



Gender differences in empathic responses to others' economic payoffs: an event-related potentials study

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Abstract

Although gender differences in empathy have been well established through measuring subjective outcomes, some studies of the neural mechanisms of pain empathy have not found gender differences. This inconsistent evidence may be caused by different research methods or different paradigms. The present study adopted a different approach from the pain empathy paradigm to examine gender differences in empathic responses to others' economic payoffs using event-related potentials. The results showed that the N2 amplitudes in female participants were more negative than those in male participants, indicating a greater female than male susceptibility to facial expressions at the early stage of empathy. The LPP amplitudes for male participants were found to be more positive in the observation condition (involving no self-interest) than in the participation condition (involving self-interest), but there was no significant difference in the LPP amplitudes for the female participants between the two conditions. The results suggest that females' empathic responses are more likely to be elicited automatically by the perception of others' emotional states. In contrast, males' empathic responses are more likely to be mediated by self-interest, which subsequently reduces their empathic responses.

Keywords Affective empathy · Cognitive empathy · N2 · Late positive potential (LPP) · Event-related potential

Introduction

Empathy denotes the ability to identify with other people's thoughts, intentions, desires and feelings, and to respond to others' mental states with an appropriate emotion (Baron-Cohen and Wheelwright 2004). We have a propensity to resonate emotionally with others (Decety 2011; Decety and Jackson 2004), and viewing another's emotional expressions may induce a mimicking response in the observer (Niedenthal 2007). However, our emotional reactions are not always congruent with the emotional state of the other. Previous studies have established that empathic responses

are modulated by contextual appraisal (Gu and Han 2007; Hein and Singer 2008; Singer and Lamm 2009; Yamada et al. 2011; Singer et al. 2006), such as a competitive relationship, competitive intensity (Luo et al. 2018), and the intensity of the stimulation or displayed emotion (Avenanti et al. 2006; Saarela et al. 2007). In particular, empathy is weakened when there is a conflict between self-interest and the interests of others. Previous studies, using the zero-sum game experiment, have found that people are more concerned about their own outcomes than with others' benefits, and evaluate others' outcomes from an egocentric perspective (Fukushima and Hiraki 2006; Itagaki and Katayama 2008; Ma et al. 2011). Even if there is no direct competition, individuals will typically produce an incongruent emotion with respect to others once self-interest is involved (Jie et al. 2019). This discrepant emotional response, which is incongruent, or even at odds with the emotional state of others, has been called "counter-empathy" (Yamada et al. 2011).

In reviewing previous empathy research, however, it is not clear whether there are gender differences in counter-empathic responses toward others' economic payoffs. From a sociocultural perspective, women are more communal in their orientation, less selfish, more caring, more friendly,

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and emotionally expressive (Eagly 2009). The stereotype of the female social role assumes that women are more empathic than men. Indeed, previous studies have demonstrated that females show higher levels of self-reported affective empathy as well as cognitive empathy compared to males (Berthoz et al. 2008; Eisenberg and Lennon 1983; Knafo et al. 2008; Lam et al. 2012; Lawrence et al. 2004; Reniers et al. 2011; Topcu and Erdur-Baker 2012; Williford et al. 2016). For example, one study investigated 3159 seventh graders (average age 13.67 years; 56% girls) from 166 school classes. The results indicated female superiority in self-reported affective empathy (Wölfer et al. 2012). Another study found female superiority in both affective empathy and cognitive empathy (Reniers et al. 2011). Intriguingly however, in research on the neural mechanisms of empathy, some studies have failed to find any kind of gender difference, including studies of both children and adults using functional MRI and EEG (Cheng et al. 2014; Decety et al. 2012, 2015; Lamm et al. 2011; Michalska et al. 2013; Perry et al. 2010). For example, a meta-analysis of 32 fMRI studies of pain empathy did not find any evidence for gender-specific activation differences, even when lowering the threshold to very liberal levels (Lamm et al. 2011). Another study found an effect of gender in the self-report measures of empathy, but no significant main or interaction effects of gender in the early and late ERP responses (Decety et al. 2015). Similarly, a study using high-density EEG and faces expressing pain found no effect of gender in any of the measures (Ibanez et al. 2011). These inconsistent results suggest that self-reported differences may reflect differences in the willingness to report higher levels of empathic capacity between males and females, as opposed to actual neurobiological differences (Michalska et al. 2013). However, most of the studies of the neural mechanisms of empathy have focused on empathy for physical pain rather than empathy for negative social experiences, such as unfair economic distribution. It is therefore unclear whether there are gender differences in empathic responses toward others in an economic payoff situation; nor is it clear whether there are gender differences in the reduction of empathic responses when self-interest is involved.

Previous research on empathy has indicated that empathy includes an early emotion-sharing component (bottom-up processing) and a late cognitive evaluation component (top-down processing) (Shamay-Tsoory et al. 2009; Xiang et al. 2018). Research has also shown that N2, as a short-latency affective response, is associated with affective arousal (Cuthbert et al. 2000; Olofsson and Polich 2007). As this automatic arousal is a feature of the early stage of empathy, we assume in the current study that this would be reflected in N2. On the other hand, LPP, as a long-latency empathic response, has been found to be correlated more strongly with cognitive-related empathy toward strangers than with

affective empathy (Kiat and Cheadle 2017). As LPP is also an indicator of emotion regulation (Olofsson et al. 2008; Dennis and Hajcak 2009), we also assume that the top-down process of empathy would be reflected in LPP.

These assumptions raise other questions. Are males' or females' empathic responses to others' economic payoffs more likely to be influenced by self-interest, and which component is more likely to be affected by self-interest if that is the case? Addressing these questions could help to resolve some of the gaps and apparent anomalies in the current literature on gender differences in empathy. Moreover, research has found correlations between several psychiatric conditions and the different components of empathy. For example, individuals with autism are likely to show difficulties with cognitive empathy but not with affective empathy (Baron-Cohen 2009; Baron-Cohen and Wheelwright 2004), whereas individuals with schizophrenia are more likely to report higher personal distress and emotional contagion (Lehmann et al. 2014). Understanding the gender differences in the temporal dynamics of the neural mechanisms involved in counter-empathic responses can help us to understand the causes of gender differences in several psychiatric conditions (Decety et al. 2015).

