Biological Psychology 176 (2023) 108465

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Journal:	Biological Psychology
Manuscript ID	BIOPSY-D-22-00152_R3
Manuscript Type:	Empirical Article
Date Submitted by the Author:	n/a
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Keywords:	Eye contact; Skin conductance; Heart rate; EMG; Multi-person interaction

Skin conductance, Facial EMG, and Heart Rate Responses in Multi-person Gaze Interactions

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Highlights

•Participants were observing two persons who could look at each other (eye contact).

•Observing eye contact between two persons did not elicit vicarious responses.

•Either one or two of these persons could also send direct gaze to the participant.

•SCR and zygomatic EMG responses were greater to direct gaze sent by two persons.

•HR deceleration response was greater to direct gaze sent by just one person.

Abstract

Previous literature has reported enhanced affective and attentional responses to faces with a direct vs. averted gaze. Typically, in these studies, only single faces were presented. However, daily social encounters often involve interaction with more than just one person. By employing an experimental set-up in which the participants believed they were interacting with two other persons, the present study, for the first time, investigated participants' skin conductance, facial electromyographic (EMG), and heart rate deceleration responses in multi-person eye contact situations. Responses were measured in two different social contexts; i) when the participants observed eye contact between two other persons ('vicarious eye contact effect'), and ii) when the participants themselves received direct gaze either from one or two persons. The results showed that the skin conductance, facial EMG, and heart rate deceleration responses elicited by observing two other persons making eye contact did not differ from those elicited by observing one person looking at the other while the other person was not reciprocating with their gaze. As a novel finding, the results showed that receiving direct gaze from two persons elicited greater affective arousal and zygomatic EMG, but smaller heart rate deceleration responses in participants than receiving direct gaze from one person only. The findings are thoroughly discussed and it is concluded that physiological responses in multi-person interaction contexts are influenced by many social effects between the interactors and can be markedly different from those observed in two-person interactions.

Keywords: Eye contact; Skin conductance; Heart rate; EMG; Multi-person interaction

1. Introduction

Eye contact has a variety of effects on people's cognition and emotion. A perceived direct gaze automatically captures the beholder's attention, influences memory functions, enhances self-awareness, and activates pro-social behaviors and positive appraisals of others (Senju & Johnson, 2009; Conty et al., 2016). Direct gaze also modulates observers' emotions typically resulting in affectively positive reactions when the effects of other emotional, contextual factors have been controlled (for a review, see Hietanen, 2018). Psychophysiological studies have shown, for example, that observing direct gaze as compared with averted gaze elicits larger skin conductance (SCR) and pupil dilation responses associated with physiological (affective) arousal (e.g., Nichols & Champness, 1971; Porter et al., 2006; Helminen et al., 2011; Jarick & Bencic, 2019; Prinsen & Alaerts, 2019), relatively greater electroencephalographic (EEG) activity in the left than right frontal areas associated with approach motivational tendency (Hietanen et al., 2008; Pönkänen et al., 2011), and increased electromyographic (EMG) activity of the *Zygomaticus major* muscle (the muscle that elevates the corners of the mouth) (Hietanen et al., 2018; Hietanen et al., 2020; Hietanen & Peltola, 2021; Kiilavuori et al., 2021) associated with positively valenced affective and affiliative reactions. Psychophysiological studies have also shown that perception of another's direct gaze induces a more pronounced heart rate deceleration response (Akechi et al., 2013; Myllyneva & Hietanen, 2015a; Tsuji & Shimada, 2015; Kiilavuori et al., 2021), a response associated with attentional orienting toward external stimuli.

So far, the studies investigating affect and attention related psychophysiological responses to seeing another individual's direct gaze have investigated the effects when the participants themselves have been the target of another person's direct gaze (i.e., from the first-person perspective). However, emotions can be elicited not only when experiencing an emotional event directly (first-hand emotion) (Wondra & Ellsworth, 2015), but also vicariously, i.e., when an individual observes another person experiencing an emotion or observes another person in an emotionally evocative situation, even if the situation is not immediately relevant to the observer (Niedenthal & Brauer, 2012; Wondra & Ellsworth, 2015). This prompted us to ask whether observing two other individuals making eye contact, i.e. eye contact from a third-person perspective, would elicit affect and attention related psychophysiological responses similar to those triggered when experiencing eye contact from a first-person perspective. In other words, is there a *vicarious eye contact effect?*

Vicarious emotions can provide useful information to the observers. They can help individuals regulate their own behavior in order to respond to others in an appropriate way, and thus facilitate social interaction (Galinsky et al., 2005; Paulus et al., 2013). The phenomenon of vicarious emotions is pervasive. People feel vicarious anger when they perceive unfair treatment of others, and this leads to a desire to help the victim and punish the perpetrator (Vitaglione & Barnett, 2003; Batson et al., 2007; Hechler & Kessler, 2018). People feel embarrassed and guilty when they witness other people making mistakes (Stocks et al., 2011; Welten et al., 2012; Lickel et al., 2015), and people feel vicarious anxiety when they observe others facing a threat (Shu et al., 2017). Vicarious emotions have been suggested to originate from the simulation processes of mirroring and mentalizing (Paulus et al., 2013). Mirroring processes map the observed behaviors into the observers' own nervous system and allow sharing the targets' feelings in an embodied manner. Mental processes enable the observers to project themselves into other individuals' position and imagine themselves in the same social situation. Mirroring others' state in a near-simultaneous isomorphic fashion is modulated by mentalizing. The two streams of simulation, mirroring and mentalizing allow the perceivers to simulate the state of others from the egocentric perspective (Paulus et al., 2013).

