5 optode probe set (eight emitters and seven detectors, 3 cm optode separation) including 22 recording channels (CH) was used.

The placement of the patch followed the International 10–20 system. The lowest probe was aligned with the horizontal reference curve, with the middle optode placed on the frontal pole midline point (Fpz). Meanwhile, the middle probe of patches was aligned exactly along the sagittal reference curve (see Fig. 2A). The virtual registration method was used to determine the correspondence between the NIRS channels and the measurement points on the cerebral cortex (Singh et al., 2005; Tsuzuki et al., 2007).

2.6. Interpersonal brain synchronization (IBS)

Because the HbO signal has been demonstrated to be more sensitive to changes in cerebral blood flow than the HbR signal during fNIRS measurements (Cui et al., 2012; Hoshi, 2007; Jiang et al., 2012), we mainly focused on the HbO signal.

The raw data of each participant was preprocessed with hrf low-pass filtering and Wavelet minimum description length (Wavelet-MDL) detrending algorithm in NIRS-SPM (Brigadoi et al., 2014; Jang et al., 2009; Tang et al., 2016; Ye et al., 2009). By applying low-pass filtering, high-frequency non-neuronal components in the NIRS data could be attenuated. In addition, the Wavelet-MDL detrending algorithm was used to remove the unknown global trend due to breathing, cardiac, vaso-motion or other experimental errors. Wavelet-MDL detrending algorithm works with input of GLM model (specified in the SPM design matrix). We specified the GLM model by setting the onset and duration of the resting-state session as the block of trial 1 and setting the onset and duration of the brainstorming session as the block of trial 2. During preprocessing, data in the initial 30 s and ending 30 s periods of brainstorming session were removed to obtain data within the period of steady state, leaving 240 s of data for the brainstorming session. Data collected during the resting-state and brainstorming session were entered into analyses. Further, wavelet transform coherence (WTC) was used to calculate the relationship between HbO time series for each dyad (Interpersonal brain synchrony, IBS) (Grinsted et al., 2004). In

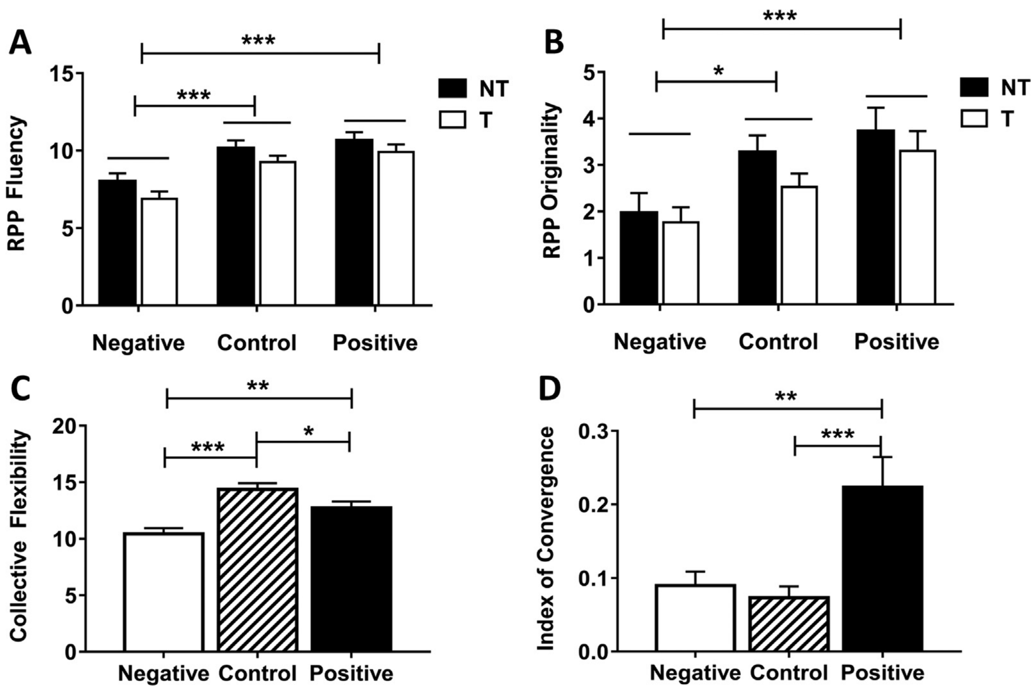

Fig. 3. Performance on the Realistic Presented Problem (RPP) and collective communication behaviour. (A) RPP fluency of participants in different conditions. (B) RPP originality of participants in different conditions. (C) Collective flexibility in different feedback conditions. (D) Index of convergence in different feedback conditions. Error bars indicate standard errors of the mean. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

each group, we calculated the IBS between 'Target' and 'Non-target' (TN dyad), the IBS between 'Target' and 'False participant' (TF dyad), as well as the IBS between 'Non-target' and 'False participant' (NF dyad) for each CH. The time-averaged IBS of the resting-state session was subtracted from that of the brainstorming session, and the difference was used as an index of the IBS increment for each dyad. For further analysis, the IBS increment was converted to Fisher z-statistics (Chang and Glover, 2010; Cheng et al., 2015; Cui et al., 2012)

To identify the frequency band of interest (FOI), one-sample *t*-test was performed to evaluate time-averaged IBS increment in each CH along the full frequency range (0.01–0.7 Hz) (Nozawa et al., 2016; Xue et al., 2018; Zheng et al., 2018). Since data above 0.7 Hz suffers from aliasing of higher frequency physiological noise such as cardiac activity (0.8–2.5 Hz) (Barrett et al., 2015; Guijt et al., 2007; Tong et al., 2011), data above 0.7 Hz were excluded from the study. Moreover, to avoid bias, the IBS increments in all conditions were averaged before the aforementioned *t*-test. The *t*-test results were thresholded at $p < 0.0005$. Given that this analysis was only used to identify the FOI rather than to obtain the final results, no further correction was performed (Dai et al., 2018; Zheng et al., 2018). We found that the frequencies between 0.022 and 0.025 Hz as well as the frequencies between 0.036 and 0.042 Hz had CHs whose *p* values survived the thresholding. These two frequency bands were separated by only 5 frequencies and the *p* values from these frequencies were less than 0.05 (at same CHs that had the *p* values survived the thresholding). Therefore, the above frequency bands and the frequencies (*p* values were less than 0.05) that were around the above frequency bands were clustered and chosen as the FOI (Zheng et al., 2018; Pan et al., 2018). Consequently, the FOI in the study was identified as the frequency band between 0.018 and 0.048 Hz. The IBS increment within the FOI was averaged for further analyses. Furthermore, to identify condition specific enhancement of IBS, one-sample *t*-tests were performed on the IBS increments from all CHs in all conditions respectively. The t-maps of IBS increment would be generated and smoothed by the spline method. To compare IBS increments among all conditions, two-way ANOVAs with Feedback (Positive/Control/Negative) and DYAD (TN/TF/NF) as the between-subject factors would be conducted on the IBS increments across all CHs. For both analyses, the resulting *p* values were corrected with false discovery rate (FDR) method ($p < 0.05$). Bonferroni correction was used to account for post-hoc multiple comparisons. Follow-up simple effect analyses with Bonferroni corrections were performed, when necessary. Finally, bivariate Pearson correlations between IBS increment and behavioural indices (i.e., fluency, originality and IOC) were estimated to reveal brain-behaviour relationship.

3. Results

3.1. Manipulation check

Three-way mixed-design ANOVA, with TIME POINT as the within-subject factor and FEEDBACK and AGENT as the between-subject factors, was performed on participants' liking for the evaluator as well as participants' valence and arousal of emotional state. The results revealed that the 'Target' in the negative/positive feedback condition showed decreased/increased liking for the evaluator, whereas the 'Target' in the control condition showed no significant variation in liking for the evaluator ($ps < 0.001$). Meanwhile, the results showed that participants in the positive feedback condition ($p < 0.001$) and control condition ($p = 0.013$) both showed increased emotional valence, whereas no significant variation was observed in emotional valence for participants in the negative feedback condition. Moreover, the results also showed that participants showed significantly increased emotional arousal in all conditions ($ps < 0.05$). These results confirmed that the participants perceived feedback in the study (see details in the Supplement (S1)).

3.2. Performance on RPP task

Two-way ANOVA with FEEDBACK and AGENT as the between-subject factors was performed on RPP fluency. Results showed a significant main effect of FEEDBACK on RPP fluency, F (2, 112) = 17.78, $p < 0.001$, $\eta_p^2 = 0.24$ (see Fig. 3A). The post-hoc test showed that the fluency in the negative feedback condition ($M = 7.45$, $SD = 2.24$) was significantly lower than in the positive feedback condition ($M = 10.28$, $SD = 2.33$; $p < 0.001$, Cohen's $d = 1.24$) and control condition ($M = 9.70$, $SD = 2.10$; $p < 0.001$, Cohen's $d = 1.04$). Results also showed a significant main effect of AGENT on RPP fluency, F (1, 112) = 5.12, $p = 0.026$, $\eta_p^2 = 0.04$. The post-hoc test showed that

‘Non-target’ showed significantly higher fluency ($M = 9.63$, $SD = 2.58$) than that of ‘Target’ ($M = 8.71$, $SD = 2.39$). No significant interaction effect of FEEDBACK × AGENT was observed, which suggested that the fluency of ‘Non-target’ was also affected.

