The enhancement effect of social interaction on emotional contagion: an EEG-based hyperscanning study

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Abstract

Emotional contagion refers to the tendency for individuals to replicate the emotional states of others primarily within the context of social interactions. Prior research has focused on real-time emotional contagion during interpersonal communication. However, this study proposed that social interaction experiences might also play a role in promoting emotional contagion. To investigate this issue, the present study divided participants into the interactive group and the control group and conducted EEG-based hyperscanning to investigate the impact of interpersonal interaction experience on emotional contagion. Behavioral results indicated that individuals reported a greater psychological closeness to their partners after experiencing interaction. Additionally, the interactive group showed stronger emotional congruence between observers and senders. EEG results further demonstrated that inter-brain synchrony in the emotional contagion phase among the observer and sender of the interactive group was significantly higher than that of the control group, particularly in the negative emotions. This research suggests that social interaction experience may affect emotional contagion by altering the interpersonal states. It also adds to our understanding of how social interactions can shape our emotional experiences and emphasizes that interpersonal experiences might be a key factor in promoting emotional contagion.

Introduction

Emotions can rapidly spread among individuals. It is a common phenomenon that laughter is contagious, mothers empathize with their children's pain, and friends naturally synchronize their emotions when together. Researchers have employed various terms to describe this phenomenon of one person "catching" another person's emotions, such as "emotional spread" and "emotional replication" (Dezecache, Jacob, et al., 2015). The most widely recognized term for this phenomenon is "emotional contagion". Scheler (2017) also referred to it as "psychic contagion" and provided an example of a person entering a bar and immediately absorbing the prevailing atmosphere of joy.

Some researchers use the mimicry theory to explain the mechanism behind emotional contagion (Hatfield et al., 1992, 1993, 2009). According to this theory, emotional contagion is based on the perception-action link and occurs through an automatic mimicry process of perceived actions. And one person's proprioceptive feedback induced by mimicking the actions leads them to experience the same emotional state as others, resulting in emotional convergence. For emotional contagion to occur, there must be a mirroring or "copying" of others' feelings (Darwall, 1998). This process is also deemed a fundamental form of empathy (Darwall, 1998; de Waal, 2012; Jackson et al., 2005).

The task used to study emotional contagion contains two roles: the observer and the sender. In some studies, the sender is presented as an emotional picture on a computer, and the observer is asked to rate his/her feelings of happiness and anger while viewing the picture (Lishner et al., 2008; Tamm et al., 2020). In other studies, the sender is a live person who expresses emotions (Dezecache et al., 2013; Hietanen et al., 2019). The observer watches the sender's facial expressions in real-time, attempting to feel with him/she (Anders et al., 2011; Kinoshita et al., 2019). However, it is important to note that these studies often take place in controlled environments, which lack the richness of signals that exist in natural settings.

Emotional contagion does not occur in isolation, but rather within the context of social interaction, such as between the teacher and students or actors and audiences. It also commonly occurs in the context of social relationships and is influenced by a variety of situational and social cues (Bourgeois & Hess, 2008). For example, when we see a friend or romantic partner sad, our mood is likely to be affected. However, this effect is rarely observed with strangers. Therefore, some research has investigated emotional contagion in social situations, such as during communication. For instance, in a face-to-face dialogue, researchers examined whether listeners mimic a speaker's facial expressions in a dyadic setting. Researchers also measured the listeners’ facial expressions while they listened to their partner recounting emotional events (Hess & Bourgeois, 2010; Stel & Vonk, 2010). These studies capture more natural interpersonal interaction scenarios, as face-to-face conversations provide visible and audible social communication resources that not only include facial expressions, but also words, prosody, gestures, gaze direction and duration, body orientation, and objects in the shared environment.

However, previous research remains two common limitations to be addressed. Firstly, although emotional contagion can be triggered in various situations, such as sharing stories or discussing video fragments that individuals watched beforehand (Hess & Bourgeois, 2010; Stel & Vonk, 2010), there is a lack of direct comparison between the effects of emotional contagion in interactive and non-interactive situations, which prevents us from further understanding the facilitative effect of interpersonal interaction on emotional contagion. Secondly, the significance of human interaction experiences is not emphasized. A more comprehensive examination of the meaning of interpersonal interaction is necessary.

Because some behaviors could occur both during and after the interaction. In other words, interaction is meaningful for the behaviors that happened in it and also affects subsequent behaviors due to changes in social relationship state, such as changes in one's sense of belongingness (Sandstrom & Dunn, 2014). The changes in the social relationship state could lead to increased or reduced mimicry. Hühnel et al. (2018) investigated emotional mimicry to younger and older actors following an encounter with virtual partners of different age groups in a cyber game. The cyber game consisted of two situations: the first was the completely excluded situation where the participants were excluded by both younger and older partners, and the second was the partially excluded situation where the younger partners excluded the participants, but the older partners accepted them. The results revealed a higher level of mimicry to older actors following the partially excluded situation compared to the completely excluded situation, suggesting that an increased sense of belongingness in interpersonal interactions promoted emotional contagion. Individuals were more likely to become emotionally congruent with the closer partner.