To resolve these problems, we investigated gender differences in empathy in an economic payoff situation using event-related potentials (ERPs). Our analyses focused on two distinct ERP components: N2 and LPP. Previous studies have linked these two components to gender differences in empathy. Luo et al. (2014) found that both males and females, in responding to highly negative stimuli, showed a short-latency affective response (reflected in the N2) and a long-latency affective response (reflected in the LPP). However, a long-latency affective response to moderately negative stimuli was present only in females. This suggests that females are more sensitive to the affective state of persons undergoing moderate suffering. Groen et al. (2013) investigated gender differences in the temporal dynamics of experiencing empathy. They found that females, in comparison with males, showed increased anterior N2 amplitudes in responding to humans contrasted with scenes (independent of emotional valence) and to negative contrasted with neutral emotions (independent of human presence). The findings of the above studies lead us to postulate that females' empathic responses are likely to be affected by others' emotional states, as reflected in facial expressions. We hypothesize further that females' affective empathy is likely to be stronger than that of males. The amplitude of the N2 has been reported to correlate with the subjective ratings of affective empathy (Sessa et al. 2014). Therefore, we predict that the N2 amplitude will be more negative in females than in males. Additionally, the LPP has been reported to correlate with cognitive empathy (Kiat and Cheadle 2017). Therefore, if the LPP amplitude in females is more positive

than that in males, it suggests that females have a stronger cognitive empathy for other’s economic payoffs than males, and vice versa. If there are no gender differences in the cognitive component of empathy, differences in the LPP amplitude would be indistinct between the female and male participants.

Additionally, considering the influence of self-interest, we expected participants in this ERP study to be more concerned about their own outcomes compared to others’ benefits when self-interest was involved, which would reduce their empathic responses toward others and result in counter-empathic responses. If there are differences in the amplitude of N2 between the observation and participation conditions, this indicates that self-interest has affected the early stage of empathic responses to economic inequality. If there are differences in the LPP amplitude between the observation and participation conditions, this indicates that self-interest has affected the late stage of empathy. If there are no significant differences, this indicates on the contrary that self-interest has not affected the empathic responses to others’ economic payoffs. We also hypothesized that males’ counter-empathic responses would be more intensive than females’ responses, given the assumption that men would be more competitive and dominant.

Materials and Methods

Participants

Forty-eight healthy adults aged between 18 and 25 years participated in the study as paid volunteers. There were 24 males (mean age 20.58 years, SD ± 1.998) and 24 females (mean age 19.92 years, SD ± 1.248). All participants were college students, right-handed, had normal or corrected-to-normal vision, and no history of neurological or mental health disorders. Informed consent was obtained from each participant prior to the study’s commencement. The procedure of the experiment was consistent with the principles of international research involving human subjects as stated in the Declaration of Helsinki (World Medical Organization 1999). The study was approved by the Ethics Committee of South China Normal University.

Visual stimuli

Participants were comfortably seated in a dimly lit, sound-attenuated, and electrically shielded room. The stimuli were presented at the center of a 17-inch color monitor with a white background. Each stimulus (inclusive of textual information) consisted of an image measuring 10.5 cm × 14 cm (width × height), subtending a visual angle of 6.02° × 8.02° at a viewing distance of 100 cm. In the observation condition

(OC), the participant saw an unknown dominant player allocating 10 yuan to a powerless stranger. In the participation condition (PC), he or she saw the dominant player allocating 10 yuan to himself/herself and the powerless player. In both cases, the gender of the dominant player matched the gender of the participant, and the facial expressions of the dominant player serving during the experiment were neutral and selected from an ID photo. Feedback consisted of three kinds of facial expressions (frown, neutral, smile) of a male or female powerless player serving during the experiment, selected from the CAS-PEAL Chinese face database (Wen et al. 2008); again, matching the gender of the participant. Three still shots were used for the responses, clearly expressing a discernible frown, neutral expression, or smile, as follows: the frown in response to “disadvantageous inequality” (DI), meaning less money than the dominant player or the participant is distributed to the powerless player; the neutral expression in response to a “relatively fair” (RF) distribution, meaning the distribution to the powerless player is basically equal to that of the others; and the smile in response to “advantageous inequality” (AI), meaning more money than the dominant player or the participant is distributed to the powerless player (see Table 1). Brightness, size, contrast, and color settings of these pictures were unified using photo editing software.

Experimental procedure

Prior to recording, participants read the instructions to understand the rules of the experimental task. We used a payoff distribution task preceded by an Ultimatum Game (Sanfey et al. 2003). The formal experiment consisted of an observation condition (OC) followed by a participation condition (PC).

In the OC, participants were convinced that the dominant player was empowered to distribute 10 yuan to the powerless player. As observers, the participants had no chance of receiving a payment of 10 yuan. Table 1 shows the offers that were defined a priori by the experimenters. The relative

Table 1 The list of payoff pairs used in the money distribution task

	OC		PC	
	Assigner	Other	Self	Other
DI	9	1	9	1
	8	2	8	2
RF	6	4	6	4
	5	5	5	5
AI	4	6	4	6
	2	8	2	8
	1	9	1	9

The unit is ¥

fairness of these ranged from extreme DI (a distribution ratio of 1:9 or 2:8), wherein the dominant player offered 1 or 2 yuan out of 10 yuan to the other player, leaving the rest for himself/herself, to RF (a distribution ratio of 5:5, 6:4, or 4:6), and to AI (a distribution ratio of 9:1 or 8:2 to the powerless player). Each observer was asked to pay attention to the facial expression of the powerless person and the money outcome for the two confederates. The three levels of fairness were randomly presented.

At the beginning of each trial, a fixation mark was displayed at the center of the screen for a duration of 400–600 ms. Subsequently, participants were presented with the dominant player's photograph for 800 ms, followed by a blank screen for 500–800 ms prior to the onset of the powerless player's facial expression (frown, neutral, or smile; in response to DI, RF, and AI distributions to the powerless player, respectively). The facial expression remained on screen for 1000 ms. Following the facial expression, the outcome of money distribution was presented for 1000 ms (see Fig. 1). Each level of fairness was presented for 60 trials, making a total of 180 trials. To encourage the participants to concentrate on the task, a question mark was presented instead of the outcome every 30 trials. The participants were asked to judge whether the money offered to the powerless player was AI, RF, or DI at this time. The keyboard numbers 1, 2, and 3 represented AI, RF, and DI, respectively. At the end of the OC task, the participants completed a rating scale to measure the degree of unpleasantness experienced for each level of fairness, using a 5-point scale ranging from

0 (“not at all”) to 4 (“very much”). Each distribution ratio (1:9, 2:8, 4:6, 5:5, 6:4, 8:2, and 9:1) was presented once.

