
Social Neuroscience

ISSN: 1747-0919 (Print) 1747-0927 (Online) Journal homepage: http://www.tandfonline.com/loi/psns20

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**To cite this article:** Ruida Zhu, Haiyan Wu, Zhenhua Xu, Honghong Tang, Xueyi Shen, Xiaoqin Mai & Chao Liu (2017): Early Distinction between Shame and Guilt Processing in an Interpersonal Context, Social Neuroscience, DOI: 10.1080/17470919.2017.1391119

**To link to this article:** http://dx.doi.org/10.1080/17470919.2017.1391119

Accepted author version posted online: 10 Oct 2017.

**Publisher:** Taylor & Francis

**Journal:** *Social Neuroscience*

**DOI:** 10.1080/17470919.2017.1391119

# Early Distinction between Shame and Guilt Processing in an Interpersonal Context

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**Abstract.** Shame and guilt have been compared in many behavioral and functional magnetic resonance imaging studies. However, the time course of shame and guilt processing remains unknown. We conducted an event-related potential (ERP) study to investigate the temporal dynamics of shame and guilt in an interpersonal context. Behaviorally, participants reported "shame" when their wrong advice was correctly rejected by a confederate, whereas reported "guilt" when their wrong advice resulted in economic loss of a confederate. The ERP results showed significant difference between the shame and guilt conditions in the early P2 component (140–220 ms) over the frontal region and the alpha oscillations (240–1000 ms) over the parietal region. No significant difference was found between the shame and guilt conditions in the N2, P3, and theta oscillations. These results supported previous findings that shame compared to guilt involves more self-referential processing, whereas guilt compared to shame involves more empathetic processing, and provided evidence that the distinction between shame and guilt could occur in an early stage.

**Keywords:** shame, guilt, self-referential processing, empathetic processing, event related potential





## Introduction

Shame and guilt are two frequently experienced emotions in moral life. As typical moral emotions, they usually occur in response to moral violation and promote adherence to social norms (Haidt, 2003). In light of the important role of moral emotions in maintaining interpersonal relationships for individuals and realizing social order for society, many studies have focused on the psychological and neural mechanisms of shame and guilt.

Some cognitive processes and emotional experiences are shared by shame and guilt. In the cognitive aspect, it is postulated that the ability to understand others' evaluations and a sense of self are required to experience these emotions (Heerey, Keltner, & Capps, 2003; Tangney & Dearing, 2003). Consistent with this postulation, developmental studies have found children are not able to feel shame and guilt until the emergence of theory of mind and self-concept at about 3 years old (Brüne & Brüne-Cohrs, 2006; Kochanska & Aksan, 2006; Nelson & Fivush, 2004). In the emotional aspect, shame and guilt are negative emotions that cause negative feelings and psychological pain (Tangney, Miller, Flicker, & Barlow, 1996). Functional magnetic resonance imaging (fMRI) studies have showed that both these emotions activate the insula and amygdala, which are involved in negative feelings and pain processing (Basile et al., 2011; Michl et al., 2014; Roth, Kaffenberger, Herwig, & Bruehl, 2014; Wagner, N'Diaye, Ethofer, & Vuilleumier, 2011).

Despite these similarities, shame and guilt also have theoretical and empirical differences. It has been assumed that shame involves a global devaluation of the self, whereas guilt involves a condemnation of one's unethical behavior and a concern about its bad influence on others (Tangney, Stuewig, & Mashek, 2007). Correspondingly, behavioral studies have revealed that shame is associated with concerns over ones' own self-image and causes hide, escape, and repair of one's own image (de Hooge, Zeelenberg, & Breugelmans, 2010; Gausel & Leach, 2011; Sznycer et al., 2016). On the other hand, guilt is related to understanding victims' thoughts and feelings, which results in apology and compensation (Haidt, 2003; Tangney & Dearing, 2003). Some neuroimaging studies support the assumptions. Compared with guilt, shame increased more activation in the anterior cingulate cortex, posterior cingulate cortex, and hippocampus (Michl et al., 2014; Takahashi et al., 2004), which have a close relation to self-evaluation (Northoff et al., 2006). In contrast, guilt relative to shame activates regions typically associated with theory of mind and empathy, including the dorsal medial prefrontal cortex, temporo-parietal junction, and temporal pole (Takahashi et al., 2004; Wagner et al., 2011); These results suggest that shame recruits more self-referential processing than guilt, while guilt recruits more theory-of-mind/empathetic processing than shame**.** In addition, a behavioral study reveals that shame is evaluated to be more psychologically painful than guilt according to participants' subjective reports (Tangney, 1993). However, fMRI studies have not identified such differences in the brain (Michl et al., 2014; Takahashi et al., 2004; Wagner et al., 2011).