The various eye contact effects on affect and cognition have been suggested to result from the experience of being watched by another individual, being the object of another's attention (Conty et al., 2016). This *watching eyes effect* is presumed to capture the observer's attention, trigger self-referential processing (a heightened processing of information in relation with the self), and lead, for example, to the enhancement of self-awareness, activation of pro-social behavior, positive appraisals of others, and positive affective reactions (Conty et al., 2016; Hietanen, 2018). An important finding is that the psychophysiological responses to watching eyes, as described above, are not simply responses to the visual appearance of a pair of eyes looking towards the observer, but require the experience of being watched. This idea is supported by findings showing that seeing a person's direct versus averted gaze elicits greater skin conductance responses, greater evoked visual brain responses, and relatively greater left-sided frontal EEG asymmetry when the person is presented live, whereas no effect of gaze direction is observed when the same faces are shown as still images or pre-recorded videos (Hietanen et al., 2008; Pönkänen et al., 2011; Prinsen & Alaerts, 2019). It has been suggested that another individual's direct gaze has these effects only when the observer knows that the *self* is being looked at by another mind (e.g., Hietanen et al., 2008). Even more direct evidence for that the experience of being looked at is the critical ingredient has been gained from studies in which the participants' belief of whether a live person is able to see them or not has been directly manipulated, for example, by using a one-way window or a video-call in which the partner cannot see the participant's face. The results have shown that the autonomic skin conductance responses and heart rate deceleration responses are greater to another's direct versus averted only when the participants know that the other person can see them (Hietanen et al., 2020; Myllyneva & Hietanen, 2015a).

Now, considering that, in social situations, humans tend to automatically mentalize, make inferences about other individuals' mental states (Frith & Frith, 2006), we can presume that watching eye contact between two other individuals could trigger mentalizing about how these individuals react to the experience of being watched. As described above, this can lead to a simulation process and sharing the other individuals' feelings and accompanying physiological reactions (Paulus et al., 2013). In the present study, we were interested in studying psychophysiological responses to vicarious eye contact, that is, when the participants were observing eye contact between two other individuals. To this end, we measured psychophysiological responses in a following experiment. In one block of the experiment, the participants were observing two other individuals sitting opposite to each other. In the beginning of each trial, both individuals had their heads bent down and they were looking down (starting position). After a while, either one of the individuals or both of them raised their head and gaze and looked at the other. In the latter condition, they were making eye contact. By comparing the participants' responses in the latter condition to those in the former conditions we studied whether there exists a vicarious eye contact effect.

We also collected data in another block in which the stimulus person(s) was making eye contact with the participants themselves. In this block, after the starting position, either one of the stimulus persons or both of them raised and rotated their head and gaze and looked at the participant. This block served two functions. First, in a case that we would not find any evidence for a vicarious eye contact effect, in the first block, finding expected psychophysiological eye contact effects, in this block, would indicate that our methodology was working, Secondly, the conditions in this block also offered an interesting possibility to investigate participants' psychophysiological responses when receiving direct gaze from one person vs. two persons. Social interactions in real life are often not limited just to two-person interactions. By using the virtual reality technology, Llobera and his colleagues (2010) presented the participants with one or four virtual characters who walked towards them and showed that the skin conductance changes were greater when four characters simultaneously approached them as compared when only one character approached (see also Christou et al., 2015). To our knowledge, no previous studies has directly investigated the psychophysiological responses triggered by perceiving multiple direct gazes simultaneously.

In sum, in the present experiment we measured participants' skin conductance responses (SCR), zygomatic EMG responses, and heart rate deceleration responses a) when the participants observed two other individuals making eye contact or not, and b) when the participants themselves made eye contact with one or two other individuals. These physiological indicators provide an objective way to study individuals' affective and attentional responses to the gaze stimuli. SCRs are controlled by the sympathetic nervous system and they are considered to be a reliable measure of affective arousal (Critchley, 2002). The *zygomaticus major* elevates the corners of the mouth during smiling. Increased zygomatic EMG activity can reflect both automatic positive affective reactions (Cacioppo et al., 1986; Dimberg, 1990; Larsen et al., 2003) or automatized affiliative reactions (Hess & Fischer, 2013; Niedenthal et al., 2012). The heart rate deceleration response is an autonomic response indexing the attentional orienting to external stimuli (Graham & Clifton, 1966). As described in the beginning of this introduction, previous research has indicated that all these psychophysiological responses are greater to seeing another individual's direct versus averted gaze.

In order to attain a good control over a relatively complex stimulus presentation, the participants were shown pre-recorded videos. As mentioned above, because several previous studies have shown that the psychophysiological eye contact responses require the experience of being watched and are not elicited if participants are watching still images or video shootings (Hietanen et al., 2008; Pönkänen et al., 2011; Myllyneva & Hietanen, 2015a; Lyyra et al., 2018), we led the participants to believe that they were having a video call with two other persons (the stimulus persons) in an adjacent room. Recently, it was shown that perceiving another person's direct vs. averted gaze triggers enhanced skin conductance and zygomatic EMG responses both in the "live" (i.e., when the participant and the other person are in the same room) and in the video call conditions (Hietanen et al., 2020). Importantly, these results showed that the physical presence of the other person is not necessary for the psychophysiological responses to eye contact. Based on the previous studies (e.g., Llobera et al., 2010; Paulus et al., 2013; Myllyneva & Hietanen, 2015a; Hietanen et al., 2018; Hietanen et al., 2020), we hypothesized that participants' SCRs, zygomatic responses, and heart rate deceleration responses would be greater when (a) the participants observe two other individuals making eye contact as compared to when these individuals do not make eye contact, and (b) when the participants receive direct gaze (eye contact) from two individuals simultaneously as compared when watched only by one individual.