Further, two-way ANOVA using FEEDBACK and AGENT as the between-subject factors was performed on RPP originality. Results demonstrated a significant main effect of FEEDBACK on RPP originality, F (2, 112) = 8.68, $p < 0.001$, $\eta_p^2 = 0.13$ (see Fig. 3B). The originality in the negative feedback condition ($M = 1.87$, $SD = 1.63$) was significantly lower than in the positive feedback condition ($M = 3.51$, $SD = 2.08$; $p < 0.001$, Cohen’s $d = 0.88$) and control condition ($M = 2.90$, $SD = 1.49$; $p = 0.011$, Cohen’s $d = 0.66$). No other significant main effect or interaction effect of FEEDBACK × AGENT was observed, which suggested that the originality of ‘Non-target’ was also affected.

Moreover, we performed two-way ANOVAs with FEEDBACK and AGENT as the between-subject factors on the openness, preference for teamwork and RIBS scores. Results demonstrate no significant main effect or interaction effect ($ps > 0.05$). The main effect of FEEDBACK on fluency remained significant after these variables were added to the aforementioned ANOVA model as covariates, F (2, 109) = 17.57, $p < 0.001$, $\eta_p^2 = 0.24$. Similarly, the main effect of AGENT on fluency also remained significant, F (1, 109) = 4.39, $p = 0.039$, $\eta_p^2 = 0.04$. In addition, the main effect of FEEDBACK on originality remained significant after these variables were added to the aforementioned ANOVA model as covariates, F (2, 109) = 8.32, $p < 0.001$, $\eta_p^2 = 0.13$.

3.3. Collective communication behaviour of target and non-target

One-way ANOVA using FEEDBACK as the between-subject factor was performed on the collective flexibility. Results showed a significant main effect of FEEDBACK on the collective flexibility, F (2, 56) = 12.90, $p < 0.001$ (see Fig. 3C). The post-hoc test revealed that the collective flexibility in the control condition ($M = 14.35$, $SD = 2.50$) was significantly higher than in the positive feedback condition ($M = 12.72$, $SD = 2.51$; $p = 0.037$, Cohen’s $d = 0.88$) and negative feedback condition ($M = 10.45$, $SD = 2.18$; $p < 0.001$, Cohen’s $d = 1.66$). In addition, the collective flexibility in the positive feedback condition was significantly higher than in the negative feedback condition ($p = 0.005$, Cohen’s $d = 0.97$).

Further, one-way ANOVA using FEEDBACK as the between-subject factor was performed on the IOC. Results demonstrated a significant main effect of FEEDBACK on the IOC, F (2, 56) = 9.02, $p < 0.001$, $\eta_p^2 = 0.24$ (see Fig. 3D). The post-hoc test revealed that the IOC in the positive feedback condition ($M = 0.22$, $SD = 0.18$) were significantly higher than in the negative feedback condition ($M = 0.09$, $SD = 0.08$; $p = 0.001$, Cohen’s $d = 0.93$) and control condition ($M = 0.07$, $SD = 0.07$; $p < 0.001$, Cohen’s $d = 1.10$).

3.4. Interpersonal brain synchronization (IBS) in different conditions

A series of one-sample t-tests were conducted on the IBS increments across all channels in all conditions (FEEDBACK: positive/negative/control; DYAD: TN/TF/NF). With respect to the IBS increment of TN, after FDR correction, results showed significant IBS increments at CH2, CH5, CH8, CH9, CH10, CH12, CH14, CH15, CH17, CH18, CH21, CH22 in the positive feedback condition ($ps < 0.05$) and CH11, CH14 in the negative feedback condition ($ps < 0.05$) (see Fig. 4A). With respect to the IBS increment of TF, after FDR correction, results showed significant IBS increments at CH7, CH10, CH12, CH22 in the negative feedback condition ($ps < 0.05$) (see Fig. 4B). With respect to the IBS increment of NF, after FDR correction, results showed significant IBS increment at CH22 in the positive feedback condition ($p < 0.05$) and CH9 in the negative feedback condition ($p < 0.05$) (see Fig. 4C). In contrast, no significant IBS increment was observed in other conditions.

Further, two-way ANOVA with FEEDBACK and DYAD as the between-subject factors was performed on the IBS increments across all CHs. The resulting p values were FDR corrected ($p < 0.05$). Based on the results corrected by FDR, significant difference in IBS increments among conditions were observed at CHs as follow: CH11, CH16 (roughly located in the frontopolar cortex); CH10, CH14 (roughly located in left-DLPFC; l-DLPFC); CH17, CH22 (roughly located in right DLPFC; r-DLPFC) ($ps < 0.05$) (see Fig. 5A). Besides, a marginal difference in IBS increments among conditions was observed at CH5 ($p_{corr} = 0.052$; roughly located in l-DLPFC).

Specifically, two-way ANOVA using FEEDBACK and DYAD as the between-subject factors was performed on the IBS increment at CH11. Results showed a significant main effect of FEEDBACK on IBS increment at CH11, F (2, 168) = 4.39, $p_{corr} = 0.043$, $\eta_p^2 = 0.05$. The post-hoc test revealed that the IBS increment in the control condition ($M = 0.00$, $SD = 0.11$) was significantly lower than in the negative feedback condition ($M = 0.05$, $SD = 0.10$; $p = 0.035$, Bonferroni corrected). Although results showed no significant interaction effect of FEEDBACK × DYAD on the IBS increment, further simple effect analysis was still performed (see Fig. 5E). With regard to DYAD, the IBS increment of TN was significantly lower in the control condition ($M = -0.01$, $SD = 0.08$) than in the negative feedback ($M = 0.08$, $SD = 0.09$; $p = 0.028$, Bonferroni corrected). In contrast, no significant difference in the IBS increment of TF or NF was observed among different feedback conditions. With regard to FEEDBACK, no significant difference was observed.

Besides, two-way ANOVA using FEEDBACK and DYAD as the between-subject factors was performed on the IBS increment at CH16. Results showed a significant main effect of FEEDBACK on the IBS increment, F (2, 168) = 4.67, $p_{corr} = 0.047$, $\eta_p^2 = 0.053$. The post-hoc test revealed that the IBS increment in the control condition ($M = -0.01$, $SD = 0.12$) was significantly lower than in the positive feedback condition ($M = 0.05$, $SD = 0.10$; $p = 0.009$, Bonferroni corrected). No other significant effect was observed.

Moreover, two-way ANOVA using FEEDBACK and DYAD as the between-subject factors was performed on the IBS increment at CH5. Results showed a significant main effect of FEEDBACK on IBS increment at CH5, F (2, 168) = 5.10, $p_{corr} = 0.052$, $\eta_p^2 = 0.06$. The post-hoc test revealed that the IBS increment in the control condition ($M = -0.02$, $SD = 0.12$) was significantly lower than in the positive feedback ($M = 0.03$, $SD = 0.10$; $p = 0.01$, Bonferroni corrected) and negative feedback condition ($M = 0.02$, $SD = 0.11$; $p = 0.04$, Bonferroni corrected). Although results showed no significant interaction effect of FEEDBACK × DYAD on the IBS increment, further simple effect analysis was still performed (see Fig. 5B). With regard to DYAD, the IBS increment of TN was significantly lower in the control condition ($M = -0.06$, $SD = 0.14$) than in the positive feedback ($M = 0.06$, $SD = 0.10$; $p = 0.005$, Bonferroni corrected) and negative feedback conditions ($M = 0.06$, $SD = 0.12$; $p = 0.003$, Bonferroni corrected). In contrast, no significant difference in the IBS increment of TF or NF was observed among different feedback conditions. With regard to FEEDBACK, no significant difference was observed.

In addition, two-way ANOVA using FEEDBACK and DYAD as the between-subject factors was performed on the IBS increment at CH10. Results showed a significant main effect of FEEDBACK on IBS increment at CH10, F (2, 168) = 5.02, $p_{corr} = 0.042$, $\eta_p^2 = 0.06$. The post-hoc test revealed that the IBS increment in the control condition ($M = -0.02$, $SD = 0.13$) was significantly lower than in the positive feedback ($M = 0.04$, $SD = 0.12$; $p = 0.013$, Bonferroni corrected) and negative feedback condition ($M = 0.04$, $SD = 0.08$; $p = 0.035$, Bonferroni corrected). Although results showed no significant interaction effect of FEEDBACK × DYAD on the IBS increment, further simple effect analysis was still performed (see Fig. 5C). With regard to DYAD, the IBS increment of TN was significantly lower in the control condition ($M = -0.02$, $SD = 0.14$) than in the positive feedback ($M = 0.09$, $SD = 0.13$; $p = 0.007$, Bonferroni corrected). In contrast, no significant difference in the IBS increment of TF or NF was observed among