In the PC, the dominant player was empowered to distribute 10 yuan to the participant and the powerless player. As shown in Table 1, the offers were defined a priori by the experimenters and were identical to those in the OC. Each level of fairness was presented for 60 trials, making a total of 180 trials. The participants were told that one trial would be drawn at random from the pool of money distribution as their reward.

In summary, there were 400 trials in the whole experiment, including 14 practice trials, 12 judgment trials, and 14 rating trials. Note that only 360 trials of the formal experiment were analyzed; the judgment and assessment data were not included. The participants took part in the experiment first as observers of the game and subsequently as participants in the money distribution task.

Following the ERP recording, to measure individual differences of empathy, participants were instructed to complete the Interpersonal Reactivity Index (IRI) (Davis 1983), including four subscales: perspective taking (PT), fantasy scale (FS), empathic concern (EC), and personal distress (PD). The aim here was to find out if there were any gender differences in trait empathy.

Electroencephalogram recording and analysis

The electroencephalography was continuously recorded from 62 scalp electrodes and the addition of two mastoid electrodes

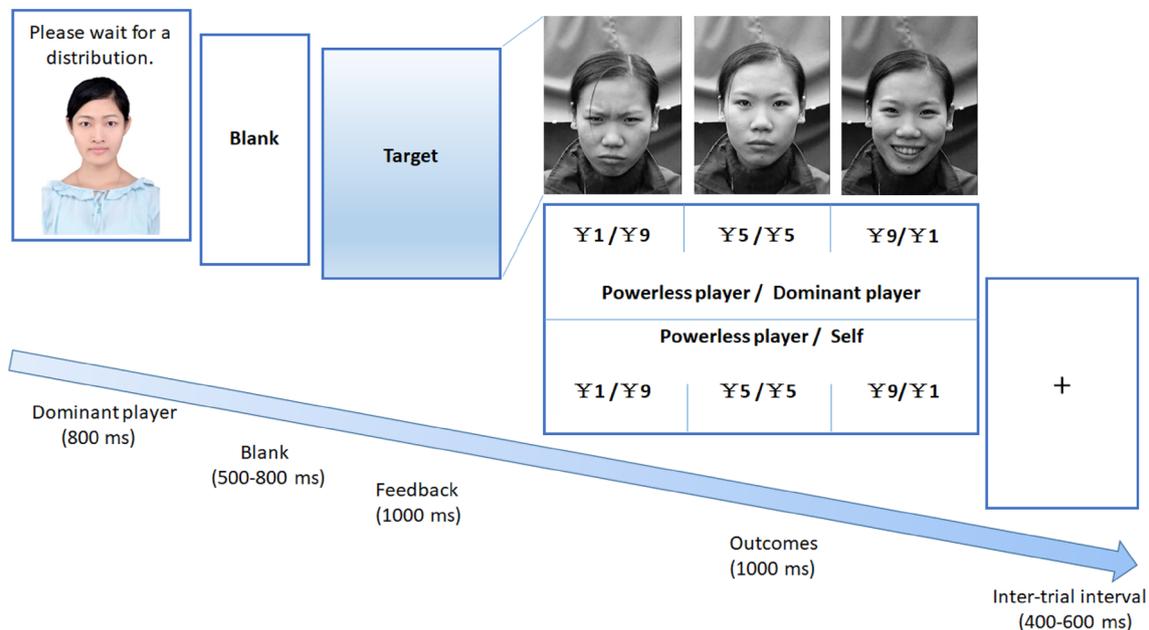


Fig. 1 Examples of experimental design: after the fixation marker, the participants were presented with the dominant player's photograph, followed by a blank screen prior to the onset of the powerless player's facial expression, followed by the outcome of the money distribution

with BrainAmp DC amplifiers (Brain Products, Germany). All electrodes were re-referenced off-line to an averaged mastoid reference, with a forehead ground being employed. Eye blinks and vertical eye movements were monitored with electrodes located above the right eye. The horizontal electrooculographic-recording electrodes were positioned at the outer canthi of both eyes. Electroencephalographic and electrooculographic activity was amplified by applying a band-pass filter from 0.01 to 100 Hz and was continuously sampled at 500 Hz/channel. All electrode impedances were maintained at less than 5 kΩ. The electroencephalograms averaged for the trials under each condition were computed separately off-line using BrainVision Analyzer 2.0 software (Brain Products, Germany) (Fritsch and Kuchinke 2013). Each epoch continued for 1200 ms, with 200 ms before the facial expression (feedback) onset for the baseline correction. In addition, the epochs that included artifacts due to body movements or muscle or skin potentials were removed by semi-automatic artifact rejection. The epochs with artifacts greater than ± 100 μV at any electrode were excluded from averaging. The total rejection rate of the trials was 2.49%.

Our analyses focused on two distinct ERP components: the N2 and the LPP. As mentioned above, previous research on empathy has indicated that empathy includes an early emotion-sharing component and a late cognitive evaluation component (Fan and Han 2008). The amplitude of the N2 has been reported to correlate with the subjective ratings of affective empathy (Sessa et al. 2014), whereas the LPP has been found to be correlated with cognitive empathy (Kiat and Cheadle 2017). Based on previous studies (Fan and Han 2008; Luo et al. 2015) and our visual observations, we analyzed the mean amplitude from 200 to 230 ms after the onset of the facial expression for the N2, and from 330 to 550 ms after the onset of the facial expression for the LPP. For statistical analysis, we selected nine electrodes in the frontocentral area for the N2 (F3, F4, C3, C4, Fz, Cz, FCz, FC3, and FC4), and six electrodes in the central parietal area for the LPP (P3, P4, Pz, CP3, CP4, and CPz).