Though previous studies have investigated the potential psychological components and the neural correlates of shame and guilt, the temporal dynamics of shame and guilt processing is poorly understood. At a first glance, one may expect that a relative long time would be taken to distinguish complex moral emotions such as shame and guilt. However, more and more event-related potential (ERP) studies have found that moral information could be processed rather quickly (Decety & Cacioppo, 2012; Gan et al., 2016; Gui, Gan, & Liu, 2015; Yoder & Decety, 2014). For example, a high density ERP study revealed that the temporo-parietal region was involved in moral information processing as quickly as 62 ms post-stimulus (Decety & Cacioppo, 2012). Moreover, emotional responses triggered by moral stimuli in a moral picture-viewing task were found to be related to an early component (P2) (Gui et al., 2015). The time course of shame and guilt is worth studying.

Previous fMRI studies evoked shame and guilt by presenting participants hypothetical scenarios of transgression (Michl et al., 2014; Takahashi et al., 2004) or asking them to recall personal events (Wagner et al., 2011). However, such paradigms could hardly be used in an ERP study, which requires strictly time-locked events. Besides, imagination and recall are not common ways for normal people (but might be common ways for depressed patients) to experience shame and guilt, and they activate psychological process unrelated to shame and guilt experience, such as retrospective memory. To solve these problems, we developed an advice-decision game that could induce shame and guilt in an interpersonal context (see the Method section).

The aim of the current study thus was to investigate the time dynamics of shame and guilt processing in an interpersonal context. Specifically, we used an interpersonal paradigm to induce the target emotions and tracked the related electroencephalogram (EEG) patterns by analyzing ERP components (P2, N2, and P3) and EEG oscillations (theta and alpha) that are likely to be related to shame and guilt processing.

The P2, as an early ERP component, is suggested to play a role in early attentional selection and perceptual processing (Chen, Xu, et al., 2008; Hillyard & Anllo-Vento, 1998; Martin & Potts, 2004; Potts, Patel, & Azzam, 2004). It is often reported that the P2 becomes larger when early attention is automatically allocated to preferred stimuli, such as task-relevant stimuli and important feedback, in the absence of top-down cognitive control (Bar-Haim, Lamy, & Glickman, 2005; Hämmerer, Li, Müller, & Lindenberger, 2011; Luck, Woodman, & Vogel, 2000). As self-relevant information is more attention-capturing than non-self-relevant information, many studies showed enhanced P2 amplitudes over the frontal region to self-relevant stimuli than to non-self-relevant stimuli (Chen et al., 2011; Hu, Wu, & Fu, 2011; Meixner & Rosenfeld, 2010). For example, Meixner et al. (2010) found larger P2 amplitudes for participants' own birth date than for irrelevant dates. Given that people are more likely to perceive their self-image being threatened (self-relevant information) when they feel shame than when they feel guilt (Tangney & Dearing, 2003), we expected that the P2 would be larger in the shame condition than the guilt condition.

The N2 component is associated with cognitive control (see a review, Folstein & Van Petten, 2008). The N2 becomes smaller with the decrease of the need for controlled attention (Bartholow et al., 2005; Van Noordt & Segalowitz, 2012; Van Veen & Carter, 2002). It is proposed that self-relevant stimuli, because of their adaptive values to people, could be retrieved and processed more easily, with less controlled attention consumption relative to non-self-relevant stimuli (Campanella et al., 2002; Chen et al., 2011). Many studies found that self-relevant stimuli elicit smaller N2 amplitudes than non-self-relevant stimuli do (Chen, Weng, Yuan, Lei, & Qiu, 2008; Chen et al., 2011; Keyes, Brady, Reilly, & Foxe, 2010; Wu, Yang, Sun, Liu, & Luo, 2013). As more self-relevant information are involved in the shame condition than the guilt condition (Tangney & Dearing, 2003), we expected that the N2 would be smaller in the shame condition than the guilt condition.