2. Method

2.1 Participants

Forty-three participants (26 females, age range: 18 − 28 years, mean age 21.14 years) from Soochow University with normal or corrected-to-normal vision were recruited. A sensitivity analysis with G*power 3 (Version 3, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, DE) suggested that the current sample size was able to detect a small to medium effect (Cohen's *d* = 0.44) for a paired t-test at 0.80 power and α level of 0.05 (Cohen, 1992; Faul et al., 2009). The participants were paid 30 yuans (equivalent of 4.65 dollars) for participating. All participants signed the consent form approved by the Human Research Protection Program of Soochow University. Four participants were excluded because of unsuccessful manipulation, that is, they did not believe that they were participating in a real-time video call communication. Four other participants were excluded from data analyses due to technical errors. Additionally, one participant who had 56% of the trials (including all trials in the condition of two models looking towards the participant) with responses occurring earlier than the typical SCR latency window (see below) was excluded from the SCR analysis. Hence, the final data sample consisted of 35 participants (18 females, mean age = 21.11) for the EMG and ECG data analyses, and 34 participants (17 females, mean age = 23.09) for the SCR data analyses. This number of the participants was still enough to detect a medium effect (Cohen's *d* = 0.50).

2.2 Stimuli

The stimuli were 24 videos with a male and a female model sitting opposite to each other and posing six different gaze behaviors. The videos included three conditions in which the models were directing their gaze towards the other person on the video and three conditions in which the models were directing their gaze towards the camera/participant. For each condition, four different videos were filmed in order to avoid presenting identical video stimuli repeatedly. All the videos started with both individuals having their heads bent down and looking down (starting position). In order to increase the unpredictability and to convince the participants that they were watching a real time video call, the duration of the starting position was randomized between 2 and 3 seconds. In the three conditions in which the models directed their gaze towards the other, the starting position was followed by (a) the male model raising his head and gaze to look towards the female model's eyes, but the female model not responding, (b) the female model raising her head and gaze to look towards the male model's eyes, but the male model not responding, and (c) both models raising their heads and gaze to look at each other in the eyes (eye contact). In the three conditions in which the models looked towards the camera making an eye contact with the participants, the starting position was followed by (d) the male model raising and rotating his head and gaze to look towards the camera/participant, (e) the female model raising and rotating her head and gaze to look towards the camera/participant, and (f) both models raising and rotating their heads and gaze to look towards the camera/participant. The duration of gazing period in the videos was 3 seconds. Figure 1 illustrates models' gaze behaviors in all conditions.

PLEASE INSERT FIG. 1 HERE

The videos were shot with the male and the female model in grey hoodies sitting opposite to each other against a black background. During the shooting, the models were asked to maintain a neutral expression, sit as still as possible without any facial and body movements, and not to blink excessively. In addition to the 24 videos used as stimuli, four extra videos on which for example, two models failed to raise their heads simultaneously were recorded to serve as failed trials. The purpose of these trials was to convince the participants that they were watching a real time video call. Also, two longer videos were prepared; one showing the two models setting up their laboratory (Lab 2) and another showing the participant's laboratory (Lab 1). The purpose of these videos was to help in convincing the participants that they were watching the models in a real time video call (see, 2.3 Procedure). All videos were shot with the resolution of 1280 * 1024. Adobe Premiere Pro2020 software was used to edit the videos. The videos were presented on a 27-inch computer screen with a refresh rate of 100 Hz. The distance between the participant and the screen was 60 cm.

2.3 Procedure

Upon arrival to Lab 1, the participants were explained that the purpose of the experiment was to measure their physiological responses in a real time social interaction via video call. The participants were shown a screen on which the video showing the two models setting up Lab 2 was running. Participants were told that two other experimenters (the models) were preparing the experiment in a nearby room (Lab 2) right now and that the experimenters were able to see the participant via the webcam located on top of the computer screen in Lab 2. To increase the credibility that the stimulus videos which the participants were about to see during the experiment would be real time video call views from Lab 2, the participants were taken to Lab 2. In this lab, the participants saw the two models sitting in front of the screen equipped with a camera. After a brief conversation with the two models, they were shown the screen on which the video showing the participant's lab (Lab 1) was displayed. After bringing the participant back to Lab 1, the experimenter then attached the electrodes and instructed the participants to avoid unnecessary movements during the experiment. Then the participants were instructed that, during the experiment, the video-call window they had just seen would turn on several times for short periods of time separated by a blank screen between adjacent video-call windows. The participants' task was to look at the screen when the video-call window was turned on.