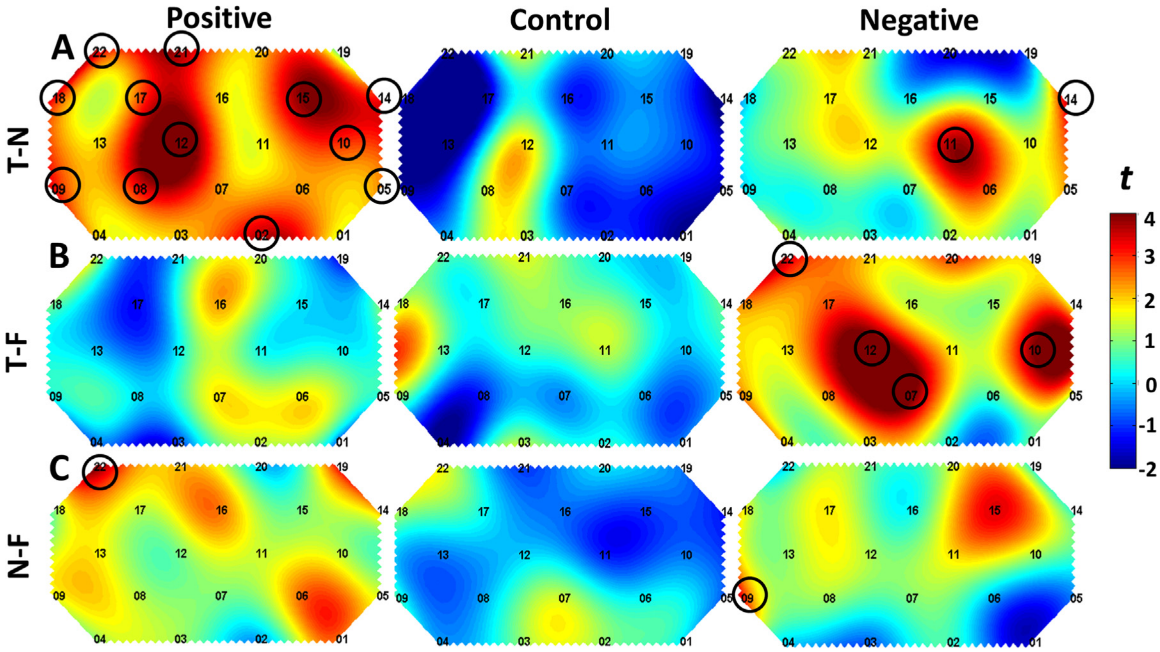

Fig. 4. One-sample *t*-test maps of IBS increment in different conditions. (A) One-sample *t*-test maps of IBS increment of TN in different feedback conditions. Significant IBS increments were observed at CH2, CH5, CH8, CH9, CH10, CH12, CH14, CH15, CH17, CH18, CH21, CH22 in the positive feedback condition ($ps < 0.05$) and CH11, CH14 in the negative feedback condition ($ps < 0.05$) (B) One-sample *t*-test maps of IBS increment of TF in different feedback conditions. Significant IBS increments were observed at CH7, CH10, CH12, CH22 in the negative feedback condition ($ps < 0.05$). (C) One-sample *t*-test maps of IBS increment of NF in different feedback conditions. Significant IBS increments were observed at CH22 in the positive feedback condition ($p < 0.05$) and CH9 in the negative feedback condition ($p < 0.05$).

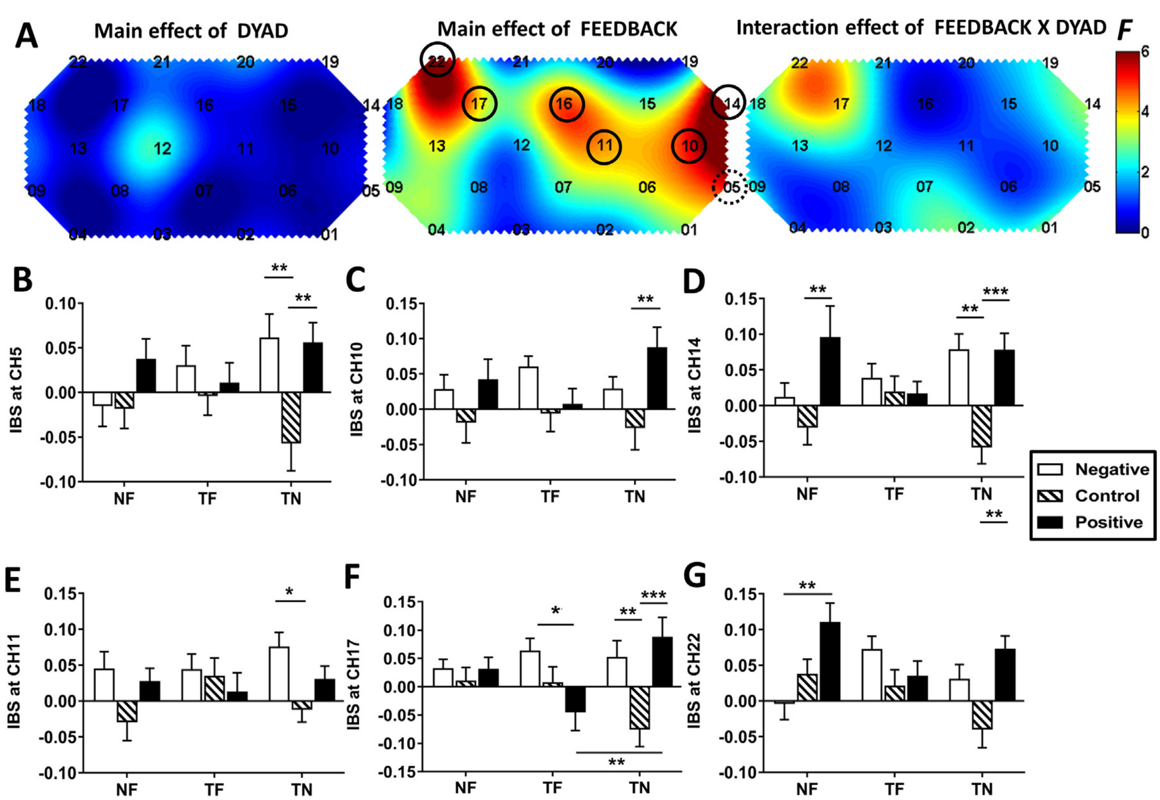

Fig. 5. Variations in the IBS increment in different conditions. (A) Two-way ANOVA results to identify the significant main effect or interaction effect on the IBS increment (FDR corrected). (B) The amplitude of IBS increment at CH5. (C) The amplitude of IBS increment at CH10. (D) The amplitude of IBS increment at CH14. (E) The amplitude of IBS increment at CH11. (F) The amplitude of IBS increment at CH17. (G) The amplitude of IBS increment at CH22. Error bars indicate standard errors of the mean. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

different feedback conditions. With regard to FEEDBACK, no significant difference was observed.

Further, two-way ANOVA using FEEDBACK and DYAD as the between-subject factors was performed on the IBS increment at CH14. Results showed a significant main effect of FEEDBACK on IBS increment at CH14, F (2, 168) = 8.90, p_{corr} = 0.005, η_p^2 = 0.10. The post-hoc test revealed that the IBS increment in the control condition (M = −0.02, SD = 0.11) was significantly lower than in the positive feedback condition (M = 0.06, SD = 0.14; p < 0.001, Bonferroni corrected) and negative feedback condition (M = 0.04, SD = 0.10; p = 0.008, Bonferroni corrected). Results also showed a significant interaction effect of FEEDBACK × DYAD on the IBS increment, F (4, 168) = 3.16, p = 0.016, η_p^2 = 0.07 (see Fig. 5D). With regard to DYAD, the IBS increment of TN was significantly lower in the control condition (M = −0.06, SD = 0.11) than in the positive feedback (M = 0.08, SD = 0.11; p < 0.001, Bonferroni corrected) and negative feedback conditions (M = 0.08, SD = 0.10; p = 0.001, Bonferroni corrected). Meanwhile, the IBS increment of NF was significantly lower in the control condition (M = −0.03, SD = 0.11) than in the positive feedback (M = 0.09, SD = 0.20; p = 0.002, Bonferroni corrected). In contrast, no significant difference in the IBS increment of TF was observed among different feedback conditions. With regard to FEEDBACK, no significant difference was observed.

Furthermore, two-way ANOVA using FEEDBACK and DYAD as the between-subject factors was performed on the IBS increment at CH17. Results showed a significant main effect of FEEDBACK on IBS increment at CH17, F (2, 168) = 4.44, p_{corr} = 0.049, η_p^2 = 0.05. The post-hoc test revealed that the IBS increment in the control condition (M = −0.02, SD = 0.13) was significantly lower than in the negative feedback condition (M = 0.05, SD = 0.10; p = 0.012, Bonferroni corrected). Results also showed a significant interaction effect of FEEDBACK × DYAD on the IBS increment, F (4, 168) = 4.17, p = 0.003, η_p^2 = 0.09 (see Fig. 5F). With regard to DYAD, the IBS increment of TN was significantly lower in the control condition (M = −0.07, SD = 0.14) than in the positive feedback (M = 0.09, SD = 0.16; p < 0.001, Bonferroni corrected) and negative feedback conditions (M = 0.05, SD = 0.13; p = 0.006, Bonferroni corrected). Meanwhile, the IBS increment of TF was significantly lower in the positive feedback condition (M = −0.04, SD = 0.15) than in the negative feedback condition (M = 0.06, SD = 0.10; p = 0.027, Bonferroni corrected). In contrast, no significant difference in the IBS increment of NF was observed among different feedback conditions. With regard to FEEDBACK, in the positive feedback condition, TN (M = 0.09, SD = 0.16) showed significantly higher IBS increment than that of TF (M = −0.04, SD = 0.15; p = 0.004, Bonferroni corrected). In contrast, no significant difference in IBS increment in the negative feedback or control conditions was observed among different dyads.