The P3 is a late ERP component, which has been related to numerous controlled and elaborative cognitive processes, such as context updating, working memory, attentional resource allocation, and emotional processing (e.g. Ito, Larsen, Smith, & Cacioppo, 1998; Polich, 2007, 2012). For instance, as to attentional resource allocation, it has been found that P3 amplitudes are larger when people allocate more attentional resource to the current task compared to when they did/could not (Isreal, Chesney, Wickens, & Donchin, 1980; Ullsperger, Metz, & Gille, 1988; Wickens, Kramer, Vanasse, & Donchin, 1983). As to emotional processing, the P3 amplitudes become larger when the emotional valence of stimuli become more negative (Ito et al., 1998; Olofsson, Nordin, Sequeira, & Polich, 2008). It is very likely that some high-level cognitive processes which could be reflected by the P3 are involved in the shame and guilt processing, but it has not been explored by any previous study yet. Therefore, we did not have a specific expectation about whether the P3 amplitudes would show significant difference between the shame and guilt conditions.

Regarding the frequency domain, theta oscillations are related to (emotion-related) salience detection (Basar, 1998, 1999). Studies using different types of stimuli (e.g. faces, pictures, and films) have observed a significant theta power increase (over the frontal and parietal regions) in response to emotional stimuli with high arousal compared to neutral stimuli with low arousal (Knyazev, Slobodskoj-Plusnin, & Bocharov, 2009; Knyazev, Bocharov, Savostyanov, & Slobodskoy-Plusnin, 2015; Krause, Viemero, Sillanma, & Teresia, 2000). As there is no consistent neural evidence to support that shame compared to guilt (or guilt compared to shame) more strongly activates brain regions related to emotional arousal (Basile et al., 2011; Michl et al., 2014; Roth et al., 2014; Wagner et al., 2011), we anticipated that the theta oscillations would not show significant difference between the shame and guilt conditions.

Alpha oscillations have been associated with basic cognitive processes such as attention (see a review, Wolfgang Klimesch, 2012). A study on attention found that the alpha desynchronization over parietal regions is larger for tasks with external attention focus (e.g. tasks that require processing of external information from surroundings) than for tasks with internal attention focus (Benedek, Schickel, Jauk, Fink, & Neubauer, 2014). It is believed that the alpha desynchronization could reflect attentional orienting (Benedek, Bergner, Könen, Fink, & Neubauer, 2011; Benedek et al., 2014; Rowland, Meile, & Nicolaidis, 1985). Considering guilt compared to shame is more related to orienting focus on others (instead of internal self) and showing empathetic concerns about others (Tangney & Dearing, 2003), we predicted that the alpha desynchronization would be larger in the guilt condition than the shame condition.

## Methods

### Participants

Twenty-eight students from Beijing Normal University participated in the study. All participants were right-handed, had normal or corrected-to-normal vision, and reported no history of neurological or mental diseases. Three participants were excluded due to misunderstanding the instructions or dropping out for personal reasons, leaving 25 participants (17 females, $M_{age}$ = 20.56 years, $SD$ = 1.69) in analyses. One male and one female undergraduate students (both aged 20 years), who were strangers to the participants, were recruited as confederates. The study was approved by the Institutional Review Board of Beijing Normal University.

**Procedures**

Upon arrival, participants were informed that they would played an advice-decision game (adpated from Yu, Hu, Hu, & Zhou, 2014) with a same sex confederate on computers. After signing the informed consent form together, the participants and the confederate were arranged to different rooms. There were two roles, an advisor and a decider, in this game. In each trial, the advisor saw a picture of points (always containing 20 points but in random positions for each display) for 1.5 s and gave advice to the decider about whether the number of points was more or less than 20 within 2 s. Meanwhile, the decider saw the same picture, but only for 0.75 s, and then made a decision whether the number of points was more or less than 20 after he or she received advice from the advisor within 3 s. Then, both the advisor and decider saw the outcomes about whether the advice and decision were right or wrong. Finally, a pair of emotional words appeared. Different pairs of emotional words followed different outcomes (see Table 1). The positions of the words were counterbalanced. The participants were asked to choose one word that best described their emotion at that time. Importantly, they were formally informed that they could choose not to respond if none of these words matched their current emotion so it is NOT a forced choice. In fact, the participants did give up responding in 0.53% trials. The timelines for the advisor and decider are shown in Figure 1.