The experiment was conducted in two separate blocks of trials, one showing the conditions in which the models were looking towards the other, and the other in which the models were looking towards the camera/participant. The two blocks were presented in a counterbalanced order across participants. In both blocks, eight trials were presented in each three condition (each of the four original videos were shown twice). Thus, there were 24 trials per block and 48 trials, in total. Within a block, stimuli from different conditions were presented in a random order. A failed trial was randomly presented in the experiment for each participant, and the data of the failed trial were excluded from the analysis. During the break after the block with the failed trial, the experimenter apologized for the unstandardized movement which just occurred and explained to the participants that it might have happened because the models were distracted for some reasons or they were tired. A computer-controlled intertrial interval (from offset to onset) was randomized between 14 s and 20 s. At the end of the experiment, to check for participants' suspicion of the deceit, the experimenter asked each participant three open-ended questions and recorded their answers: (a) what did they think about the experiment? (b) what suggestions did they have for the models? and (c) did they feel anything unnatural during the experiment? The participants (4) who clearly expressed their doubts of that they were interacting with live persons in real time were excluded from the analysis.

2.4 Measures and data reduction

Skin conductance was measured with 6 mm Ag-AgCl electrodes coated with isotonic paste placed adjacently on the index finger and middle finger, amplified with a GSR100C amplifier and used with an MP150 system (BIOPAC Systems, Inc., Goleta, CA). Offline, the data were re-sampled to 125 Hz and filtered with a 50 Hz comb band-stop filter using AcqKnowledge4.1 software (Version 4.1, BIOPAC Systems, Inc., Goleta, CA). The amplitude of SCR was calculated by subtracting the amplitude at the baseline (at the stimulus onset) from the peak amplitude detected during 1−6 s after the gaze stimulus onset (i.e., the moment when the gazing started). The responses on trials with slight amplitude changes (less than 0.01 μS) were coded as a zero response. To take both the response amplitude and frequency into account, trials with zero responses were also included to compute the magnitude of SCR for each condition (Dawson et al., 2017). The proportion of zero-response trials from the total number of accepted trials for each condition was 59.34% (a + b), 60.98% (c), 52.91% (d + e), and 40.64% (f). Furthermore, trials with amplitude rise of over 0.1 μS during the first second after the gaze stimulus onset were rejected in the analysis (23.8% of all trials). Based on visual inspection, trials with artifacts were rejected (1.1% of all trials). The mean number of accepted trials in each condition was 5.97 (a + b), 6.18

(c), 6.13 (d + e) and 6.20 (f). A logarithmic transformation [log (SCR+1)] was applied to correct for non-normal distribution.

Facial muscle activity was measured over the zygomaticus major region and amplified with a EMG100C amplifier (BIOPAC Systems, Inc., Goleta, CA). Bipolar 4 mm Ag-AgCl electrodes filled with electrode paste were attached 1 cm apart over the muscle sites according to the placement guidelines by Fridlund and Cacioppo (1986). A ground electrode was attached to the middle of the forehead below the hairline. Offline, the signal was filtered with a 10–500Hz band-pass filter by Acqknowledge4.1. The EMG signals were integrated using root mean square. Then, the signal was segmented into 500 ms epochs from 500 ms prior to the gaze stimulus onset (baseline) to 5,000 ms after the gaze stimulus onset. Trials with excessive distortion in the EMG signal (1.2%) were excluded. The mean number of accepted trials in each condition was 7.92 (a + b), 7.91 (c), 7.92 (d + e), and 7.83 (f). The values were standardized within each participant. The responses were calculated by subtracting the baseline muscle activity from the average value of each 500 ms epoch and then averaged across these epoch (because we were not interested in the time-course of the response). Finally, the responses were averaged across all accepted trials within each experimental condition. These responses were used in the statistical analyses.

Electrocardiogram (ECG) was measured from electrodes placed on the left and right inner forearm and amplified with a ECG100C amplifier (BIOPAC Systems, Inc., Goleta, CA). Offline, Acqknowledge4.1 was used to identify R peaks in the ECG signal and to calculate the heart rate (beats per minute, BPM). Trials with excessive distortion in the ECG signal (1.9%) were excluded. The mean number of accepted trials in each condition was 7.86 (a + b), 7.80 (c), 7.87 (d + e), and 7.83 (f). The HR data were segmented into 5500 ms epochs starting 500 ms prior to the gaze stimulus onset, then averaged across the trials within each condition. The analyses were performed with HR change scores, which were calculated by subtracting the baseline BPM during the 500 ms preceding the gaze stimulus onset from each of the BPMs during the 500-ms intervals after the gaze started. Thus, positive HR-change scores indicated HR acceleration, and negative scores indicated HR deceleration.

2.5 Data analysis

The data were separately analyzed for the block showing one or both of the models looking towards the other (vicarious eye contact) and the block showing one or both of the models looking towards the camera/participant (eye contact with the participant). To pre-analyze whether the match between the gender of the gazing model (in the conditions showing only one gazing model) and the participants' gender had an effect on the results, we conducted a pre-analysis for the same-sex and opposite-sex conditions. Paired t-tests showed that there were no significant differences between the same-sex and opposite-sex conditions for any of the dependent measures. Therefore, for the main analyses, data from these two conditions were combined. In the vicarious eye contact blocks, the SCRs and zygomatic responses were analyzed with paired t-tests (no eye contact vs. eye contact) and the HR data were analyzed with a 2 (no eye contact vs. eye contact) × 10 (time) repeated measures ANOVA. In the eye contact with the participant condition, similar analyses were performed on the SCR, EMG and HR data, in this case the independent variable being the number of models (i.e., one gazer vs. two gazers) looking into the participant's eyes. Furthermore, to test whether the different gazing conditions elicited affective and attentional responses, one-sample t-tests were carried out to compare the responses with zero. A Greenhouse-Geisser correction was applied when appropriate (the effect of time on HR data). Finally, we also run analyses in which the presentation order of the blocks (vicarious eye contact vs. eye contact with the participant) was included as a variable. As these analyses did not show the main effect of presentation order or interaction between presentation order and gaze direction, the presentation order is not included as a variable in the reporting of the results below. All statistical analyses were performed using the SPSS package (Version 25.0, IBM Corp, Armonk, NY).