Eventually, two-way ANOVA using FEEDBACK and DYAD as the between-subject factors was performed on the IBS increment at CH22. Results showed a significant main effect of FEEDBACK on IBS increment at CH22, F (2, 168) = 6.37, p_{corr} = 0.024, η_p^2 = 0.07. The post-hoc test revealed that the IBS increment in the control condition (M = 0.01, SD = 0.11) was significantly lower than in the positive feedback condition (M = 0.07, SD = 0.11; p = 0.002, Bonferroni corrected). Results also showed a significant interaction effect of FEEDBACK × DYAD on the IBS increment, F (4, 168) = 3.59, p = 0.008, η_p^2 = 0.08 (see Fig. 5G). With regard to DYAD, the IBS increment of TN was significantly lower in the control condition (M = −0.04, SD = 0.12) than in the positive feedback (M = 0.07, SD = 0.09; p = 0.002, Bonferroni corrected). Meanwhile, the IBS increment of NF was significantly lower in the negative feedback condition (M = 0.00, SD = 0.10) than in the positive feedback condition (M = 0.11, SD = 0.12; p = 0.002, Bonferroni corrected). In contrast, no significant difference in the IBS increment of TF was observed among different feedback conditions. With regard to FEEDBACK, no significant difference was observed.

3.5. The IBS-behaviour relations

Schoot et al. (2016) suggested that IBS increment occurred during verbal interaction may indicate a state of mutual understanding. Mutual understanding is quite necessary for idea combination, namely individuals cannot combine their ideas with others' or improve upon others' ideas without understand others' ideas. Individuals who were interacted with each other effectively were more likely to being engaging in mutual understanding. Since higher level of IOC of TN dyad was induced in the positive feedback condition when compared to other conditions, we hypothesized there might be an IBS-IOC relation in the positive feedback condition. To test this hypothesis, bivariate Pearson correlations were performed on the IBS increment of TN dyad at the following CHs (frontopolar: CH16; l-DLPFC: CH10, CH14; r-DLPFC: CH17, CH22) and IOC in the positive feedback condition only. However, the results revealed no significant correlation.

In addition, Lu et al. (2018) and Xue et al. (2018) have found that IBS increment in the PFC covaries with dyad creative performance. Besides, such an IBS-creativity relation is only specific to dyads engaging in cooperative interpersonal interaction. This may indicate that the IBS-creativity relationship was dependent on the cooperative interaction. Since higher level of IOC of TN dyad was induced by positive feedback when compared to other conditions, we hypothesized there might also be an IBS-creativity relation in this study. Therefore, bivariate Pearson correlations were performed on the IBS increment of TN at aforementioned CHs and RPP fluency as well as originality in the positive feedback condition. Results showed that the IBS increment at CH5 was positively correlated with RPP fluency (r = 0.38, p = 0.047, one-tailed) and originality (r = 0.42, p = 0.031, one-tailed) in the positive feedback condition (see Fig. 6A, B). Besides, results also showed that the IBS increment at CH16 was positively correlated with RPP originality (r = 0.47, p = 0.019, one-tailed) in the positive feedback condition (see Fig. 6C). Moreover, results also showed that the IBS increment at CH22 was positively correlated with RPP originality (r = 0.47, p = 0.019, one-tailed) in the positive feedback condition (see Fig. 6D).

4. Discussion

In this study, we investigated how different feedback affects the creative performance of brainstorming groups and revealed the underlying interpersonal neural correlates using the fNIRS-based hyperscanning technique. Participants were asked to solve one RPP in three-person brainstorming groups. Results revealed that the RPP fluency and originality of groups in the positive feedback condition and control condition were significantly higher than in the negative feedback condition. Moreover, we also observed that the IOC in the positive feedback condition was significantly higher than in the other two conditions. Further, results showed that the collective flexibility in the control condition was significantly higher than in the positive feedback condition and negative feedback condition. More importantly, fNIRS results demonstrated significant IBS increments in the frontopolar cortex (CH2, CH7, CH8, CH11, CH12), l-DLPFC (CH5, CH10, CH14, CH15), and r-DLPFC (CH9, CH17, CH18, CH21, CH22). Furthermore, with respect to the IBS increment of TN, the IBS increments in the frontopolar cortex (CH11, CH16), l-DLPFC (CH5, CH10, CH14), and r-DLPFC (CH17, CH22) were stronger for the positive feedback condition than for the control condition. Meanwhile, the IBS increment in the frontopolar cortex (CH16) as well as bilateral DLPFC (CH5, CH22) covaried with group creative performance.

Results revealed that the creative performance of both 'Non-target' and groups in the negative feedback condition was significantly worse than in the control feedback condition and positive feedback (see Fig. 3). This may indicate a negative effect of negative feedback on 'Non-target' and group creative performance, even if there was only one member in the group who received negative feedback. One reason for

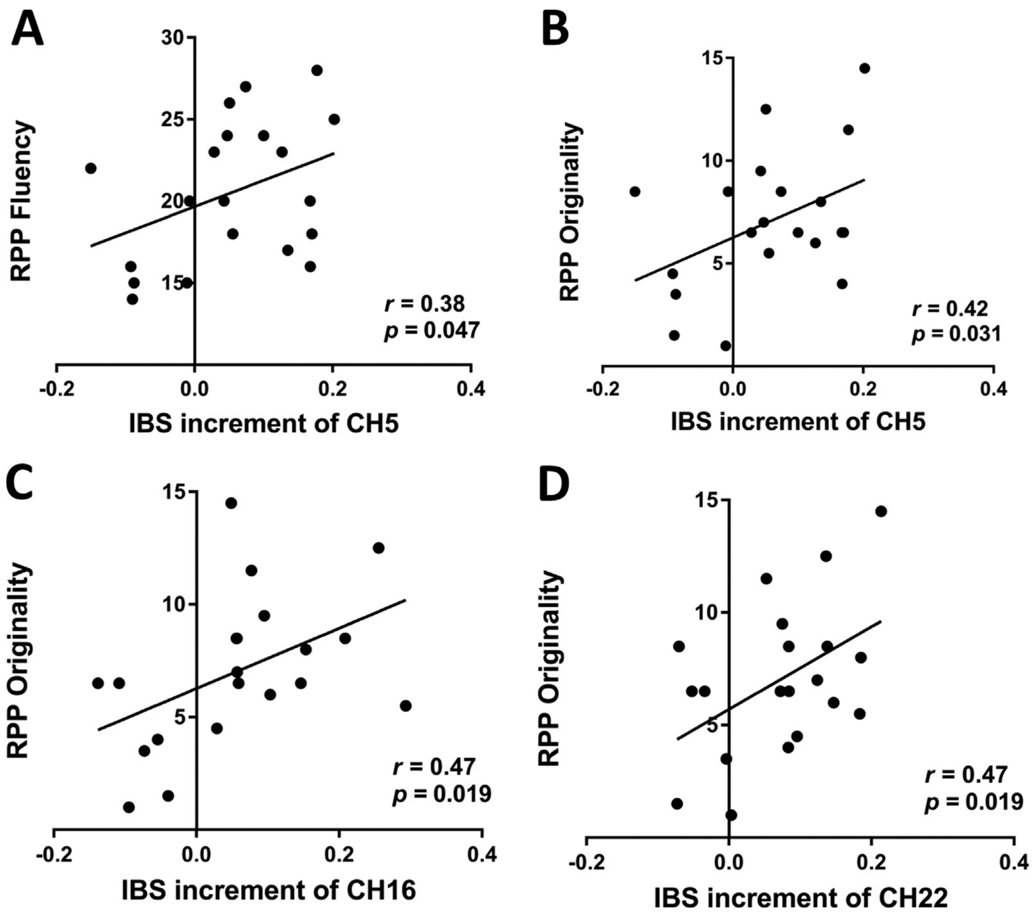

Fig. 6. Correlations between the IBS increment of TN and behaviour in the positive feedback condition. (A) Correlation between the IBS increment at CH5 and RPP fluency. (B) Correlation between the IBS increment at CH5 and RPP originality. (C) Correlation between the IBS increment at CH16 and RPP originality. (D) Correlation between the IBS increment at CH22 and RPP originality.

this may be that the fear of negative feedback can inhibit individuals' ability and motivation to be creative (Camacho and Paulus, 1995; De Dreu et al., 2008; Diehl and Stroebe, 1987). Moreover, individuals may disengage from the creativity task altogether to shun further negative feedback or offer themselves an excuse for subsequent failures (Dweck, 1986; Yeo and Neal, 2004). In addition, results showed that the 'response duration' was higher in the negative feedback condition than in the other feedback conditions (see details in the Supplement (S2)) and the 'collective flexibility' was the lowest in the negative feedback condition. Also, the IOC in the negative feedback condition was not significantly higher than in the control condition. This may imply that individuals' motivation to be creative was inhibited in the negative feedback condition. To shun further negative feedback, they might be more cautious and hesitating during task performance. All of this may even result in an ineffective interpersonal interaction process.