Imagine this scenario: You are at a party and see two unfamiliar individuals. However, your friend tells you that you had non-face-to-face contact with one of them in online gaming. Does this prior experience make you more susceptible to his/her emotions? The present study still explores emotional contagion occurring in the context of interpersonal interaction. The difference from previous studies is that the present study does not embed emotional contagion in any of activities that happen at the same time. In other words, emotional contagion in this study is not focused during the interaction but rather after it. The research aims to investigate whether, after experiencing interaction, the observer shows more emotional convergence when the sender merely presents the observer with emotional facial expressions, without supplementary social cues such as verbal content, prosody, or gestures. If this proves to be the case, it suggests that emotional contagion in social interactions is not solely influenced by a combination of other social cues like tone of voice, gestures, and eye gaze – as explored in previous studies – but also by changes in interpersonal factors, such as perceived closeness or likability shaped by recent experience.

The present study adopted cooperation as a form of interaction. Participants were paired and divided into two groups: the cooperation group, where two participants in the interaction phase needed to work together in a non-face-to-face manner, and the control group, where the task was performed independently by each participant. The following emotional contagion phase adopted a classic task in which one participant in each dyad acted as the observer, while another participant acted as the sender, expressing both sad and happy emotions to the observer. It is worth noting that the difference in the contagion effect caused by valence is not the focus of this study, as the arousal of real time emotions expressed by the senders is hard to be consistent.

The study employed likability and perceived closeness to the partner as indicators to assess changes in interpersonal relationship characteristics resulting from the interaction. Additionally, empathy was measured to control its impact on the results. Individuals with high levels of empathy are more likely to exhibit emotional contagion because they share and feel with others, driven by their motivation to show care and concern (Andreychik & Migliaccio, 2015). Emotional regulation ability was also measured, as individuals use emotion regulation strategies to prevent themselves from experiencing certain emotions (Cameron & Payne, 2011).

To measure the effect of emotional contagion, we not only collected participants' subjective feelings but also utilized electroencephalography (EEG) - based hyperscanning technology. Hyperscanning allows us to explore the real-time brain-to-brain coupling between individuals, as the neural basis of contagion lies in the "interaction" of signals between their brains. Previous research have used hyperscanning to examine the impact of interpersonal interaction on emotion perception (Zhu et al., 2018) and to investigate emotional inter-brain synchrony (IBS) during music production (Acquadro et al., 2016; Babiloni et al., 2011, 2012). IBS, which is based on multiple exchanges of sensory signals between individuals (Hari et al., 2013; Hasson & Frith, 2016; Konvalinka & Roepstorff, 2012), refers to the tendency of one person to be coupled or synchronized with others during interaction (Golland et al., 2015; Hasson et al., 2012; Hasson & Frith, 2016; Kinreich et al., 2017).

The hypothesis posited that participants in the cooperation group would be more susceptible to their partner's emotions compared to those in the control group. It was expected to observe this effect not only in the convergence of emotional responses, as reflected in the subjective evaluations of observers in the interaction group being more aligned with the emotions expressed by their peers (senders), but also at the neural level, with higher levels of IBS exhibited by dyads in the cooperation group compared to the control group. Moreover, the present study anticipated that the evaluation of likability or/and perceived closeness to partners would increase after engaging in cooperation.

Method

Participant

To detect a medium effect size (0.25) with power (1 - β) = 0.80 and α = 0.05, the minimum sample size recommended by G*power (Faul et al., 2007) is 34. A total of 40 dyads of undergraduates and graduates from multiple universities participated in this research. They were paid for participating in the experiment. All participants self-reported having no history of mental illness and had normal vision or corrective vision. The research procedures were approved by the Ethics Review Committee at local university to ensure compliance with ethical guidelines.

Participants were randomly assigned to forty dyads, with 21 dyads assigned to the cooperation group and 19 dyads assigned to the control group. Within each dyad, one participant was randomly designated as the sender, while another was the observer. Prior to the beginning of the tasks, participants were asked if they were acquainted with each other. Due to equipment malfunctions, data from one dyad in the cooperation group was not recorded, resulting in a final sample of 20 dyads in the cooperation group. Table 1 presents the demographic information of the participants.

Table 1

The demographic information of participants.

Group	Number of dyads	Mean age (SD)
Cooperation	20	19.88 (2.37)
Control	19	20.66 (2.03)

Procedure

The experimenter introduced the participants the experimental procedure, emphasizing the importance of completing tasks carefully. After signing the informed consent form, participants were seated in front of their monitors respectively. They were not allowed to communicate with each other during the tasks. To prevent visual and action communication between them, the two monitors were positioned back-to-back.

Step 1. Filling out questionnaires

The Chinese version of Interpersonal Reactivity Index (C-IRI) (Rong et al., 2010) is a measure of empathy and consists of a total of 28 items using a 5-point Likert scale ranging from "totally inconsistent" to "totally consistent". Nine items were reverse-scored and converted accordingly. A higher total score on the C-IRI indicates a greater level of empathy. In the present research, the Cronbach's alpha for the C-IRI was 0.81.