3. Results

3.1. Vicarious eye contact

Figure 2a shows the SCR responses in the no eye contact and eye contact conditions in the vicarious eye contact block. The statistical analysis showed that the magnitudes of the responses were not significantly different between the no eye contact (0.13 ± 0.20, mean ± *SD*) and eye contact conditions (0.14 ± 0.19) [$t(33) = -0.49$, $p = .628$, $d = 0.083$]. The zygomatic muscle responses were also not significantly different between no eye contact (-0.05 ± 0.16) and eye contact conditions (-0.003 ± 0.23) in the vicarious eye contact block [$t(34) = -0.95$, $p = .348$, $d = 0.161$] (Figure 2b). A 2 ×

10 (time) ANOVA on the heart rate responses revealed a main effect of time, reflecting a significant HR deceleration after the stimulus onset [$F(9, 306) = 23.35$, $p < .001$, $\eta_p^2 = .407$]. Instead, the main effect of eye contact [$F(1, 34) = 0.35$, $p = .558$, $\eta_p^2 = .010$] or the interaction between eye contact and time [$F(9, 306) = 0.73$, $p = .523$, $\eta_p^2 = .021$] were not statistically significant (Figure 2c). The one-sample t-tests showed that seeing both no eye contact and eye contact conditions increased the autonomic arousal significantly above the baseline level, i.e., resulted in SCRs [$t(33) = 4.01$, $p < .001$, $d = 1.396$ and $t(33) = 4.66$, $p < .001$, $d = 1.622$, respectively]. Similarly, both gazing conditions resulted in HR deceleration responses [$t(34) = -6.13$, $p < .001$, $d = 2.102$ and $t(34) = -4.92$, $p < .001$, $d = 1.687$, respectively]. Instead, neither of the gazing conditions resulted in a zygomatic response [$t(34) = -1.92$, $p = .063$, $d = 0.659$ and $t(34) = -0.08$, $p = .934$, $d = 0.028$, respectively].

PLEASE INSERT FIG. 2 HERE

3.2. Eye contact with the participant

Figure 3a shows the participants' SCRs when receiving direct gaze from one vs. two gazers. The analysis indicated that the SCRs were significantly greater when the participants were looked at by two gazers (0.39 ± 0.43) as compared when looked at by one gazer (0.19 ± 0.24) [$t(33) = 3.43$, $p = .002$, $d = 0.614$]. The zygomatic responses were also greater in response to receiving direct gaze by two gazers (0.15 ± 0.28) than just by one gazer (-0.02 ± 0.19) [$t(34) = 2.61$, $p = .014$, $d = 0.44$] (Figure 3b). A 2 × 10 (time) ANOVA on the HR data showed a significant main effect of time [$F(9, 306) = 59.47$, $p < .001$, $\eta_p^2 = .636$] reflecting a HR deceleration response. More interestingly, the analysis also showed a main effect of the number of models [$F(1, 34) = 7.08$, $p = .012$, $\eta_p^2 = .172$]. The HR deceleration was more prominent for one gazer (-2.66 ± 0.33) than two gazers (-1.85 ± 0.30). The interaction between the main effects was not statistically significant [$F(9, 306) = 2.70$, $p = .063$, $\eta_p^2 = .074$] (Figure 3c). The one-sample t-tests showed that both the one gazer and two gazers conditions resulted in SCRs [$t(33) = 5.35$, $p < .001$, $d = 1.863$ and $t(33) = 6.24$, $p < .001$, $d = 2.172$, respectively] and HR deceleration responses [$t(34) = -8.16$, $p < .001$, $d = 2.798$ and $t(34) = -6.22$, $p < .001$, $d = 2.134$, respectively]. The condition of two gazers also resulted in zygomatic responses [$t(34) = 3.21$, $p = .003$, $d = 1.102$], whereas the zygomatic activity was not increased above the baseline level in the one gazer condition [$t(34) = -0.69$, $p = .493$, $d = 0.238$].

PLEASE INSERT FIG. 3 HERE

4. Discussion

In the present study, we investigated individuals' psychophysiological responses, including SCR, zygomatic EMG, and HR deceleration response in a multi-person social interaction, i.e., when participants observed eye contact between two other persons and when they themselves made eye contact with one or two other persons. We had two hypotheses. We expected that participants' SCRs, zygomatic responses, and heart rate deceleration responses would be greater when (a) the participants observe two other individuals making eye contact as compared to when these individuals do not make eye contact, and (b) when the participants receive direct gaze (eye contact) from two individuals simultaneously as compared when watched only by one individual. Our first hypothesis was not supported by the results. None of the measured responses were greater to observing two other persons making eye contact as compared to responses elicited by observing one person to look at the other while the other was not reciprocating with their gaze. This finding seems to indicate that there is no *vicarious eye contact* effect. Instead, our second hypothesis was partially supported by the results. The present study showed, for the first time, larger SCR and zygomatic EMG responses when the participants received direct gaze from two vs. one gazer. These results indicate that receiving direct gaze simultaneously from two persons triggered greater affective arousal and greater affective/affiliative response than receiving direct gaze from just one person. However, contrary to the expectation, the HR deceleration response reflecting attention allocation was greater for receiving direct gaze from one person vs. two persons.