In contrast, results showed no significant difference in the creative performance of groups between the positive feedback condition and control condition. We found that the IOC in the positive feedback condition was significantly higher than in the negative feedback and control condition (see Fig. 3D). The higher IOC may reflect that the group members showed higher tendency to combine their ideas with others and improve upon other's idea, and indicate to a more effective interpersonal interaction process. In other words, in the positive feedback condition, group members did not only generate the ideas themselves but also shared their own ideas, carefully attended to others' ideas and actively processed them (Gilson and Shalley, 2004; Hargadon and Bechky, 2006; Van Knippberg et al., 2004; Vera and Crossan, 2005). According to the aforementioned review, such an effective interpersonal interaction may contribute to the group creative performance. Therefore, with regard to the similar group creative performance in the positive feedback and control conditions, there may be another possible explanation. The Dual Pathway to Creativity Model (DPCM) (De Dreu et al., 2008; Nijstad et al., 2010) depicts two pathways (i.e. flexibility and persistence) to creativity. The model proposes that both persistent (ex., exloring ideas in one category) and flexible pathway (ex., exploring ideas in many categories) provide access to creativity. In light of DPCM, the creative performance of brainstorming groups may also depends on both persistent pathway (indicated by the IOC) and flexible pathway (indicated by collective flexibility). Our results showed that the 'collective flexibility' in the positive feedback condition was significantly lower than in the control condition. This may imply that when positive feedback occurred, individuals may tend to combine their ideas with or improve upon ideas that are positively evaluated. This will lead group members to generate more ideas belonging to one category, which contribute to higher persistence. However, in the case of no feedback, individuals may tend to generate self-interested ideas independently, which contribute to higher flexibility. According to the DPCM, both higher persistence/flexibility contributed to the creative performance of groups in the positive feedback/control conditions. Therefore, although group creative performance in these two conditions were better than in the negative feedback condition, no difference was observed between them.

The fNIRS results demonstrated IBS increments in the frequency band between 0.018 and 0.048 Hz in the positive and negative feedback conditions. Previous researches have shown that IBS increment in the PFC is usually associated with interpersonal interaction between individuals, which may even reflect a state of mutual understanding (ex., Cheng et al., 2015; Cui et al., 2012; Dommer et al., 2012; Funane et al., 2011; Ikeda et al., 2017; Tang et al., 2016). In this study, because participants in each group have not met each other before the experiment, the IBS increment could not be induced by prior familiarity or emotional factors. Therefore, the observed IBS increment might reflect the underlying interpersonal neural correlates between individuals engaging in interpersonal interaction.

The IBS increment observed was roughly located in the l-DLPFC, r-DLPFC, frontopolar cortex. Previous studies have reported the association between interpersonal neural correlates in the l-DLPFC and social processing underlies interpersonal interaction such as cooperative games and teaching-learning task (Cheng et al., 2015; Takeuchi et al., 2017). Moreover, involvement of the rDLPFC has been confirmed in functions such as overriding self-interested motivation (Knoch et al., 2006), monitoring responses, and top-down inhibition of pre-potent ideas as well as task-irrelevant stimuli (Anticevic et al., 2012; Jahanshahi et al., 2000; Mansouri et al., 2007, 2009; Miller and Cohen, 2001; Nachev et al., 2008; Petrides, 2000). Further, previous studies have shown that the PFC (and especially the DLPFC) is responsible for the suppression of 'ego-centered' behaviour (Baeken et al., 2010) and commitment in significant relationships (Petrican and Schimmack, 2008). In addition, it has been implicated that the frontopolar cortex is involved in cognitive processes essential for successful interpersonal communication such as mentalizing, understanding others' beliefs and intentions, and multi-task coordination (Amodio and Frith, 2006; Gilbert et al., 2006; Stephens et al., 2010). Nozawa et al. (2016) also found significant IBS increments in the frontopolar cortex, during cooperative communication. Accordingly, the findings that higher IBS increment of TN in the positive feedback condition compared to the control condition may imply that individuals were more willing to make more of an effort to override their own self-interested motivation, attended to their partners' ideas carefully, processed and comprehended their partners' ideas actively, and had more interest in interacting with their partners (ie., build their own ideas with others', improve upon others' ideas). This was partly supported by the finding that both the IBS increment and IOC were significantly higher in the positive feedback condition when compared to the control condition. Besides, the IBS increment in the l-DLPFC (CH5) and r-DLPFC (CH22) were positively correlated with group creative performance in the positive feedback condition. We also examined the effect of feedback on the individual neural activity of the 'Target' participant. The results showed that the neural activity in the r-DLPFC (CH22) was significantly enhanced. Our explanation might be partly supported by this finding as well (see details in the Supplement (S3)).

Moreover, results even showed significantly higher IBS increment of TN in the negative feedback condition than in the control condition in the l-DLPFC (CH5, CH14), frontopolar cortex (CH11), r-DLPFC (CH17) (see Fig. 5). This may also reflect that group members tended to attend to others' ideas, process and comprehended others' ideas in the negative feedback condition. However, their purpose might be different from those in the positive feedback condition. For instance, since ideas of the 'Target' were negatively evaluated, the 'Non-target' might process and comprehend the ideas of the 'Target' to avoid reporting similar ideas. Therefore, although higher IBS increment was observed in the negative feedback condition than in the control condition, no difference in IOC was observed between these two conditions.

Moreover, we found that significant IBS increment was not specific to the dyad of TN. With respect to the positive feedback condition, results showed higher IBS increment of TN than that of TF (r-DLPFC, CH17). With respect to the IBS increment of NF, we observed higher IBS increment in the positive feedback condition when compared to the control condition (l-DLPFC, CH14) or negative feedback condition (r-DLPFC, CH22). With regard to the IBS increment of TF, we also observed higher IBS increment in the negative feedback condition when compared to the positive feedback condition (r-DLPFC, CH17). This may imply that when feedback occurred in brainstorming groups, not only the interaction between the 'Target' and 'Witness' (TN), but also the interaction between the 'Target' and 'Evaluator' (TF) and 'Witness' and 'Evaluator' (NF) can be affected. When positive feedback occurred, the 'Non-target' may be more interested in interacting with the 'Evaluator' so that they can generate ideas which can be positively evaluated by the evaluator. However, when negative feedback occurred, the 'Target' may be more inclined to interact with the 'Evaluator' so that they can generate ideas which will not be negatively evaluated by the evaluator.

The application of hyperscanning devices such as fNIRS is increasingly being accepted as a promising technique for exploring the interpersonal neural mechanism in the context of social interactions. Nevertheless, analytic challenges of fNIRS should be noted. First, the fNIRS signals can be contaminated by physiological activities in the periphery such as respiration, cardiac pulsation (Dommer et al., 2012), and oscillations of blood flow (Lloyd-Fox et al., 2010; Scholkmann et al., 2014). Therefore, the hrf low-pass filtering and Wavelet-MDL detrending algorithm were performed on the raw data during preprocessing to ruled out these potential contaminant effects (Brigadoi et al., 2014; Jang et al., 2009; Tang et al., 2016; Ye et al., 2009). In addition, previous studies have also found that signals in the frequency bands lower than 0.2 Hz in frontal cortex are covarying with cognitive performance (Cheng et al., 2015; Cui et al., 2012; Duan et al., 2013; Jiang et al., 2012). The IBS increment found in this study should not be primarily determined by the aforementioned noises, although we could not eliminate the effect of these noises on our study completely. Second, the fNIRS device can also record changes in HbR, which might provide additional information. However, the HbO signal is suggested to be more sensitive to changes in cerebral blood flow during fNIRS measurements (Cui et al., 2012; Lindenberger et al., 2009), we mainly focused on the HbO signals during our analyses.

There were several limitations in this study. Primarily, participants in each group were unfamiliar with their partners prior to the experiment. However, in the real world, individuals in brainstorming groups are supposed to be acquainted with each other. Therefore, the possible effects of familiarity on the relationship between feedback and group creativity should be further tested. Besides, although the prepared ideas were equal among different conditions, the quality of these ideas might contaminate the results by interacting with the feedback. For instance, negative feedback from poor idea generator might cause frustration toward the evaluator. We found that the originality of the participants was significantly higher than that of the 'evaluator' in the study, $t(117) = 10.34, p < 0.001$, Cohen's $d = 1.91$. Accordingly, we were not able to rule out the potentially contaminant effect due to the interaction between the low idea quality of the 'evaluator' and negative feedback in the study. Meanwhile, the same negative feedback from superior idea generator might be accepted more easily. Further studies should be conducted to investigate this potential interaction. Moreover, previous studies have shown that gender composition can confound the relationship between interpersonal neural synchrony and behaviour (Baker et al., 2016). In this study, the number of male participants was too small to use gender as a variable. More male participants will need to be recruited so that the effect of gender on the relationships among feedback, group creativity and underlying interpersonal neural mechanism can be revealed fully. In addition, in this study, only the prefrontal cortex region was covered by the fNIRS optode probe set, with other regions remaining unexplored. Previous studies on creativity have shown that the default network, which comprises midline and posterior inferior parietal regions, plays a pivotal role in creative cognition (Beaty et al., 2017; Benedek et al., 2014a, 2014b). The coverage of the fNIRS optode probe sets should be expanded so that the involvement of these brain regions in group creative performance can be explored fully. Eventually, providing feedback in the fixed turns irrespective of the Target's actual ideas might lead to invalid feedback (e.g. positive feedback to poor ideas and negative feedback to good ideas). There were several reasons why we determined to provide feedback in fixed turns. First, it could be difficult for the evaluator to determine the moment to provide feedback himself. Second, it could be hard for the evaluator to evaluate the quality of ideas himself. Third, to exclude the potential effect of the frequency of feedback, feedback was only provided three times. Nevertheless, a more appropriate way to provide feedback should be adopted in future studies so that the potential effect of invalid feedback could be ruled out.