Emotion Regulation Questionnaire (ERQ) (WANG et al., 2007) measures emotional regulation ability and consists of 10 items using a 7-point Likert scale, with 1 indicating "completely disagree" and 7 indicating "completely agree". A higher total score on the ERQ indicates more frequent use of emotional regulation strategies. In the present research, the Cronbach's alpha for the ERQ was 0.71.

Additionally, participants evaluated their initial impressions of their partners, which involved two items: 1. "how much you like your partners" and 2. "your psychological distance from your partners". Both items used a 5-point scale, with higher scores indicating greater likability or a closer psychological distance to the partner.

Step 2. Completing the button-pressing task.

The button-pressing task, adapted from Li et al. (2021), varied between the cooperation and control groups.

In the cooperation group, participants were assigned as either participant #1 or participant #2. The displays on their screens were synchronized, allowing them to view the same stimuli simultaneously. Each trial involved the presentation of a circle with a diameter of 3 cm in the center of the screen for 300 ms. The circle appeared in one of three colors: green, blue, and yellow. If the circle appeared in yellow, participant #1 was required to press the "Z" key on the keyboard, while participant #2 did not need to react. If the circle was green, participant #2 pressed the "M" key, and participant #1 did not need to react. If the circle was blue, both participant #1 and participant #2 were instructed to press their respective keys simultaneously ("Z" for participant #1 and "M" for participant #2). Each color appeared 10 times, resulting in a total of 30 trials. Feedback was provided for each reaction. In trials involving individual reactions (yellow or green circles), if the reaction time for pressing the "Z" or "M" key was between 80 ms and 300 ms, the feedback presented on the screen indicated a "win". If there was no reaction, the wrong key was pressed, or the pressing time fell outside the 80-300 ms range, the feedback indicated a "lose". In trials involving joint reactions (blue circles), the feedback was based on the time difference between pressing the "Z" key and the "M" key. If the time difference was less than the sum of respective reaction times divided by 8, the feedback was "win". However, if the latency difference between the two pressings exceeded the sum of their individual times divided by 8, the screen displayed "+" and "-" symbols. Specifically, if the "Z" key was pressed faster than the "M" key, the "+" symbol appeared on the left half of the screen, while the "-" symbol appeared on the right half. Conversely, if the "Z" key was pressed slower than the "M" key, the "-" symbol appeared on the left half of the screen, while the "+" symbol appeared on the right half. In addition, if the buttons pressed did not include the "Z" or "M" keys, the feedback provided was "lose." The primary goal of the dyads in the cooperation group was to maximize the occurrence of "win" feedback. A bonus was awarded based on the number of wins achieved.

Unlike the cooperation group, participants in the control group completed the task independently. Their screens were not synchronized. For green circles, the participants should press the "Z" keys. For yellow circles, they should press the "M" keys. For blue circles, they pressed both the "Z" and "M" keys simultaneously by themself. The feedback mechanism was consistent with that of the cooperation group. Each participant aims to accumulate as much "win" feedback as possible. As with the cooperation group, the more "win" received, the more bonus they received.

To ensure participants understood the requirements of the task, both the cooperation and control groups completed a practice session before the task.

Step 3. Assessing partner impressions.

After completing the button-pressing task, participants were asked to evaluate their feelings of likability and psychological closeness towards their partners, using the same measures as in Step 1.

Step 4. Conducting the emotional contagion.

EEG signals were recorded in this phase.

Within each dyad, participant #1 acted as the sender, mimicking dynamic facial expressions shown on his/her monitor, which were not displayed on participant #2's screen. A camera captured participant #1's expressions and streamed them to participant #2's monitor in real-time. Meanwhile, participant #2, the observer, watched participant #1's expressions without access to the original expression stimuli on the sender's screen.

The task included two blocks: a positive block with five joyful expressions and a negative block with five sad expressions, each expression lasting 7 s. The sequence of the two blocks was randomized for each dyad. Prior to the task, pairs engaged in a practice session to ensure a clear understanding of the requirements.

Before and after each block, participants completed a subjective rating on a 5-point scale that assessed their emotional state, with 1 representing "very negative" and 5 signifying "very positive".

EEG acquisition

EEG signals were collected at 500 Hz by two Neuroscan amplifiers which were connected to synchronize the recording. Curry 8 acquisition software was used to digitalize EEG signals. Sixty-four electrodes in each cap were placed at the 10 - 20 international position system. Impedances were kept below 10 kΩ.

Analysis and Results

Personal characteristic

Emotional regulation ability and empathy. A 2 (Group: interaction vs control) * 2 (Role: sender vs observer) between-subjects ANOVA was conducted to test the difference in scores of ERQ and C-IRI respectively. The results showed that neither the main effects nor the interaction effects were significant (*ps* > .335).

Interpersonal state

Likeability. The observer and sender's evaluation of the likability to each other pre- and post- the button-pressing task was shown in Figure 1(left panel). A paired sample *t*-test analysis was conducted to evaluate the variance of likeability. The results showed that neither the sender nor the observer changed in their likeability for their partner, not only in the control group but also in the cooperation group (*ps* >.109), indicating that the cooperation did not significantly impact participants' perceptions of likability towards their partners.