**[Insert Table 1 about here]**

**[Insert Figure 1 about here]**

The participants were informed that, in this game when acting as the decider, a right decision earned the participants 0.5 Chinese yuan and a wrong decision cost the participants 0.5 Chinese yuan. When acting as the advisor, regardless of the correctness of the advice, the participants earned 60 Chinese yuan as a participation fee. In other words, when being the advisor, the participants' performance would not influence their own payment.

To strength the feelings of shame and guilt, the participants acted as the decider for 30 trials before they acted as the advisor. The outcome of the decision was displayed according to following rules: if the participant followed the advisor's advice, he or she will be correct 80% times; otherwise he or she will be correct 20% times. Previous studies have found that responsibility and task difficulty affect the feeling of shame and guilt (Hoffman, 1982). Such a manipulation is for highlighting the responsibility of the advisor and implied the difficulty of the advisor's task was not too high, which could enhance the participants' shame and guilt when they acted as the advisor later.

We focused on the behavioral and EEG data when the participants acted as the advisor. The participants acted as the advisor for 160 trials. In 50 of these trials, the participants were informed that the advice and the decision were both wrong (the guilt condition). This implies that the participants' wrong advice resulted in the decider's economic loss, at least to some extent. The bad outcome and the responsibility for the bad outcome could cause guilt (Carnì, Petrocchi, Del Miglio, Mancini, & Couyoumdjian, 2013; Tangney & Dearing, 2003; Tracy & Robins, 2006). In another 50 trials, the advice was wrong and the decision was right (the shame condition). This implies that the decider rejected the advice correctly and his or her performance was obviously much better than the participants, considering the decider had less time (0.75 s) to see the picture of the points than the advisor (1.5 s). The feelings of rejection and inferiority could result in shame (Leach, 2011; Smith, Webster, Parrott, & Eyre, 2002; Tangney & Dearing, 2003; Tracy & Robins, 2006). In still another 50 trials, the advice and the decision were both right (the happiness condition). Happiness is a non-moral positive emotion. No study suggests that happiness specially involves self-referential processing, empathetic processing, or pain related processing. So happiness could serve as a baseline condition to explore how related psychological processes change in the shame and guilt conditions (e.g. whether the self-referential processing increases in shame condition or the self-referential processing decreases in the guilt condition). In the remaining 10 trials, the advice was right and the decision was wrong. The number of trials of this condition was set to be few, because in the pilot experiments we found that they reduced participants' feelings of shame in the shame condition. If the decider correctly rejected the advice as many times as they wrongly rejected the advice, the participants thought the decider's good performance in the shame condition was just by luck and did not feel inferior and ashamed in the shame condition. Trials of different conditions were presented in a pseudo-random order, with the guarantee that trials of the same condition did not appear consecutively more than three times.

After the game, participants rated on a list of emotional words (sadness, shame, happiness, guilt, anger, and pride) how strongly they felt each of these emotions under different conditions (1 = not at all, 9 = very strong). Participants also finished a test of instruction comprehension. Only when their answers on this test were all correct were their data included in analyses. In the end, all participants were debriefed and received 70 Chinese yuan as payment.

To test the paradigm above, we conducted a behavioral pilot study with 27 participants before the formal study. The results showed that the paradigm could successfully induce target emotions (see Supplementary Materials).





**EEG/ERP recording and analysis**

During the advice-decision game, the EEG was recorded from 64 locations using electrodes mounted in an elastic cap (NeuroScan Inc.). Signals were referenced online to the left mastoid. Horizontal electrooculogram (EOG) was recorded from two electrodes placed at the outer canthi of both eyes. Vertical EOG was recorded from electrodes placed above and below the left eye. The EEG and EOG data were amplified, bandpass filtered (0.05–100 Hz), and digitized (500 Hz). Electrode impedances were maintained below 5 kΩ.

*Preprocessing*. EEG signals were re-referenced offline to bilateral mastoids. Ocular artifacts were removed using a regression procedure implemented in the Neuroscan software (Semlitsch, Anderer, Schuster, & Presslich, 1986). The data were digitally filtered with a 0.5 Hz highpass filter, segmented into 3000 ms time windows with a pre-stimulus time of 800 ms, and baseline corrected using the 200 ms prior to the outcome of the decider's decision. Epochs containing artifacts exceeding ± 100 μV were rejected from the analysis. On average, 47.24 ± 3.23, 47.16 ± 3.88, and 47.96 ± 3.23 artifact-free trials were left in the guilt, shame, and happiness conditions after artifact rejection.