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Conflict of interest

The authors have nothing to disclose.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.neuropsychologia.2019.01.004.

References

Agnoli, S., Corazza, G.E., Runco, M.A., 2016. Estimating creativity with a multiple-measurement approach within scientific and artistic domains. Creat. Res. J. 28, 171–176. https://doi.org/10.1080/10400419.2016.1162475.
Amodio, D.M., Frith, C.D., 2006. Meeting of minds: the medial frontal cortex and social cognition. Nat. Rev. Neurosci. 7, 268–277. https://doi.org/10.1038/nrn1884.
Anticevic, A., Cole, M.W., Murray, J.D., Corlett, P.R., Wang, X.J., Krystal, J.H., 2012. The role of default network deactivation in cognition and disease. Trends Cogn. Sci. 16, 584–592. https://doi.org/10.1016/j.tics.2012.10.008.
Baeken, C., De Raedt, R., Van Schuerbeek, P., Vanderhasselt, M.A., De Mey, J., Bossuyt, A., Luypaert, R., 2010. Right prefrontal HF-rTMS attenuates right amygdala processing of negatively valenced emotional stimuli in healthy females. Behav. Brain Res. 214, 450–455. https://doi.org/10.1016/j.bbr.2010.06.029.
Baker, J.M., Liu, N., Cui, X., Vrticka, P., Saggar, M., Hadi Hosseini, S.M., Reiss, A.L., 2016. Sex differences in neural and behavioral signatures of cooperation revealed by fNIRS hyperscanning. Sci. Rep. 6https://doi.org/10.1038/srep26492. (article 26492).
Barrett, K.E., Barman, S.M., Boitano, S., Brooks, H., 2015. Ganong's Review of Medical Physiology. Appleton and Lange ISE.
Beaty, R.E., Benedek, M., Silvia, P.J., Schacter, D.L., 2016. Creative cognition and brain network dynamics. Trends Cogn. Sci. 20, 87–95. https://doi.org/10.1016/j.tics.2015.10.004.
Beaty, R.E., Christensen, A.P., Benedek, M., Silvia, P.J., Schacter, D.L., 2017. Creative constraints: brain activity and network dynamics underlying semantic interference during idea production. NeuroImage 148, 189–196. https://doi.org/10.1016/j.neuroimage.2017.01.012.
Benedek, M., Beaty, R., Jauk, E., Koschutnig, K., Fink, A., Silvia, P.J., Neubauer, A.C., 2014a. Creating metaphors: the neural basis of figurative language production. NeuroImage 90, 99–106. https://doi.org/10.1016/j.neuroimage.2013.12.046.
Benedek, M., Jauk, E., Fink, A., Koschutnig, K., Reishofer, G., Ebner, F., Neubauer, A.C., 2014b. To create or to recall? Neural mechanisms underlying the generation of creative new ideas. NeuroImage 88, 125–133. https://doi.org/10.1016/j.neuroimage.2013.11.021.
Bittner, J.V., Bruena, M., Rietzschel, E.F., 2016. Cooperation goals, regulatory focus, and their combined effects on creativity. Think. Skills Creat. 19, 260–268. https://doi.org/10.1016/j.tsc.2015.12.002.
Brigadoi, S., Ceccherini, L., Cutini, S., Scarpa, F., Scatturin, P., Selb, J., Cooper, R.J., 2014. Motion artifacts in functional near-infrared spectroscopy: a comparison of motion correction techniques applied to real cognitive data. NeuroImage 85, 181–191. https://doi.org/10.1016/j.neuroimage.2013.04.082.
Camacho, L.M., Paulus, P.B., 1995. The role of social anxiousness in group brainstorming. J. Pers. Soc. Psychol. 68, 1071–1080. https://doi.org/10.1037/0022-3514.68.6.1071.
Campion, M.A., Medsker, G.J., Higgs, A.C., 1993. Relations between work group characteristic and effectiveness: implications for designing effective work groups. Pers. Psychol. 46, 823–847. https://doi.org/10.1111/j.1744-6570.1993.tb01571.x.
Chaminade, T., Marchant, J.L., Kilner, J., Frith, C.D., 2012. An fMRI study of joint action-varying levels of cooperation correlates with activity in control networks. Front. Hum. Neurosci. 6, 179. https://doi.org/10.3389/fnhum.2012.00179.
Chang, C., Glover, G.H., 2010. Time-frequency dynamics of resting-state brain connectivity measured with fMRI. NeuroImage 50, 81–98. https://doi.org/10.1016/j.neuroimage.2009.12.011.
Charyton, C., Snelbecker, G.E., 2007. Engineers' and musicians' choices of self-descriptive adjectives as potential indicators of creativity by gender and domain. Psychol. Aesthet. Creat. Arts 1, 91–99. https://doi.org/10.1037/1931-3896.1.2.91.
Cheng, X., Li, X., Hu, Y., 2015. Synchronous brain activity during cooperative exchange depends on gender of partner: a fNIRS-based hyperscanning study. Hum. Brain Mapp. 36, 2039–2048. https://doi.org/10.1002/hbm.22754.
Chiu, P.H., Kayali, M.A., Kishida, K.T., Tomlin, D., Klinger, L.G., Klinger, M.R., Montague, P.R., 2008. Self responses along cingulate cortex reveal quantitative neural phenotype for high-functioning autism. Neuron 57, 463–473. https://doi.org/10.1016/j.neuron.2007.12.020.
Choi, H.S., Cho, S.J., Seo, J.G., Bechtoldt, M.N., 2016. The joint impact of collectivistic value orientation and independent self-representation on group creativity. Group Process. Inter. Relat. https://doi.org/10.1177/1368430216638539.
Cianci, A.M., Klein, H.J., Seijts, G.H., 2010. The effect of negative feedback on tension and subsequent performance: the main and interactive effects of goal content and conscientiousness. J. Appl. Psychol. 95, 618–630. https://doi.org/10.1037/a0019130.
Costa, P., McCrae, R., 1992. Revised NEO Personality Inventory (NEO-PI-R). Psychological Assessment Recourses, Lutz, FL.
Cui, X., Bryant, D.M., Reiss, A.L., 2012. NIRS-based hyperscanning reveals increased interpersonal coherence in superior frontal cortex during cooperation. NeuroImage 59, 2430–2437. https://doi.org/10.1016/j.neuroimage.2011.09.003.
Curşeu, P.L., Brink, T. t., 2016. Minority dissent as teamwork related mental model: implications for willingness to dissent and group creativity. Think. Skills Creat. 22, 86–96. https://doi.org/10.1016/j.tsc.2016.09.002.
Dai, B., et al., 2018. Neural mechanisms for selectively tuning in to the target speaker in a naturalistic noisy situation. Nat. Commun. 9, 2405.
Decety, J., Jackson, P.L., Sommerville, J.A., Chaminade, T., Meltzoff, A.N., 2004. The neural bases of cooperation and competition: an fMRI investigation. NeuroImage 23, 744–751. https://doi.org/10.1016/j.neuroimage.2004.05.025.
De Dreu, C.K., Baas, M., Nijstad, B.A., 2008. Hedonic tone and activation level in the mood-creativity link: toward a dual pathway to creativity model. J. Pers. Soc. Psychol. 94, 739–756. https://doi.org/10.1037/0022-3514.94.5.739.
Diehl, M., Stroebe, W., 1987. Productivity loss in brainstorming groups: toward the solution of a riddle. J. Pers. Soc. Psychol. 53, 497–509. https://doi.org/10.1037/0022-3514.53.3.497.
Dikker, S., Wan, L., Davidesco, I., Kaggen, L., Oostrik, M., McClintock, J., Poeppel, D., 2017. Brain-to-brain synchrony tracks real-world dynamic group interactions in the classroom. Curr. Biol. 27, 1375–1380. https://doi.org/10.1016/j.cub.2017.04.002.
Dommer, L., Jager, N., Scholkmann, F., Wolf, M., Holper, L., 2012. Between-brain coherence during joint n-back task performance: a two-person functional near-infrared spectroscopy study. Behav. Brain Res. 234, 212–222. https://doi.org/10.1016/j.bbr.2012.06.024.
Duan, L., Liu, W.-J., Dai, R.-N., Li, R., Lu, C.-M., Huang, Y.-X., Zhu, C.-Z., 2013. Cross-brain neurofeedback: scientific concept and experimental platform. PLoS ONE e64590. https://doi.org/10.1371/journal.pone.0064590.g001.
Dweck, C.S., 1986. Motivational processes affecting learning. Am. Psychol. 41, 1040–1048. https://doi.org/10.1037/0003-066X.41.10.1040.
Eisenberger, R., Aselage, J., 2009. Incremental effects of reward on experienced performance pressure: positive outcomes for intrinsic interest and creativity. J. Organ. Behav. 30, 95–117. https://doi.org/10.1002/job.543.
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. J. Biomed. Opt. 16, 077011. https://doi.org/10.1117/1.3602853.
Gilbert, S.J., Spengler, S., Simons, J.S., Steele, J.D., Lawrie, S.M., Frith, C.D., Burgess, P.W., 2006. Functional specialization within rostral prefrontal cortex (area 10): a meta-analysis. J. Cogn. Neurosci. 18, 932–948. https://doi.org/10.1162/jocn.2006.18.6.932.
Gilson, L.L., Shalley, C.E., 2004. A little creativity goes a long way: an examination of teams' engagement in creative processes. J. Manag. 30, 453–470. https://doi.org/10.1016/j.jm.2003.07.001.
Grinsted, A., Moore, J.C., Jevrejeva, S., 2004. Application of the cross wavelet transform and wavelet coherence to geophysical time series. Nonlinear Process. Geophys. 11, 561–566. 〈http://dx.doi.org/hal-00302394〉.
Guilford, J.P., 1967. The Nature of Human Intelligence. McGraw-Hill, New York.
Guijt, A.M., Sluiter, J.K., Frings-Dresen, M.H.W., 2007. Test-retest reliability of heart rate variability and respiration rate at rest and during light physical activity in normal subjects. Arch. Med. Res. 38, 113–120. https://doi.org/10.1016/j.arcmed.2006.07.009.
Hao, N., Xue, H., Yuan, H., Wang, Q., Runco, M.A., 2017. Enhancing creativity: proper body posture meets proper emotion. Acta Psychol. 173, 32–40. https://doi.org/10.1016/j.actpsy.2016.12.005.
Harvey, S., 2014. Creative synthesis: exploring the process of extraordinary group creativity. Acad. Manag. Rev. 39, 324–343. https://doi.org/10.5465/amr.2012.0224.
Hargadon, A.B., Bechky, B.A., 2006. When collections of creatives become creative collectives: a field study of problem solving at work. Organ. Sci. 4, 484–500. https://doi.org/10.1287/orsc.1060.0200.
Hattie, J., Timperley, H., 2007. The power of feedback. Rev. Educ. Res. 77, 81–112. https://doi.org/10.3102/003465430298487.
Heinonen, J., Numminen, J., Hlushchuk, Y., Antell, H., Taatila, V., Suomala, J., 2016. Default mode and executive networks areas: association with the serial order in divergent thinking. PLoS One 11, e0162234. https://doi.org/10.1371/journal.pone.0162234.
Holper, L., Goldin, A.P., Shalóm, D.E., Battro, A.M., Wolf, M., Sigman, M., 2013. The teaching and the learning brain: a cortical hemodynamic marker of teacher–student interactions in the Socratic dialog. Int. J. Educ. Res. 59, 1–10. https://doi.org/10.1016/j.ijer.2013.02.002.
Holper, L., Scholkmann, F., Wolf, M., 2012. Between-brain connectivity during imitation measured by fNIRS. NeuroImage 63, 212–222. https://doi.org/10.1016/j.neuroimage.2012.06.028.
Hoshi, Y., 2007. Functional near-infrared spectroscopy: current status and future