Closeness. The observer and sender's evaluation of the closeness to each other pre- and post- the button-pressing task was shown in Figure 1 (right panel). Using paired sample *t*-test analysis to explore the difference in perceived closeness to the partner pre- and post- the button-pressing task. The results demonstrated that in the cooperation group, the observer (t (19) = 2.5, p = .022, 95%CI [-1.42 -.12], d = .77) and the sender (t (19) = 2.8, p = .01, 95%CI [-1.5 -.24], d = .93) felt more closeness to each other. The same pattern also occurred in the senders (t (18) = 3.09, p = .006, 95%CI [-1.13 -.21], d = .97) to the observers in the control group, but observers' perceptions of closeness to senders did not increase significantly (p = .33).

Effect of emotional contagion

Observers' emotional contagion effect was the focus of the study (Figure 2). It was tested by comparing the scores of pre- and post-task subjective ratings in two groups. A 2 (Group: cooperation vs control) * 2 (Order: pre- vs post-) ANOVA was performed to explore how the observer's emotions were affected by the sender in both negative and positive conditions. Additionally, the relationship between the sender and the observer was accounted for as a covariate. Consistently found in both positive and negative conditions, the main effect of the Order was significant. Observers' emotion turned more negative after observing the sender's sad expression (F (1) = 37.48 p < .001, η_p^2 = .50), and more positive after observing the sender's joy expression (F (1) = 41.65 p < .001, η_p^2 = .52). Neither the Group main effect nor the interaction effect was significant in either the positive or negative conditions (*p*s > .20).

The association between the emotional state scores of observers and senders after the emotional contagion phase was investigated using Pearson correlation coefficients (Figure 3). In the control group, the correlation was not significant (r = -0.07, p = .69). In the cooperation group, there was a significant positive correlation (r = 0.36, p = .02).

EEG data analysis and results

Pre-processing of EEG

All pre-processing steps were performed in EEGLAB (Delorme & Makeig, 2004) and MATLAB (R2020b). First, data from the rest and practice segments was deleted and only the data for the formal tasks was reserved. The quality of the EEG signals was then preliminarily checked visually, and those that were abnormal were removed. The bandpass filtering was 0.5 – 60 Hz. Muscle, heartbeat, and blink artifacts were identified using independent component analysis (ICA) (Bell & Sejnowski, 1995) and removed if the possibility was over 90%.

Phase Locking Value (PLV) was employed as the index of IBS. PLV detects the phase consistency within a temporal window (i.e. 7 s) between EEG signals from the coupled brains, ranging from 0 (indicating no synchronization) to 1 (indicating complete synchronization or phase-lock) (Lachaux et al., 1999; Marriott Haresign et al., 2022). The measurement of phase locking within a temporal window can be found in Marriott Haresign et al. (2022). At each sampling point, we average the phase obtained from the five expressions for each block. The PLV was computed using Hilbert transfer for specific frequency bands: delta (1-4 Hz), theta (5-8Hz), alpha (9-12Hz), and beta (13-30Hz).

According to previous studies (Hu et al., 2018; Sänger et al., 2012), 21 electrodes were selected from 64 electrodes in each participant’s cap, constituting the electrodes of interest for further analysis: Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, P8, O1, Oz, and O2. This selection resulted in a total of 441 (21 × 21) electrode pairs for each dyad.

IBS in the emotional contagion phase

Independent sample *t*-test was used to examine the differences in IBS of dyads between the control group and the cooperation group (Figure 4). Notably, in the negative condition for the delta and alpha bands, the results demonstrated greater PLVs between the two brains of the sender and observer in the cooperation compared to control groups ($ts > 2.03$, $ps < .05$, $ds > .67$). Specifically, in the delta band, the connections with higher PLVs in the cooperation group were predominantly located in the anterior regions of the two brains. In the alpha band, the higher PLVs were mainly observed in the connections between the sender (or observer)'s frontal and the observer (or sender)'s posterior brain regions.

For the positive condition, the results indicated greater PLVs between the two brains of the sender and observer in the cooperation group compared to the control group ($ts > 2.05$, $ps < .05$, $ds > .68$), and these differences were observed in the theta and alpha bands. However, no specific clustered distribution of connections was evident in any brain regions.

Permutation test

While IBS in hyperscanning studies was often posited to reflect real-time social interactions, alternative explanations such as stimulus similarity, action similarity, or similar spontaneous rate in a common dominant frequency have been suggested (Burgess, 2013; Hu et al., 2021; Zamm et al., 2021). The permutation test was employed to exclude the coincidental synchrony and ascertain the specificity of identified IBS to real-time interactive behavior. The ordering of time segments within 7 s was shuffled. The shuffle was performed 200 times (Cohen, 2014), providing 200 random PLV scores for each pair of electrode connections. The real PLV score was then compared with the random PLV scores obtained from 200 random iterations via the *p*-value threshold of 0.05. If the phase locking was purely attributable to the fact that both brains oscillate at the same rhythm in a rather constant way, the time-scrambled data and the real data would show similar levels of phase locking. On the contrary, if a substantial part of the phase-locking depends on the real-time interaction between the two participants, real data would show higher PLV than scrambled data. All possible electrode connections were statistically tested in cooperation (a total of 70560 connections, $(21 \text{ electrodes/participant})^2 \times 20$ dyad × 2 conditions × 4 bands) and control (a total of 67032 connections, $(21 \text{ electrodes/participant})^2 \times 19$ dyad × 2 conditions × 4 bands) group.