The first aim of the present study was to examine whether there exists a “vicarious eye contact” effect. Previous studies have frequently reported vicarious emotions: emotions are elicited in dyads when one individual feels an emotion because they appraise another person’s situation. (Niedenthal & Brauer, 2012; Wondra & Ellsworth, 2015). The existence of vicarious emotions has been explained by suggesting that people match the emotional experiences of others from an egocentric perspective through mirroring and mentalizing (Paulus et al., 2013). As receiving another person’s direct gaze (eye contact) elicits affective reactions in us (e.g., Hietanen, 2018), it is possible that, via mirroring or mentalizing, perceiving eye contact between two other persons could elicit similar reactions in the bystanding observer. If vicarious responses for eye contact exist, we would observe psychophysiological eye contact effects even when participants observe two other persons making eye contact. However, our results showed that participants' psychophysiological responses, including SCR, zygomatic EMG responses, and HR deceleration responses, during observing eye contact between two other persons did not differ from those during observing just one person looking at the other. This result suggests that the psychophysiological responses to eye contact may not be elicited vicariously.

It could be argued that a possible reason for the results was that because the stimulus faces were presented in a profile view, the participants could not perceive the typical low-level geometrical and luminance information in the (toward looking) eyes and this sensory input is necessary for eliciting the eye contact effects. According to the first-track modulator model proposed by Senju and Johnson (2009), the eye contact effect is mediated by the subcortical route including the superior colliculus, pulvinar and amygdala and this route responds quickly to low spatial frequency visual information and regulates cortical processing. A recent two-stage model in explaining the eye contact effect also suggested that the initial stage of direct gaze capturing the attention largely relied on the low-level visual properties of the directly looking eyes (Conty et al., 2016). However, this explanation does not seem very likely. Namely, a previous study has shown that enhanced SCRs to direct gaze can be observed also when the model person's eye are not visible at all. In a study by Myllyneva and Hietanen (2015a, Experiment 2), the model was wearing three different pairs of sunglasses in three different blocks: a pair without lenses (eye visible); a pair of normal sunglasses with dark lenses (eyes not visible); and a pair with blocked lenses (eyes not visible and the model could not see through the glasses). The participants were always informed of which glasses the model was wearing. For obvious reasons, in this experiment, the models rotated their head (straight ahead or rotated 30° to the left or right) for the direct and averted gaze conditions. The results showed that the SCRs were greater to the model's direct vs. averted head orientation both when the eye were visible (glasses with no lenses) and when the eyes were not visible (normal sunglasses) and the SCRs to direct head orientation/gaze were not different between these two conditions. Instead, when the lenses were blocked, the models head/gaze direction had no effect on the participants' SCRs. Considering these previous results it is not likely that, in the preset study, the lack of vicarious eye contact effect was due to low-level visual properties perceived from the models' eyes.

Another possible explanation for not finding the vicarious eye contact effect is that the participants' experience in these two conditions might actually have been quite similar. Even though when another of the models did not reciprocate with the direct gaze, the participants still understood the one of the models was actively trying to make eye contact and the other model was being watched. Thus, the participants would observe a situation of 'being watched' in both conditions and consequently no differences in the responses between these two conditions was not observed. We ran two one-sample t-tests to test whether the responses in both conditions differed from 0. The results showed that both observing one model being watched and observing two models gazing at each other resulted in SCRs and HR deceleration responses, but not in zygomatic responses. It is, of course, impossible to know if the responses reflected the effects of affective arousal and social attention or just the effects of head movement in the stimuli. Future studies should investigate this issue, for example, by using better control stimuli such as ones showing head movements which do not result in social attention directed to another person.

One might also suspect that the failure of detecting the expected vicarious eye contact effect was because the deception procedure did not work and the participants did not believe that they were observing a real-time interaction between two live models. We do not think that this is a plausible explanation. Firstly, we interviewed the participants about this issue after the experiment, and four participants who expressed doubts about the deception procedure were excluded from the analysis. More importantly, in the conditions where the models directed their gaze toward the participant/camera, the results showed differential psychophysiological responses to making eye contact with one vs. two models. As demonstrated in previous studies, the psychophysiological eye contact responses require the experience of being watched and they are observed in the conditions of a real-time interaction with a live person, either face-to-face or through a video call (Hietanen et al., 2008; Pönkänen et al., 2011; Myllyneva & Hietanen, 2015a; Lyyra et al., 2018). Thus, if the deception procedure was not successful, in the current study, i.e., if the participants perceived themselves to be interacting with pre-recorded videos, then we should have failed to observe any the effects in this condition, too.

Another main aim of the present study was to investigate the psychophysiological responses to receiving direct gaze from one vs. two persons. The SCR was found to be greater when the participants were watched by two persons as compared when watched by one person. This result is consistent with those of previous studies which showed greater SCRs to multiple vs. single person's walking towards (Llobera et al., 2010; Christou et al., 2015). It has been suggested and supported by frontal EEG asymmetry measurements that direct gaze signals and elicits a behavioral tendency for approach (Argyle & Cook, 1976; Adams & Kleck, 2003; Hietanen et al., 2008; Pönkänen et al., 2011). The present findings seem to indicate that the magnitude of the affective arousal response is sensitive to the number of persons sending the signal of motivational approach tendency.