A mixed-model analysis of variance was conducted for the N2 and the LPP (condition: OC vs. PC) × (level of fairness: DI vs. RF vs. AI) × (gender: female vs. male). The Greenhouse–Geisser correction was applied for the violation of the sphericity assumption in the analysis of variance where appropriate, and the Bonferroni correction was used for multiple comparisons.

Results

Behavioral data

Table 2 shows the mean scores and standard errors for each subscale of the IRI. The *t* test results show that

there was no difference between the males and females within the PT, PD, EC, and FS subscales (PT: $t(1, 46) = 1.050, p > 0.05$; PD: $t(1, 46) = 1.249, p > 0.05$; EC: $t(1, 46) = 0.752, p > 0.05$; FS: $t(1, 46) = -0.115, p > 0.05$).

Figure 2 shows the average “unpleasantness” rating in each condition (OC–DI, OC–RF, OC–AI, PC–DI, PC–RF, and PC–AI) for both genders. A mixed-model analysis of variance was conducted for assessment of self-reported unpleasantness for the target person’s outcome (condition: observation/participation × fairness: DI/RF/AI × gender: male/female). The main effect for fairness was significant: $F(2, 92) = 10.039, p < 0.001, \eta^2_p = 0.179$. Also, the interaction effect between condition and fairness was significant: $F(2, 92) = 78.856, p < 0.001, \eta^2_p = 0.778$. The main effect for gender was not significant: $F(1, 46) = 0.084, p > 0.05, \eta^2_p = 0.002$. The interaction effects of other variables were also insignificant.

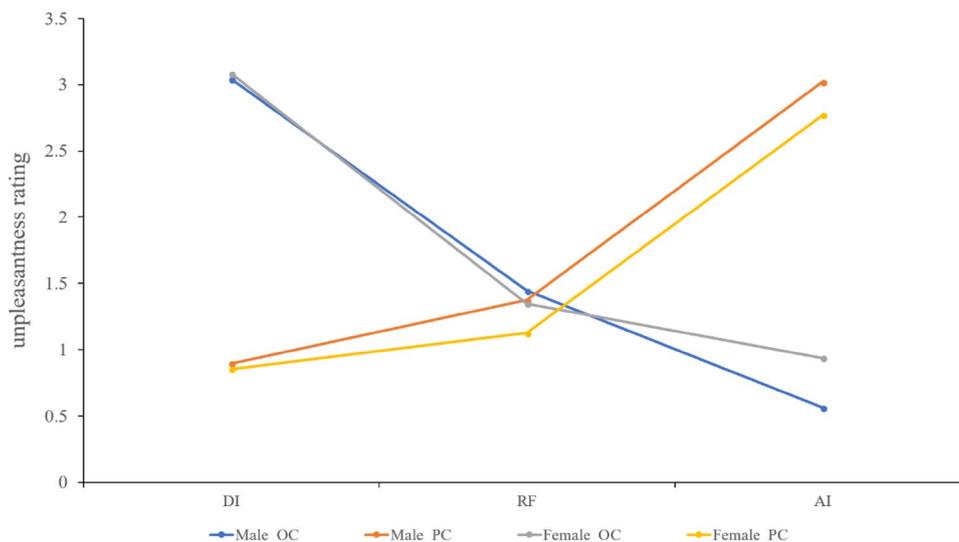
Further simple effect analysis revealed that, in the OC, participants rated themselves as feeling more unpleasant in the DI situation (3.063 ± 0.116) than in the AI ($0.740 \pm 0.129; t(47) = 12.872, p < 0.001$), and RF situations ($1.396 \pm 0.120; t(47) = 12.414, p < 0.001$). Also, they felt more unpleasant in the RF than in the AI situation; $t(47) = 3.810, p = 0.001$. However, in the PC, participants rated themselves as feeling more unpleasant in the AI (2.896 ± 0.183) than in the DI situation ($0.875 \pm 0.162; t(47) = 7.010, p < 0.001$). They also felt more unpleasant in the AI than in the RF situation ($1.250 \pm 0.125; t(47) = 7.924, p < 0.001$). For the DI situation, participants rated themselves as feeling more unpleasant in the OC than in the PC; $t(47) = 10.814, p < 0.001$. Conversely, regarding the AI situation, they felt more unpleasant in the PC than in the OC; $t(47) = 9.568, p < 0.001$. There was no significant difference between the OC and the PC in the assessment for unpleasantness in the RF situation ($p = 0.121$). These results suggest that individuals’ empathic responses to others’ economic payoffs were reversed in the PC, indicating the involvement of self-interest.

Table 2 Mean scores and standard error for the subscales of the IRI

Scores	Interpersonal Reactivity Index (IRI)			
	PT	PD	EC	FS
Males	11.79 (0.825)	9.17 (0.867)	16.46 (0.768)	15.00 (0.801)
Females	10.50 (0.913)	7.67 (0.831)	15.63 (0.798)	15.13 (0.728)

PT perspective taking, PD personal distress, EC empathic concern, FS fantasy scale

Fig. 2 The self-reported unpleasantness ratings for outcomes across DI, RF, and AI under the OC and PC



ERP data

N2

Figure 3 shows grand-averaged ERPs and topographic maps for the N2 amplitudes in different situations. The results reveal main effects for condition, $F(1, 46) = 5.403$, $p < 0.05$, $\eta^2_p = 0.105$; fairness, $F(2, 92) = 30.098$, $p < 0.001$, $\eta^2_p = 0.396$; and gender, $F(1, 46) = 6.703$, $p < 0.05$, $\eta^2_p = 0.127$. The interaction effect between fairness and gender was also significant; $F(2, 92) = 4.888$, $p = 0.01$, $\eta^2_p = 0.096$. Specifically, the N2 amplitudes for female participants were found to be more negative than male participants in the presence of frowns (DI) and smiles (AI) in the pictures of facial expressions in both the OC and the PC. In addition, there was a significant gender difference with respect to N2 amplitudes for relative equity in the OC, which showed that the N2 amplitudes in the female participants were more negative than those in the male participants. There was no significant gender difference in the relative equity situation in the PC (see Table 3).