The results showed that in both the cooperative and control groups, all real PLVs were significantly greater than the random PLVs ($ts > 65.51$, $ps < .001$).

Discussion

The present research explored the impact of interactive experiences on emotional contagion, utilizing EEG-based hyperscanning. The behavioral findings revealed that observers' emotional states became more aligned with their partners' emotions after observing their facial expressions. Specifically, exposure to a partner's positive expression enhanced the observer's happiness, while a negative expression led to increased sadness. This pattern was evident in both interactive and non-interactive groups. Further, a significant positive correlation between the emotional states of the observer and the sender was observed in the interactive group. Control analysis showed that there was no difference in empathy and emotional regulation strategies between cooperation and control groups. This suggested that interaction experience amplified emotional contagion from the sender to the observer. For EEG results, there were distinct differences in interpersonal neural coupling between the cooperation and control groups. In the cooperation group, the IBS of the dyad was significantly higher, especially in the delta band under negative conditions. These EEG findings aligned with prior research (Balconi et al., 2015; Balconi & Maria Elide Vanutelli, 2017), which demonstrated increased delta and theta band activity in response to negative stimuli. It was hypothesized that this greater activation was associated with emotional involvement in social processes, like empathy. The permutation test demonstrated that the relatively consistent phase changes of two signals were mainly caused by the real-time interaction, not by the common dominant frequency.

The current study proposed that interaction experiences enhanced emotional state alignment between observers and senders by fostering closer relational proximity. The perceived psychological distance between observers and senders was reduced following cooperation tasks. However, this effect was not observed in the control group, where the psychological distance from observers to senders remained unchanged. Supporting our findings, previous research indicate that emotional contagion is modulated by the relationship between the observer and the sender (Dezecache, Eskenazi, et al., 2015; Hess &

Bourgeois, 2010). It is more likely for individuals to mimic the emotional expressions of those they perceive as similar or socially close (de Waal, 2008), those they like or love (Lakin et al., 2003; McIntosh, 2006), and in-group members or those they expect to cooperate with (Hess & Bourgeois, 2010).

Despite the absence of extensive social cues while observing the sender’s facial expressions, the changes in interpersonal state brought about by interactive experiences significantly enhance emotional contagion. Even though the interpersonal connection is established by non-face-to-face interactions. Two key components in the cooperation task likely contribute to the closeness in psychological distance. The first is joint attention, an essential aspect of collaboration where individuals coordinate their focus on a common goal or entity (Tomasello et al., 2005), different from shared attention where the focus is on each other (Redcay et al., 2010). This coordination lays the foundation for cooperation (Pleyer & Lindner, 2014; Tomasello & Gonzalez-Cabrera, 2017), as seen in infants using pointing gestures to communicate needs (Liszkowski et al., 2008). The previous study show that shared focus increases feelings of social connection (Wolf et al., 2016). In that study, researchers employed a between-subjects design where pairs of participants were seated adjacent to each other, facing a common screen. The experiment involved a cognitive task wherein cues were used to direct the participants' gaze either toward the same or different locations on the screen. This setup was intended to elicit experiences of either joint or non-joint attention. During sessions of joint attention, cues appeared on the same side of the screen, requiring participants to focus on and respond to an identical stimulus, thus overlapping their visual fields of attention. Conversely, in non-joint attention sessions, the cues for each participant were displayed in distinct areas of the screen, prompting them to engage with different stimuli and resulting in separate attentional fields. Results indicated that merely sharing a field of view with another individual fostered a sense of connection to them. In another study (Wolf & Tomasello, 2020), a 2.5-year-old child was presented with an unfamiliar adult who either engaged in watching a movie with this child or read a book independently. The researcher measured the child's willingness to approach this unfamiliar adult. Results showed that children who shared the movie-watching experience with adults tended to approach them more readily, implying that joint attention and shared experiences foster a sense of social closeness in young children. In our study, participants of the cooperation group were asked to simultaneously focus on and react to identical stimuli on a screen, effectively achieving joint attention despite not meeting each other and using different screens. In contrast, the control group involved participants completing tasks individually, without any need for coordinating their responses, as they were presented with different stimuli. This setup did not establish a joint attention scenario.