Consistent with our expectations, the results also showed that perceiving direct gaze from two persons elicited greater zygomatic EMG responses in observers than did direct gaze from just one person. Previous studies measuring facial EMG activity have shown that perceiving another individual's direct gaze elicits greater zygomatic muscle responses than perceiving another's averted gaze, indicating that direct gaze elicits greater affective/affiliative reactions than averted gaze (Hietanen et al., 2018, Hietanen et al., 2020; Hietanen & Peltola, 2021; Kiilavuori et al., 2021). Thus, the current EMG results could be interpreted to indicate that receiving direct gaze from two individuals results in a greater positive emotional response or greater affiliative response than receiving direct gaze from a single individual. However, since the two stimulus persons were presented simultaneously in the present study, it is also possible that, in the condition showing one person with direct gaze and the other with head down, the smiling response elicited by direct gaze was attenuated (inhibited) by the simultaneously perceived averted gaze. Receiving another person's direct gaze (attention) signals social inclusion and elicits a positive affective reaction, whereas receiving another individual's averted gaze signals social exclusion (Wirth et al., 2010; Leng et al., 2018). Being excluded is a painful experience threatening the fulfillment of the basic human needs and evokes negative emotions (Williams, 2009). Therefore, it is possible that the negative reaction caused by receiving another's averted gaze may have diminished the smiling response caused by the face with direct gaze, and consequently, the presentation of these two faces led to smaller zygomatic EMG responses than did the presentation of two faces with direct gaze. In fact, the observed results provide support for this speculation. Compared to the baseline (seeing the two individuals with heads bent down), receiving direct gaze from one person with simultaneously receiving averted gaze from another person did not activate the zygomatic muscle at all (see, Figure 3b). In future studies, facial EMG responses to eye contact in multi-person interactions should be investigated by including stimuli in which all the presented persons send either direct or averted gaze.

A significant difference between one and two gazers was also found on the HR deceleration response showing that directed attention from one gazer resulted in greater HR deceleration than directed attention from two gazers. This result was contrary to our hypothesis. As direct gaze has been demonstrated to automatically capture the beholder's attention (Senju & Hasegawa, 2005), we rather simply hypothesized that receiving direct gaze from two individuals, instead of receiving it from only one individual, would result in greater allocation of attention and, thus, elicit greater HR deceleration responses. Now, the observed results suggest that this hypothesis was not considered carefully enough. The observed results may reflect the fact that it is impossible to make eye contact with two people simultaneously and, therefore, the allocation of attentional resources was, in fact, greater when there was only one individual looking at the participant. By measuring participants' gaze behavior, previous studies have revealed a pattern of distributed overt attention for dyadic and multi-person social interactions. In the context of multi-person interactions, participants must shift their attentional targets in order to extract relevant social information, for instance, in order to infer the attentional states of the present people (Birmingham et al., 2008). Müller and his colleagues (2018) found that, in a multi-person interaction, individuals did not focus their visual attention on one person but made eye contact with each person evenly. Thus, it is likely that, in the current study, participants' allocation of attention and the HR deceleration response were greater when perceiving a direct gaze from only one person. In this situation, the participants' attention could be better maintained on this particular person. However, when there were two persons sending their direct gaze, the participants had to divide their attention and shift it from one to the other, and this resulted in smaller HR deceleration response. Another explanation for this observed result could be related to an expectancy effect. Expectations, mental states that reflect information about possible future events (Summerfield & Egner, 2009), can alter attention and future behavior (Jollie et al., 2008). It is possible that, in the condition in which there was only one model looking toward the participant, the participants still expected a direct gaze from the other model, too, and therefore, because of this expectation, allocated more attention in this condition as compared to the condition showing two models turning simultaneously to them. As everyday life often involves complex social situations involving interaction with more than one person, future research could investigate the effects of perceiving multiple direct and/or averted gazes on a wider range of cognitive and affective processes.

There are some limitations, in the present study, which could be addressed in future studies. Firstly, although the present study used an experimental setting in which we convinced participants to believe that they were interacting with live persons, the stimuli were, perhaps, too controlled in some aspects. In the vicarious eye contact stimuli, the model persons did not express any observable behavioral reactions after making eye contact. Perhaps, this was seen as somewhat unnatural by the participants and dampened the expected vicarious physiological responses. Therefore, we suggest that future studies should loosen a bit from the gold-standard of stringently controlled stimuli and present more natural social interaction in the stimuli. Moreover, instead of presenting pre-recorded videos, future studies could also investigate vicarious eye contact effects when the participants observe two 'live' persons, like in the previous studies investigating the eye contact effects. Secondly, the present study was primarily designed to investigate the vicarious eye contact effect. As explained in the introduction, the second block served two functions: to confirm that it was possible with our methodology (by using pre-recorded videos and leading the participants to believe that they were having a real-time video call) to elicit psychophysiological eye contact effects, and to investigate participants' psychophysiological responses when receiving direct gaze from one person vs. two persons. However, by presenting the vicarious eye contact and first-person eye contact stimuli in different blocks, a direct comparison between responses to these stimuli would have been problematic; for example, because of the different stimulus contexts in which the vicarious and first-person eye contact stimuli were presented within their respective blocks. Therefore, future experiments should be designed in such a way that they allow direct comparison of responses to vicarious eye contact with those to genuine, first-person eye contact. Thirdly, the present experiment collected only psychophysiological data in a passive viewing task, lacking subjective reporting of the participants' emotional experiences. In future studies, self-reported data, for example, emotional valence ratings to each stimulus could be collected and compared with psychophysiological responses to clarify both explicit and implicit aspects of affective and attentional responses in multi-person gaze interactions.