prospects. J. Biomed. Opt. 12, 062106. https://doi.org/10.1117/1.2804911.

Ikeda, S., Nozawa, T., Yokoyama, R., Miyazaki, A., Sasaki, Y., Sakaki, K., Kawashima, R., 2017. Steady beat sound facilitates both coordinated group walking and inter-subject neural synchrony. Front. Hum. Neurosci. 11, 147. https://doi.org/10.3389/fnhum.2017.00147.

Jahanshahi, M., Dirnberger, G., Fuller, R., Frith, C.D., 2000. The role of the dorsolateral prefrontal cortex in random number generation: a study with positron emission tomography. NeuroImage 12, 713–725. https://doi.org/10.1006/nimg.2000.0647.

Jang, K.E., Tak, S., Jung, J., Jang, J., Jeong, Y., Ye, J.C., 2009. Wavelet minimum description length detrending for near-infrared spectroscopy. J. Biomed. Opt. 14, 034004–034013. https://doi.org/10.1117/1.3127204.

Jiang, J., Dai, B., Peng, D., Zhu, C., Liu, L., Lu, C., 2012. Neural synchronization during face-to-face communication. J. Neurosci. 32, 16064–16069. https://doi.org/10.1523/JNEUROSCI.2926-12.2012.

Kleibeuker, S.W., Koolschijn, P.C., Jolles, D.D., De Dreu, C.K., Crone, E.A., 2013. The neural coding of creative idea generation across adolescence and early adulthood. Front. Hum. Neurosci. 7, 905. https://doi.org/10.3389/fnhum.2013.00905.

Knoch, D., Pascual-Leone, A., Meyer, K., Treyer, V., Fehr, E., 2006. Diminishing reciprocal fairness by disrupting the right prefrontal cortex. Science 314, 829. https://doi.org/10.1126/science.1129156.

Knoch, D., Schneider, F., Schunk, D., Hohmann, M., Fehr, E., 2009. Disrupting the prefrontal cortex diminishes the human ability to build a good reputation. Proc. Natl. Acad. Sci. USA 106, 20895–20899. https://doi.org/10.1073/pnas.0911619106.

Korde, R., Paulus, P.B., 2017. Alternating individual and group idea generation: finding the elusive synergy. J. Exp. Soc. Psychol. 70, 177–190. https://doi.org/10.1016/j.jesp.2016.11.002.

Larey, T.S., Paulus, P.B., 1999. Group preference and convergent tendencies in small groups: a content analysis of group brainstorming performance. Creat. Res. J. 12, 175–184. https://doi.org/10.1207/s15326934crj1203_2.

Lebuda, I., Galewska-Kustra, M., Glăveanu, V.P., 2016. Creativity and social interactions. Creat. Theor. - Res. - Appl. 3, 187–193. https://doi.org/10.1515/ctra-2016-0012.

Li, J., Xiao, E., Houser, D., Montague, P.R., 2009. Neural responses to sanction threats in two-party economic exchange. Proc. Natl. Acad. Sci. USA 106, 16835–16840. https://doi.org/10.1073/pnas.0908855106.

Lindenberger, U., Li, S.C., Gruber, W., Muller, V., 2009. Brains swinging in concert: cortical phase synchronization while playing guitar. BioMed. Cent. Neurosci. 10, 22. https://doi.org/10.1186/1471-2202-10-22.

Liu, Y., Piazza, E.A., Simony, E., Shewokis, P.A., Onaral, B., Hasson, U., Ayaz, H., 2017. Measuring speaker–listener neural coupling with functional near infrared spectroscopy. Sci. Rep. 7, 43293. ⟨http://dx.doi.org/10.1038/srep43293⟩.

Lloyd-Fox, S., Blasi, A., Elwell, C.E., 2010. Illuminating the developing brain: the past, present and future of functional near infrared spectroscopy. Neurosci. Biobehav. Rev. 34, 269–284. https://doi.org/10.1016/j.neubiorev.2009.07.008.

Lu, C.M., Zhang, Y.J., Biswal, B.B., Zang, Y.F., Peng, D.L., Zhu, C.Z., 2010. Use of fNIRS to assess resting state functional connectivity. J. Neurosci. Methods 186, 242–249. https://doi.org/10.1016/j.jneumeth.2009.11.010.

Lu, K., Xue, H., Nozawa, T., Hao, N., 2018. Cooperation makes a group be more creative. *Cerebral Cortex*. Online. https://doi.org/10.1093/cercor/bhy215.

Mansouri, F.A., Buckley, M.J., Tanaka, K., 2007. Mnemonic function of the dorsolateral prefrontal cortex in conflict-induced behavioral adjustment. Science 318, 987–990. https://doi.org/10.1126/science.1146384.

Mansouri, F.A., Tanaka, K., Buckley, M.J., 2009. Conflict-induced behavioural adjustment: a clue to the executive functions of the prefrontal cortex. Nat. Rev. Neurosci. 10, 141–152. https://doi.org/10.1038/nrn2538.

McCabe, K., Houser, D., Ryan, L., Smith, V., Trouard, T., 2001. A functional imaging study of cooperation in two-person reciprocal exchange. Proc. Natl. Acad. Sci. USA 98, 11832–11835. https://doi.org/10.1073/pnas.211415698.

Miller, E.K., Cohen, J.D., 2001. An integrative theory of prefrontal cortex function. Annu. Rev. Neurosci. 24, 167–202. https://doi.org/10.1146/annurev.neuro.24.1.167.

Nachev, P., Kennard, C., Husain, M., 2008. Functional role of the supplementary and pre-supplementary motor areas. Natl. Rev. Neurosci. 9, 856–869. https://doi.org/10.1038/nrn2478.