Another explanation is that shared emotional experience during the cooperation task enhances intimacy. In each trial, participants received feedback on their success or failure. Both outcomes, whether contributing to or impeding their common goals, led to shared emotional experiences, fostering a sense of connection. Supporting this view, Golland et al. (2019) demonstrated that shared emotional experiences strengthen interpersonal bonds. In their study, pairs of strangers watched an emotionally charged film together, without any interaction during the viewing. The film served as an emotional catalyst, triggering participants’ emotional responses. After each film, participants assessed their emotional states and reported their feelings of affiliation towards each other at the end. Results showed that dyads displayed the same emotional state as the emotional valence of the movie. And the synchrony of facial muscle activity while watching the movie could predict the evaluation of the affiliative feelings for their partners.

The present study underscores the importance of interactive experiences in emotional contagion. One of the key findings suggested that emotional congruence between individuals could be facilitated even through non-face-to-face interactions. Unlike previous studies that focus on the interpersonal context in which the emotional contagion occurred, this study specifically focuses on the role of changes in interpersonal state driven by interaction, highlighting that the promotion of emotional contagion in social contexts does not solely rely on the accumulation of social cues in communication. Non-face-to-face contact also underscores how the growing reliance on the internet and mobile communication technologies is changing the ways we experience and cultivate closeness, extending to both existing relationships and interactions with strangers. In addition, in this study, a perceived reduction in psychological distance stems from interactions characterized by shorter duration and lower emotional intensity, rather than from long-term, firm social relationships. This demonstrates that brief interactive experiences carry substantial importance. Sometimes, they are also crucial to our overall well-being (Sandstrom & Dunn, 2014).

In summary, this study explores whether prior interactive experiences facilitated emotional contagion among individuals. This study also has some limitations. For instance, the cooperation conducted in this study represents a form of positive interaction. However, beyond cooperation, competition is another fundamental form of interaction. Whether and how negative interaction experiences, such as competition, influence emotional contagion is indeed a question worthy of exploration, as it adds depth to our understanding of the dynamics of emotional contagion in varying interaction contexts.

Declarations

Author Contribution

Conceptualization: HW and WC, Data curation: HW, XG, CX and WC, Methodology: HW and WC, Formal analysis: HW and WC, Writing and editing: HW and WC.