LPP

Figures 4 and 5 show grand-averaged ERPs and topographic maps for the LPP amplitudes in different situations. The statistical results reveal main effects for fairness; $F(2, 92) = 18.443$, $p < 0.001$, $\eta^2_p = 0.286$. In addition, the interaction effect between condition and gender was significant ($F(2, 92) = 4.375$, $p < 0.05$, $\eta^2_p = 0.087$), with the LPP amplitudes for male participants being more positive for the OC ($M_{OC} = 5.181$, $SE_{OC} = 0.568$) than for the PC ($M_{PC} = 4.157$, $SE_{PC} = 0.564$); $t(23) = 2.363$, $p < 0.05$. However, there was no significant difference in LPP amplitudes between the OC and the PC for female participants.

Discussion

Previous studies have investigated gender difference with respect to empathy by measuring subjective reports or empathic responses to physical pain, rather than empathy for negative social experiences. The current work extends previous research by examining gender difference in the neural processes underlying empathy for economic interactions by recording ERPs from male and female healthy adults. We found that males' empathic responses to others were reduced when self-interest became involved, as reflected in the LPP amplitude data. Perception of others' emotional facial expression (a frown or a smile, in response to disadvantageous and advantageous distribution to the powerless player, respectively) elicited a significantly larger N2 amplitude in female participants than in male participants in both the OC and the PC. Nevertheless, there were no significant gender differences in the later stage of empathic responses toward others' economic payoffs, as reflected in the LPP results. Note that the N2, in the context of pain empathy, has been interpreted as reflecting early affective arousal, whereas the LPP has been viewed as representing late cognitive evaluation (Chen et al. 2012; Mella et al. 2012). The results of the current study suggest that gender differences in empathy are mainly due to differences in emotional arousal. Individual motives are more likely to weaken males' cognitive component of empathy.

Our behavioral results found that both female and male participants in the OC rated themselves as feeling more unpleasant in the DI situation than in the AI and RF situations. This suggests that all participants, male and female, experienced others' negative emotions when their self-interest was not involved. However, both female and male participants in the PC rated themselves as feeling more unpleasant in the AI situation than in the DI and RF

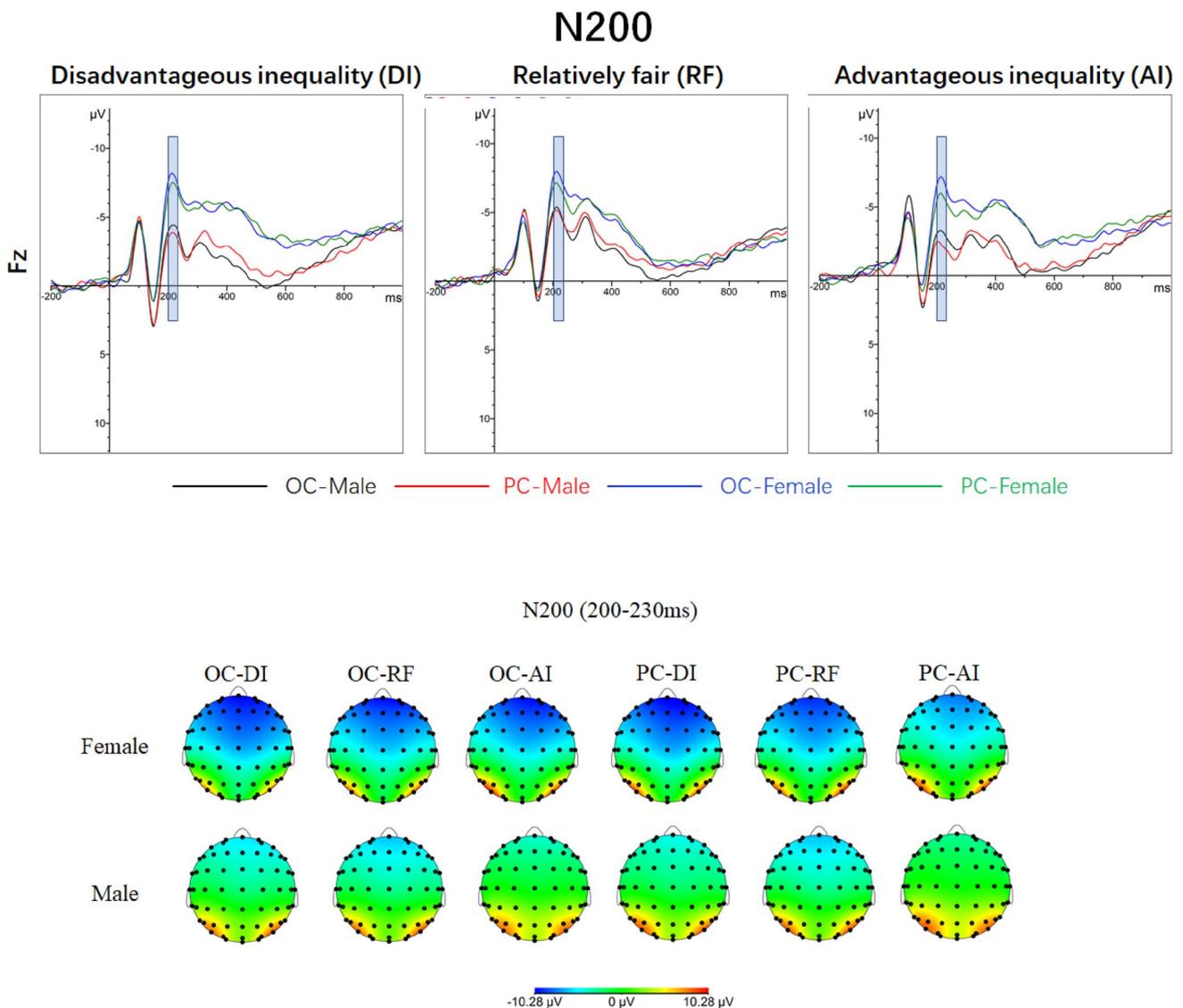


Fig. 3 Grand-averaged event-related brain potentials (ERPs) and topographic maps from the Fz regions elicited by the frown, neutral and smile expressions, in response to DI, RF, and AI distributions to the powerless player under the OC and PC

Table 3 Mean amplitudes (µV), standard error, and *t* test results in each condition at N2 (200–230 ms)