Nijstad, B.A., De Dreu, C.K.W., Rietzschel, E.F., Baas, M., 2010. The dual pathway to creativity model: creative ideation as a function of flexibility and persistence. Eur. Rev. Social. Psychol. 21, 34–77. https://doi.org/10.1080/10463281003765323.

Nozawa, T., Sasaki, Y., Sakaki, K., Yokoyama, R., Kawashima, R., 2016. Interpersonal frontopolar neural synchronization in group communication: an exploration toward fNIRS hyperscanning of natural interactions. NeuroImage 133, 484–497. https://doi.org/10.1016/j.neuroimage.2016.03.059.

Osaka, N., Minamoto, T., Yaoi, K., Azuma, M., Osaka, M., 2014. Neural synchronization during cooperated humming: a hyperscanning study using fNIRS. Procedia – Soc. Behav. Sci. 126, 241–243. https://doi.org/10.1016/j.sbspro.2014.02.395.

Osborn, 1953. Applied Imagination: Principles and Procedures of Creative Problem Solving. Scribner, New York, NY.

Osborn, 1957. Applied Imagination, 1st edition. Scribner's, New York.

Osborn, 1963. Applied Imagination: Principles and Procedures of Creative Problem Solving, Third Revised edition. Charles Scribner's Sons, New York, NY.

Pan, Y., Novembre, G., Song, B., Li, X., Hu, Y., 2018. Interpersonal synchronization of inferior frontal cortices tracks social interactive learning of a song. Neuroimage 183, 280–290. https://doi.org/10.1016/j.neuroimage.2018.08.005.

Petrican, R., Schimmack, U., 2008. The role of dorsolateral prefrontal function in relationship commitment. J. Res. Personal. 42, 1130–1135. https://doi.org/10.1016/j.jrp.2008.03.001.

Petrides, M., 2000. The role of the mid-dorsolateral prefrontal cortex in working memory. Exp. Brain Res. 133, 44–54. https://doi.org/10.1007/s002210000399.

Prabhu, V., Sutton, C., Sauser, W., 2008. Creativity and certain personality traits: understanding the mediating effect of intrinsic motivation. Creat. Res. J. 20, 53–66. https://doi.org/10.1080/10400410701841955.

Runco, M.A., 1991. Divergent Thinking. Ablex, Norwood, NJ.

Runco, M.A., Abdulla, A.M., Paek, S.H., Al-Jasim, F.A., Alsuwaidi, H.N., 2016. Which test of divergent thinking is best? Creat. Theor. – Res. – Appl. 3, 4–18. https://doi.org/10.1515/ctra-2016-0001.

Runco, M.A., Jaeger, G.J., 2012. The standard definition of creativity. Creat. Res. J. 24, 92–96. https://doi.org/10.1080/10400419.2012.650092.

Saad, G., Cleveland, M., Ho, L., 2015. Individualism–collectivism and the quantity versus quality dimensions of individual and group creative performance. J. Bus. Res. 68, 578–586. https://doi.org/10.1016/j.jbusres.2014.09.004.

Sanfey, A.G., Rilling, J.K., Aronson, J.A., Nystrom, L.E., Cohen, J.D., 2003. The neural basis of economic decision-making in the Ultimatum Game. Science 300, 1755–1758. https://doi.org/10.1126/science.1082976.

Scholkmann, F., Kleiser, S., Metz, A.J., Zimmermann, R., Mata Pavia, J., Wolf, U., Wolf, M., 2014. A review on continuous wave functional near-infrared spectroscopy and imaging instrumentation and methodology. NeuroImage 85, 6–27. https://doi.org/10.1016/j.neuroimage.2013.05.004.

Schoot, L., Hagoort, P., Segaert, K., 2016. What can we learn from a two-brain approach to verbal interaction? Neurosci. Biobehav. Rev. 68, 454–459. https://doi.org/10.1016/j.neubiorev.2016.06.009.

Seeley, W.W., Menon, V., Schatzberg, A.F., Keller, J., Glover, G.H., Kenna, H., Greicius, M.D., 2007. Dissociable intrinsic connectivity networks for salience processing and executive control. J. Neurosci. 27, 2349–2356. https://doi.org/10.1523/JNEUROSCI.5587-06.2007.

Selart, M., Nordström, T., Kuvaas, B., Takemura, K., 2008. Effects of reward on self--regulation, intrinsic motivation and creativity. Scand. J. Educ. Res. 52, 439–458. https://doi.org/10.1080/00313830802346314.

Singh, A.K., Okamoto, M., Dan, H., Jurcak, V., Dan, I., 2005. Spatial registration of multichannel multi-subject fNIRS data to MNI space without MRI. NeuroImage 27, 842–851. https://doi.org/10.1016/j.neuroimage.2005.05.019.

Sternberg, R.J., Lubart, T.I., 1996. Investing in creativity. Am. Psychol. 51, 677–688. https://doi.org/10.1037/0003-066X.51.7.677.

Stephens, G.J., Silbert, L.J., Hasson, U., 2010. Speaker-listener neural coupling underlies successful communication. Proc. Natl. Acad. Sci. USA 107, 14425–14430. https://doi.org/10.1073/pnas.1008662107.

Suzuki, S., Niki, K., Fujisaki, S., Akiyama, E., 2011. Neural basis of conditional cooperation. Social. Cogn. Affect. Neurosci. 6, 338–347. https://doi.org/10.1093/scan/nsq042.

Takeuchi, N., Mori, T., Suzukamo, Y., Izumi, S.I., 2017. Integration of teaching processes and learning assessment in the prefrontal cortex during a video game teaching-learning task. Front. Psychol. 7, 2052. https://doi.org/10.3389/fpsyg.2016.02052.

Tang, H., Mai, X., Wang, S., Zhu, C., Krueger, F., Liu, C., 2016. Interpersonal brain synchronization in the right temporo-parietal junction during face-to-face economic exchange. Social. Cogn. Affect. Neurosci. 11, 23–32. https://doi.org/10.1093/scan/nsv092.

Tekleab, A.G., Quigley, N.R., 2014. Team deep-level diversity, relationship conflict, and team members' affective reactions: a cross-level investigation. J. Bus. Res. 67, 394–402. https://doi.org/10.1016/j.jbusres.2012.12.022.

Tong, Y., Lindsey, K.P., Frederick, B.D., 2011. Partitioning of physiological noise signals in the brain with concurrent near-infrared spectroscopy and fMRI. J. Cereb. Blood Flow. Metab. 31, 2352–2362. ⟨http://dx.doi.org/10.1038%2Fjcbfm.2011.100⟩.

Tsuzuki, D., Jurcak, V., Singh, A.K., Okamoto, M., Watanabe, E., Dan, I., 2007. Virtual spatial registration of stand-alone fNIRS data to MNI space. NeuroImage 34, 1506–1518. https://doi.org/10.1016/j.neuroimage.2006.10.043.

Van Knippberg, D., De Dreu, C.K.W., Homan, A.C., 2004. Work group diversity and group performance: an integrative model and research agenda. J. Appl. Psychol. 89, 1008–1022. https://doi.org/10.1037/0021-9010.89.6.1008.

Vera, D., Crossan, M., 2005. Improvisation and innovative performance in teams. Organ. Sci. 16, 203–224. https://doi.org/10.1287/orsc.1050.0126.

Wang, X., Schneider, C., Valacich, J.S., 2015. Enhancing creativity in group collaboration: how performance targets and feedback shape perceptions and idea generation performance. Comput. Hum. Behav. 42, 187–195. https://doi.org/10.1016/j.chb.2014.02.017.

Wu, X., Yang, W., Tong, D., Sun, J., Chen, Q., Wei, D., Qiu, J., 2015. A meta-analysis of neuroimaging studies on divergent thinking using activation likelihood estimation. Hum. Brain Mapp. 36, 2703–2718. https://doi.org/10.1002/hbm.22801.

Xue, H., Lu, K., Hao, N., 2018. Cooperation makes two less-creative individuals turn into a highly-creative pair. NeuroImage 172, 527–537. https://doi.org/10.1016/j.neuroimage.2018.02.007.

Ye, J.C., Tak, S., Jang, K.E., Jung, J., Jang, J., 2009. NIRS-SPM: statistical parametric mapping for near-infrared spectroscopy. NeuroImage 44, 428–447. https://doi.org/10.1016/j.neuroimage.2008.08.036.

Yeo, G.B., Neal, A., 2004. A multilevel analysis of effort, practice, and performance: effects; of ability, conscientiousness, and goal orientation. J. Appl. Psychol. 89, 231–247. https://doi.org/10.1037/0021-9010.89.2.231.

Zheng, L., Chen, C., Liu, W., Long, Y., Zhao, H., Bai, X., Lu, C., 2018. Enhancement of teaching outcome through neural prediction of the students' knowledge state. Hum. Brain Mapp. 1–12. https://doi.org/10.1002/hbm.24059.

Zhou, J., 1998. Feedback valence, feedback style, task autonomy, and achievement orientation: interactive effects on creative performance. J. Appl. Psychol. 83, 261–276. ⟨http://dx.doi.org/002I-9010/98/S3.00⟩.