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Figures

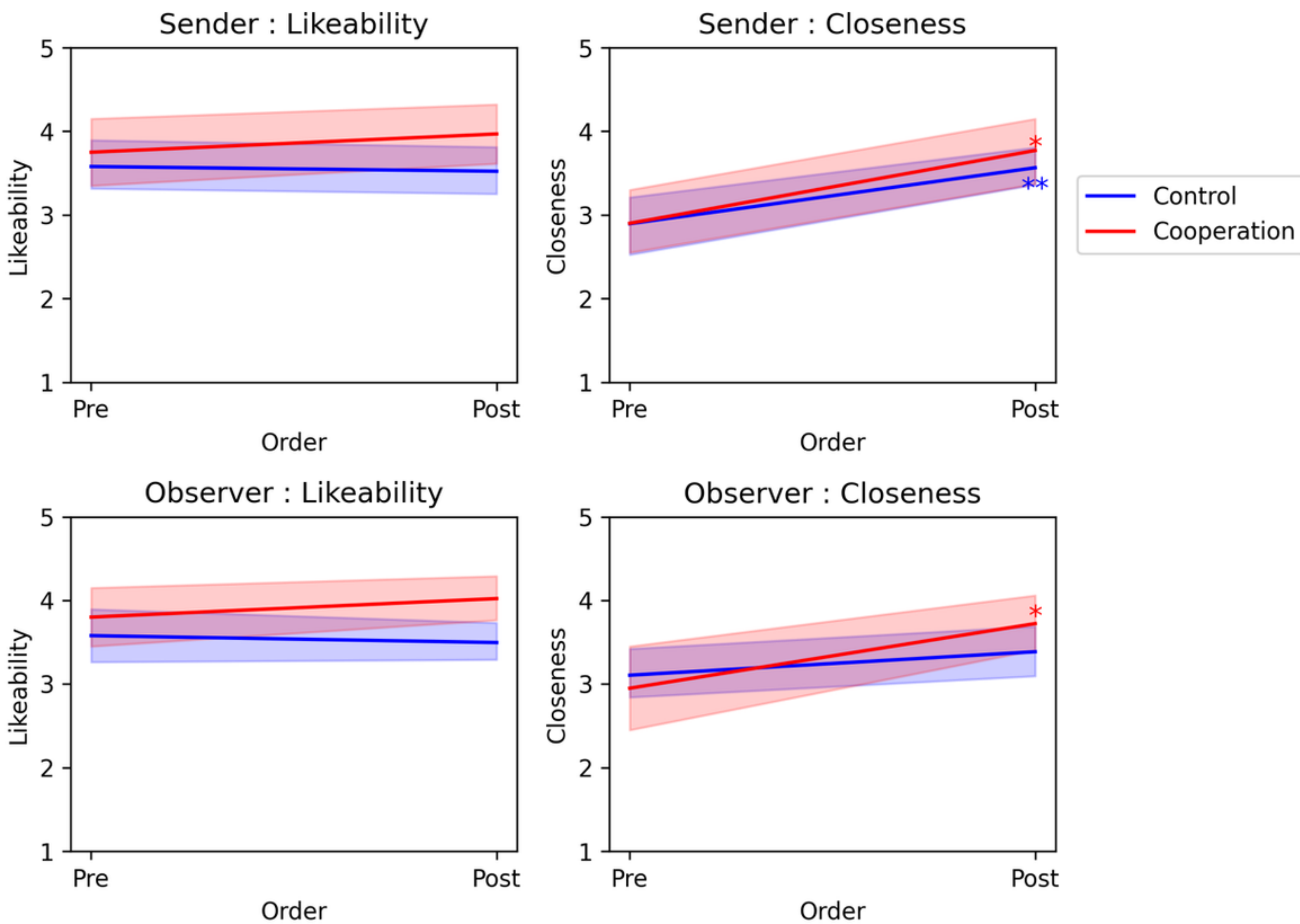

Figure 1

The estimation of interpersonal states in cooperation and control groups. Scores of pre- and post- button-pressing task were compared using the *t*-test. Upper left: the sender's rating of likeability to the observer. Lower left: the observer's rating of likeability to the sender. Upper right: the sender's rating of closeness to the observer. Lower right: the observer's rating of closeness to the sender. "Pre" refers to measurements taken before the button-pressing task, and "Post" refers to measurements taken after the task. * $p < .05$, ** $p < .01$.

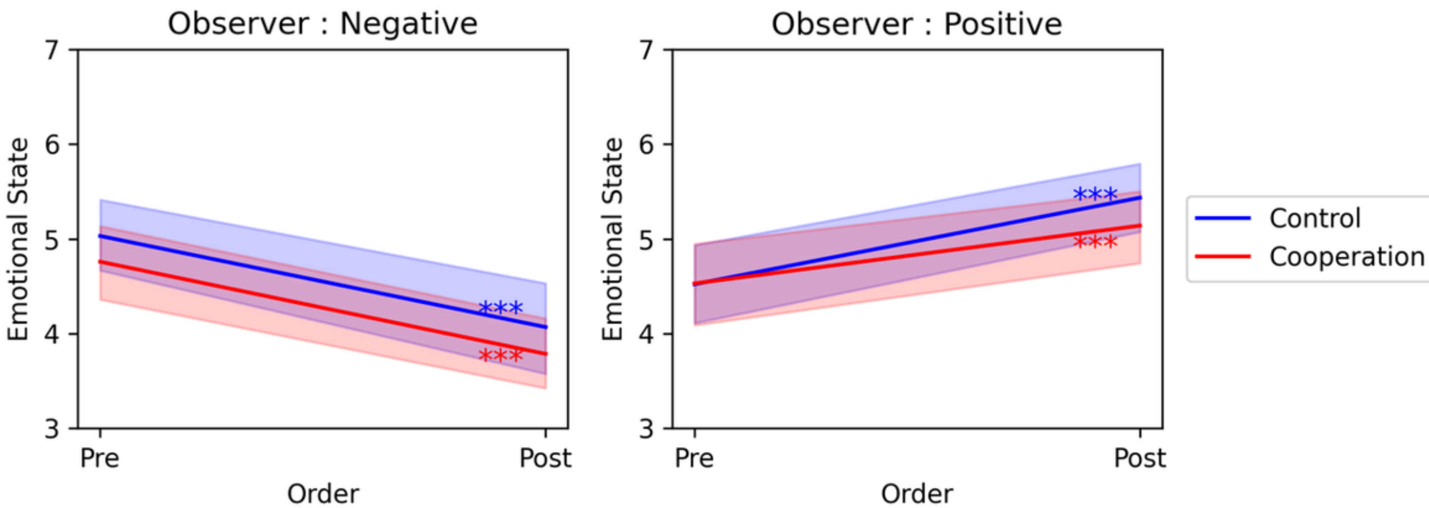

Figure 2

The estimation of emotional states. The scores of the emotional state before the emotional contagion task were compared with those after the emotional contagion task in the negative (left) and positive (right) conditions. "Pre" refers to measurements taken before the emotional contagion task, and "Post" refers to measurements taken after the emotional contagion task. *$p < .05$, ** $p < .01$.