	Male	Female	<i>t</i>	<i>p</i>
OC–DI	-2.925 ± 0.692	-6.258 ± 0.977	2.783	0.008
OC–RF	-3.554 ± 0.729	-5.879 ± 0.846	2.081	0.043
OC–AI	-1.632 ± 0.706	-5.126 ± 0.950	2.953	0.005
PC–DI	-2.540 ± 0.659	-5.456 ± 0.934	2.551	0.014
PC–RF	-3.455 ± 0.650	-5.180 ± 0.805	1.667	0.102
PC–AI	-1.051 ± 0.735	-4.063 ± 1.003	2.424	0.019

OC observation condition, PC participation condition, DI disadvantageous inequality, RF relatively fair, AI advantageous inequality

situations. This suggests that they all experienced inconsistent emotions in relation to another person when their self-interest became involved. Meanwhile, participants in the DI situation rated themselves as feeling more unpleasant in the OC than in the PC. In contrast, participants in the AI situation felt more unpleasant in the PC than in the OC. According to these results, the empathic responses of all the participants toward others’ economic payoffs were reversed following the direct involvement of self-interest. Yamada et al. (2011) showed that congruence (a cooperative condition) between a co-player’s affective expression and the participant’s outcome (win or loss) enhanced initial empathic responses, while incongruence (a competitive condition) led to counter-empathic responses.

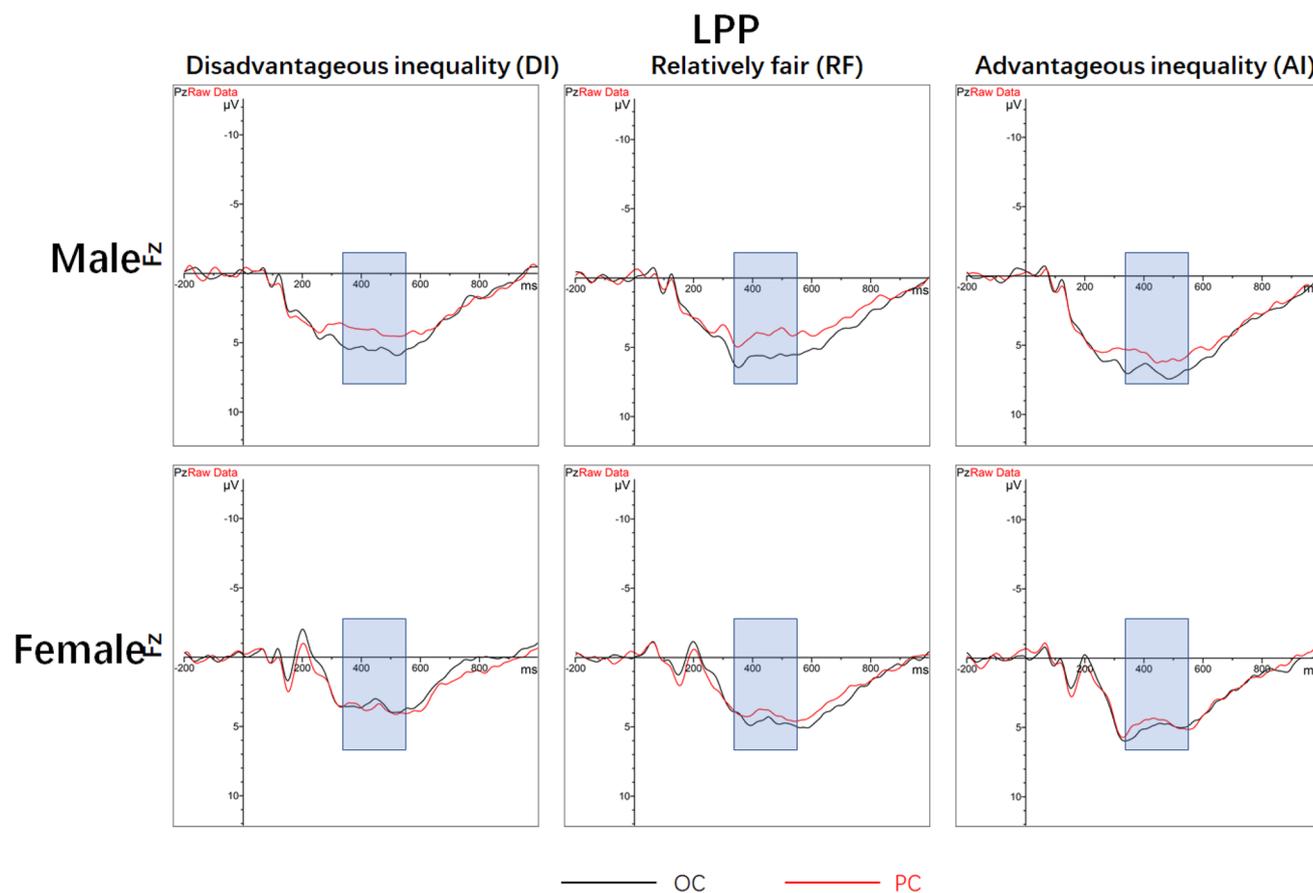


Fig. 4 Grand-averaged event-related brain potentials (ERPs) from the Pz regions elicited by the frown, neutral, and smile expressions, in response to DI, RF, and AI distributions to the powerless player under the OC and PC

Our results show that empathic responses can be reduced not only by a competitive relationship, but also by unfair distribution (for both males and females). The female participants did not show this trend in the ERPs, but this may be because seeing facial expressions automatically induces females' emotional arousal very quickly. In the subsequent evaluation stage, females could evaluate their feelings more rationally.

According to previous research, the N200 is associated with affective arousal and attention novelty (Cuthbert et al. 2000; Ibanez et al. 2012; Olofsson and Polich 2007). An increased N200 amplitude has been observed in response to situations in which subjects are required to judge the emotional significance of the stimuli (Balconi and Mazza 2009; Balconi and Pozzoli 2007). Our results suggest that females are more likely to generate automatic arousal in response to other people's emotions than males. Additionally, research has found correlations between N2 amplitude and the subjective ratings of affective empathy (Sessa et al. 2014). The current findings support previous questionnaire studies that have shown female superiority in affective empathy (Wölfer et al. 2012).