In conclusion, the present study did not provide evidence for a vicarious eye contact effect: psychophysiological responses (SCR, zygomatic EMG, HR deceleration) to watching two other persons making eye contact did not differ from those when watching just one person looking directly at the other while the other was not reciprocating their gaze. However, when the participants were involved in the interaction, skin conductance and zygomatic responses were found to be greater when the participants were looked at by two vs. one person, whereas the HR deceleration response indexing attention allocation showed the opposite pattern; directed attention from one gazer resulted in greater HR deceleration than directed attention from two gazers. These novel findings of perceivers' psychophysiological responses in triadic social encounters hopefully motivate further research on situations involving multi-person interaction.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Funding

This work was funded by Natural Science Foundation of Jiangsu Province and MOE (Ministry of Education in China) Project of Humanities and Social Sciences (Grant numbers BK20200863, 22YJCZH019 to Tingji Chen).

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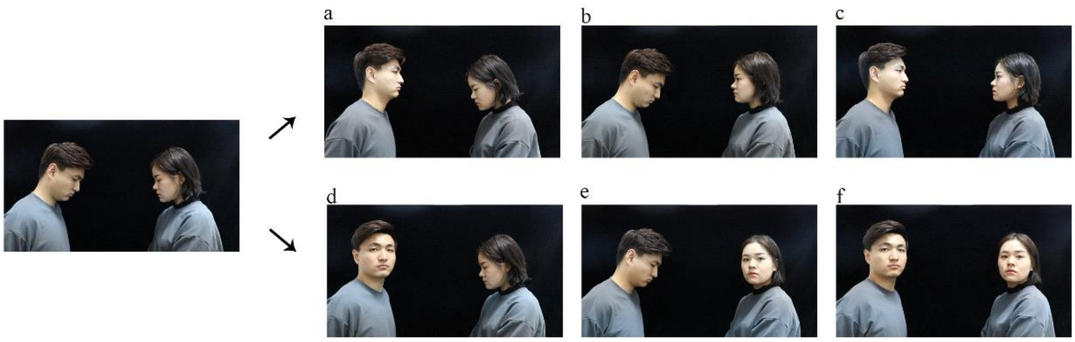

Figure 1. Illustration of the stimulus videos. Each video started with both models looking down for 2 to 3 seconds. Then one or both of the models raised their head and looked towards the other person (a, b, or c) or towards the participant (d, e, or f) for 3 seconds.

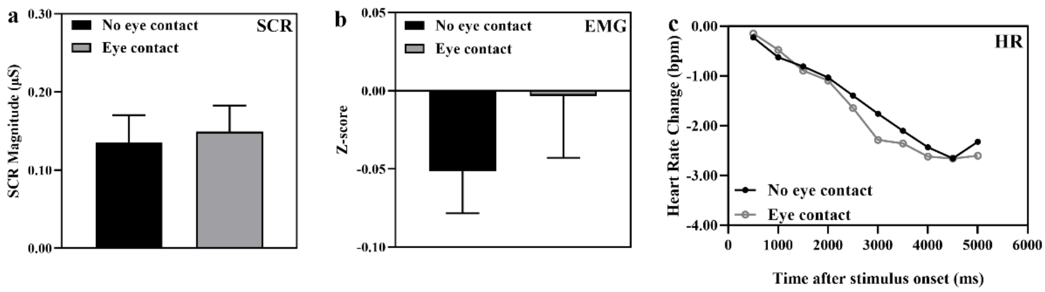

Figure 2. SCR (**a**), zygomatic EMG (**b**), and HR (**c**) responses in the no eye contact and eye contact conditions in the vicarious eye contact block.

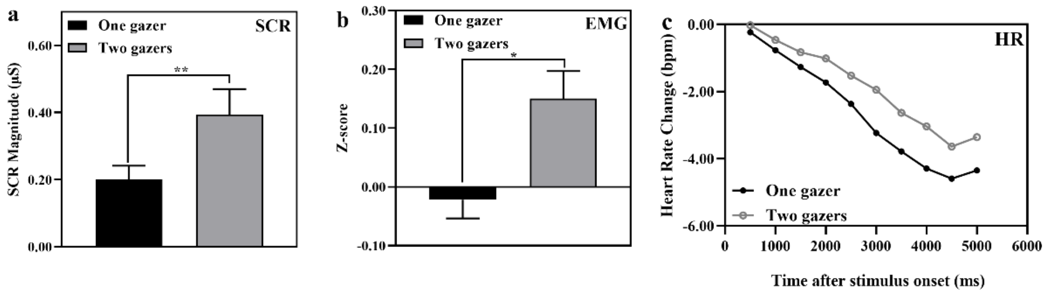

Figure 3. SCR (**a**), zygomatic EMG (**b**), and HR (**c**) responses to receiving direct gaze from one vs. two persons.