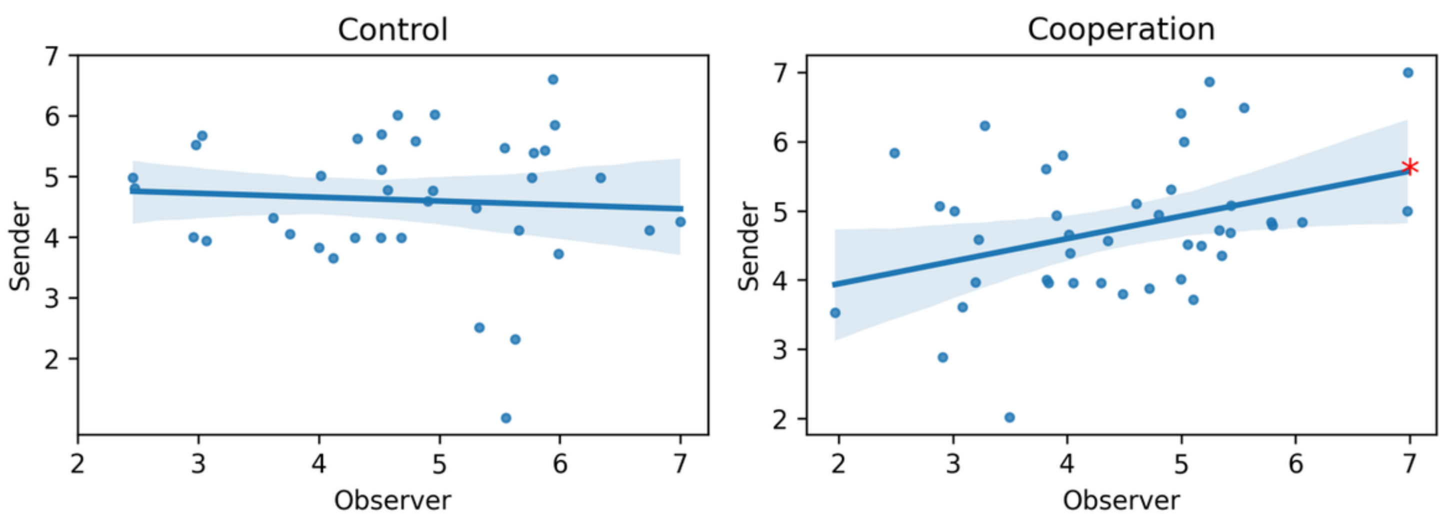

Figure 3

The correlation of emotional state between the observer and sender in the control (left) and cooperation (right) groups. The x-axis and y-axis are the observer's and sender’s scores respectively. * $p < .05$.

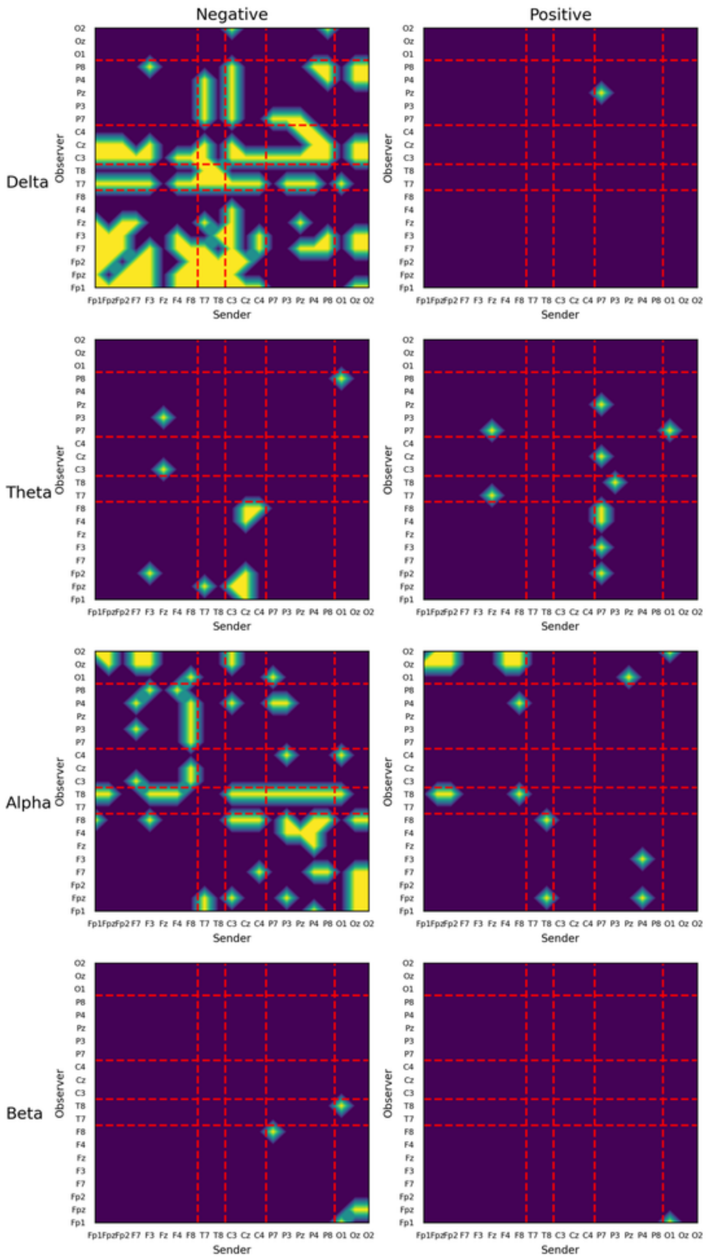

Figure 4

The difference between PLV in the cooperation group with PLV in the control group. Yellow indicated that the PLV of the cooperation group was significantly greater than that of the control group. The x-axis and y-axis showed the electrodes of interest. The red dots lines represented boundaries between different regions of the brain. For example, the electrodes surrounded by the red dot lines in the lower left corner were placed in the frontal area.