It has been suggested that the mirror neuron system constitutes the neural basis of an observer's empathy with the emotional state of another individual (Gallese 2003). The better empathic abilities of females could be related to their enhanced reliance on the human mirror neuron system when assessing others' emotional states and their own emotional response to others' feelings (Schulte-Rüther et al. 2008). A previous study has indicated the existence of neuroanatomical sex differences in the human mirror-neuron system; that is, young adult females had a significantly larger gray matter volume in the pars opercularis and inferior parietal lobule than matched male participants. The network of the human mirror-neuron system has been shown to be strongly linked to empathic competence (Cheng et al. 2009). The higher self-report scores in the emotional empathic disposition were tightly coupled with a larger gray matter volume of the pars opercularis across all female and male participants in Cheng et al.'s (2009) study. It is possible therefore that females' advantage in automatic emotion arousal might be related to their advantage in the mirror neuron system. However, this interpretation is speculative and warrants further testing.

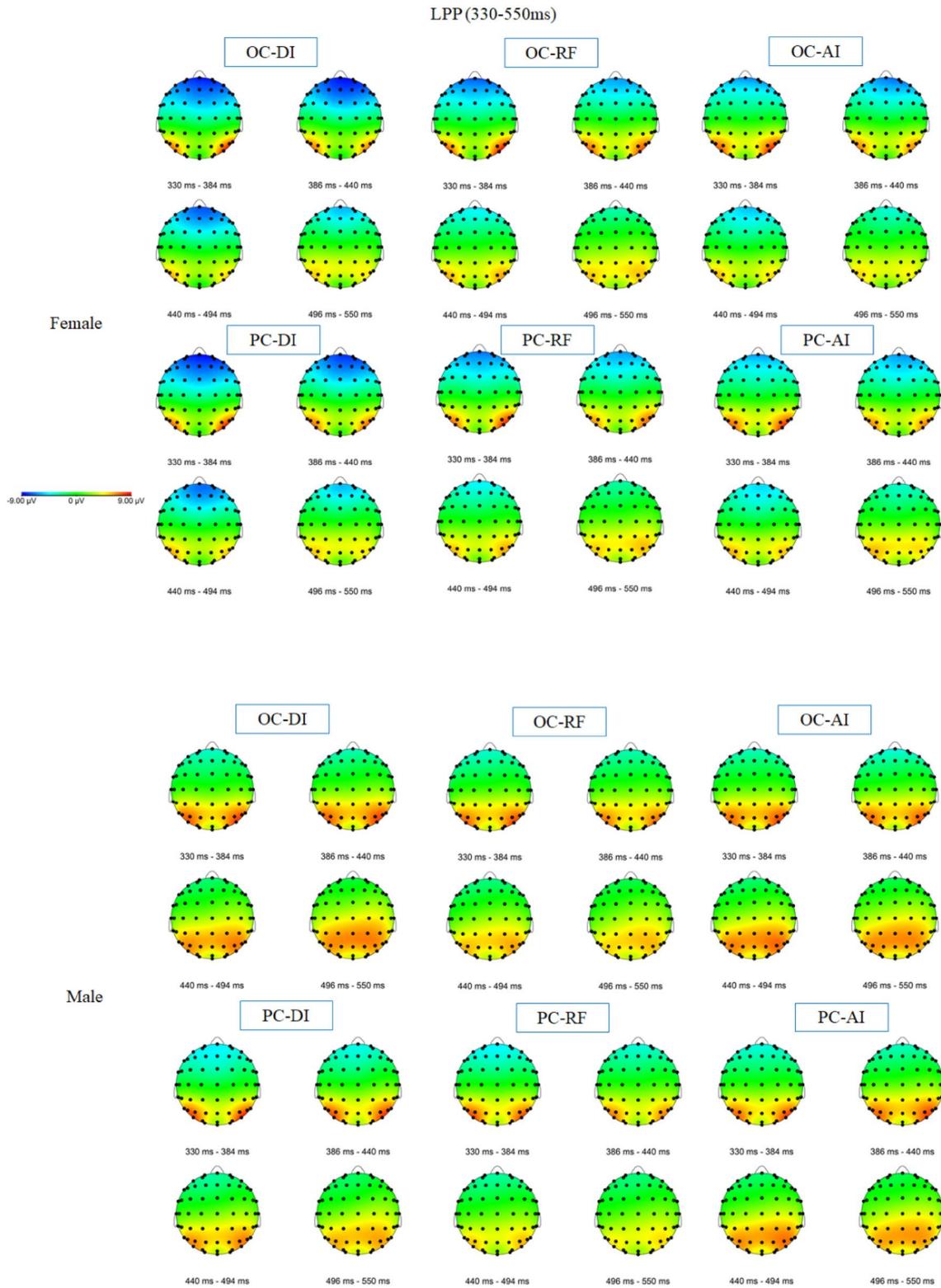


Fig. 5 Topographic maps of the LPP amplitudes in different situations

Kiat and Cheadle (2017) found that the LPP amplitude is correlated more strongly with cognitive-related empathy toward strangers than with affective empathy. The current study did not reveal any significant gender differences in the later stage of empathy to others' economic payoffs, as reflected in the LPP results. The results support some previous studies, which have found no gender differences in cognitive empathy (Derntl et al. 2009; Klein and Hodges 2001). It has been suggested that the LPP could be a neurophysiological indicator for emotion regulation (Dennis and Hajcak 2009; Olofsson et al. 2008). Our results indicate that this lack of significant gender difference in cognitive empathy is probably because males are not inferior to females in terms of their capacity for top-down regulation. Previous studies have shown that males may rely on a more cognitive strategy, especially when determining their own emotional response to the feelings of others (Schulte-Rüther et al. 2008). Although there was no significant difference, the male participants' average LPP amplitude was slightly larger than the females' in the current study. These findings are somewhat inconsistent with previous self-reported studies that have found females show higher levels of self-reported affective empathy as well as cognitive empathy compared to males (Berthoz et al. 2008; Eisenberg and Lennon 1983; Knafo et al. 2008; Lam et al. 2012; Lawrence et al. 2004; Reniers et al. 2011; Topcu and Erdur-Baker 2012; Williford et al. 2016). However, Michalska et al. (2013) suggest that these gender differences in empathy may be a reflection of females' greater willingness to report their empathic responses to others, rather than a reflection of underlying biological differences. Therefore, these inconsistencies between the results of our study and those of the self-report studies may be due to different research methods.

The results of the current study suggest that gender differences in empathic responses to others' economic payoffs are mainly due to differences in emotional arousal rather than cognitive appraisal. Notably, however, some studies of the neural mechanisms underlying empathy have failed to find any kind of gender differences in empathy in both children and adults, using functional MRI and EEG (Cheng et al. 2014; Decety et al. 2012, 2015; Lamm et al. 2011; Michalska et al. 2013; Perry et al. 2010). Such inconsistencies may stem from different research paradigms. Most of the studies of the neural mechanisms of empathy have focused on empathy for physical pain rather than empathy for negative social experiences, such as unfair economic distribution. The current study analyzed empathic responses to others' economic payoffs, not to physical pain, at the stage of facial feedback. Previous studies using facial expressions as stimulus materials have found that females, in comparison with males, are more sensitive to the affective state of others (Luo et al. 2014; Groen et al. 2013). Similarly, the current study also found that females are more likely than males to generate

automatic arousal in response to other people's emotions. Future studies could use a variety of research paradigms to compare simultaneously gender differences in empathy.

In addition, in line with our prediction, the later stage of empathic responses (reflected in the LPP) differed for males between the observation and the participation conditions. These findings indicate that male participants produced more empathic responses toward others in the observation condition. That is, male empathy toward another person is more likely to be reduced by self-interest. Previous studies have found that empathic responses are modulated by top-down control processes such as attention, and that empathic responses may be reduced when attention is distracted away from another person's pain (Gu and Han 2007). Moreover, attention to emotional stimuli can be influenced by top-down processes according to one's intentions and goals (Vromen et al. 2015). Because males tend to be more competitive than females (Niederle and Vesterlund 2007; Gneezy et al. 2008), when male participants in the current study were involved in the distribution of money, they could have had a greater incentive to gain money compared to females, resulting in a reduction of their empathic responses. In addition, males are considered to be better at distinguishing between the self-perspective and the other-perspective (Schulte-Rüther et al. 2008). In our experiment, when self-interest was involved, males could have been more concerned about their own payoffs, suggesting an initial top-down processing of information that subsequently reduced their empathic responses.

Collectively, the results suggest that females are more likely than males to empathize with the emotional state of others. Individual motives are more likely to weaken the cognitive component of empathy in males. Our results lend support to Baron-Cohen's (2009) "empathizing-systemizing" theory, which proposes that psychological gender differences can be described by the relationship between the degree of empathizing (a tendency to infer mental and emotional states of others and respond with appropriate emotional feelings and behavior) and systemizing abilities (a propensity to analyze the rules of a system and predict its behavior). Male and female brains adopt different cognitive biases with male brains 'systemizing' and female brains 'empathizing' (Baron-Cohen 2009; Baron-Cohen et al. 2005). Previous research has found that, in comparison to males, females are better at multisensory perception of emotional expression (Collignon et al. 2010), are better able to recognize subtle emotional expressions (Hoffmann et al. 2010), and are both faster and better at recognizing positive emotion and negative emotion from facial cues (Hampson et al. 2006). In addition, a recent meta-analysis of differences between males and females in responses to the Dictator Game inferred that women (but not men) may internalize altruism as their intuitive response (Rand et al. 2016); thus females could be more sensitive than males to

distress observed in other people (Rose and Rudolph 2006). We speculate that this may be one reason why females are superior in affective empathy but not in cognitive empathy.

A limitation of the current study is worth mentioning. The gender of the participant matched the gender of the dominant and powerless faces presented in the experiment (i.e., male participants only saw male faces, whereas female participants only saw female faces). Hence the results of gender differences in empathic responses to others' economic payoffs could be confounded by the differences in the differences in the neural response toward male and female faces. While the current study cannot rule out many of the low level confounds present, we could establish equivalency in expression and emphatic feelings between male and female faces. Firstly, the facial expressions were selected from the CAS-PEAL Chinese face database (Wen et al. 2008). The images were standardized and there was no significant difference in valence and arousal for the same kind of facial expression. Therefore, the gender differences in empathy were unlikely to be caused by differences in the valence and arousal of the images. Secondly, the participants completed a rating scale to measure the degree of unpleasantness experienced for each level of fairness. The results did not reveal any significant gender difference in the subjective rating of unpleasantness under the same level of fairness, indicating that the gender differences in empathy were unlikely to be caused by differences in subjective feelings induced by male and female targets. Thirdly, although the gender of the target matched the gender of the participant, the underlying meaning was the same: the frown in response to “disadvantageous inequality”; the neutral expression in response to a “relatively fair” distribution; and the smile in response to “advantageous inequality”. Therefore, the gender differences in empathy were unlikely to be caused by differences in meanings suggested by the gender of the facial expression. Based on these three considerations, we largely exclude the influence brought by the gender of the observed targets. Hence it is more likely that the results of gender differences in empathic responses to others' economic payoffs were due to a female advantage in automatic emotion sharing. Nonetheless, future investigations should examine whether the gender of the observed target affects gender differences in empathy.

Conclusions

This study has examined gender differences in empathic responses to others' economic payoffs. The N2 amplitudes for female participants were found to be more negative than male participants in responding to others' facial expressions. The results suggest that females are superior in affective empathy, and that their empathic responses tend to be

elicited automatically by the perception of others' emotional states. The current study did not reveal any significant gender differences in the later stage of empathy to others' economic payoffs, as reflected in the LPP results. The results support some previous studies, which have found no gender differences in cognitive empathy. The LPP amplitudes for male participants were more positive in the observation condition than in the participation condition. However, there was no significant difference in LPP amplitudes between the observation condition and the participation condition for female participants. These results suggest that male empathy toward another person is more likely to be mediated by self-interest, which subsequently reduces their empathic responses.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to declare.

Ethical approval All procedures involving human participants were in accordance with the ethical standards of the Ethics Committee of South China Normal University and with the 1964 Helsinki Declaration and its later amendments.

Informed consent Informed consent was obtained from all individual participants included in the study.

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