*ERP components analysis*. The artifact free data were re-segmented to epochs of 1200 ms duration time-locked to the outcome of the decider's decision (marked with a red square in Figure 1), including a 200 ms pre-stimulus baseline. Next, the data were filtered with a 30-Hz low-pass filter. Our main interest was on the P2, N2, and P3 components. The P2 component was measured as the peak amplitude by searching for the most positive peak over 140–220 ms at electrodes F3, Fz, F4, FC3, FCz, and FC4. The N2 component was measured as the peak-to-peak amplitude by searching for the most negative peak over 160–240 ms at electrodes F3, Fz, F4, FC3, FCz, and FC4 with the preceding P2 peak as baseline. We measured the N2 relative to the P2, because the P2 and N2 overlaid each other (see Gajewski, Stoerig, & Falkenstein, 2008; Picton et al., 2000). The P3 component was measured as the mean amplitude over 280-520 ms at FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, and CP2. The time windows and electrode sites for these ERP components were chosen based on previous studies (Chen et al., 2011; Hu et al., 2011; Huang & Luo, 2006) and visual inspection of the ERP waveforms.

*Time-frequency analysis*. The time frequency analysis procedure was conducted on each trial, and ERSPs (event-related spectral perturbations) were calculated using artifact free data by a complex sinusoidal wavelet transform implemented in EEGLAB running on MATLAB software (Delorme & Makeig, 2004). To prevent edge effects from contaminating time windows of interest, the time window over -800 to 2200 ms time-locked to the outcome of the decider's decision was used for time frequency analysis. The power at each time points across the frequency range of 3–100 Hz was estimated. Baseline-correction procedure was applied within a -200 to 0 ms pre-stimulus range and the power values were changed into decibel scale. The frequency epochs were averaged within each condition for each subject to yield an averaged power spectrum. All spectrum power values were log transformed prior to further analysis. The ERSP in the theta band (4–8 Hz) in the time window of 180 to 520 ms at FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, and CP2 and ERSP in the alpha band (8–12 Hz) in the time window of 240 to 1000 ms at CP5, P3, P5, P7, and TP7 were averaged for analysis. The frequency bands, time windows, and electrode sites were selected based on previous studies (Benedek et al., 2014; Knyazev et al., 2009) and visual inspection of the frequency plots.

According to an exploratory analysis, no significant difference in the beta (13–30 Hz) or gamma (>30 Hz) band was found across conditions. For conciseness, we only presented the data of interest (4–12 Hz over -200 to 1000 ms).

We focused on the data in the shame, guilt, and happiness conditions when participants acted as the advisor. The happiness condition was used as a control. The P2, N2, and P3 amplitudes and the ERSP values in the theta and alpha bands were fed into one-way (Emotion: Shame vs. Guilt vs. Happiness) repeated measure ANOVAs. Post hoc tests for multiple comparisons were corrected by the Bonferroni method. The Greenhouse-Geisser correction was used in analyses when necessary. Effect sizes were presented as partial eta squared ($\eta_p^2$).

## Results

### Behavioral results

In the shame condition, “shame” choice ($M$ = 30.24, $SD$ = 11.54) was more frequently chosen than “guilt” ($M$ = 19.40, $SD$ = 11.33; $F(1,24) = 5.62$, $p = .026$, $\eta_p^2 = .190$) and “no response” ($M$ = .36, $SD$ = .76; $F(1,24) = 313.78$, $p < .001$ , $\eta_p^2 = .929$), and the post-task ratings of shame were significantly higher than the ratings of other emotions, all $F$s > 6.05, all $ps$ < .021, all $\eta_p^2s$ > .202 (Figure 2). In the guilt condition, “guilt” ($M$ = 32.40, SD = 8.75) was more frequently chosen than “shame” ($M$ = 17.24, $SD$ = 8.52; $F(1,24) = 19.30$, $p < .001$, $\eta_p^2 = .446$) and “no response” ($M$ = .36, $SD$ = .57; $F(1,24) = 161.03$, $p < .001$, $\eta_p^2 = .870$), and the post-task ratings of guilt were significantly higher than the ratings of other emotions, all $F$s > 9.54, all $ps$ < .005, all $\eta_p^2s$ > .284. In the happiness condition, “happiness” ($M$ = 40.28, $SD$ = 9.55) was more frequently chosen than “pride” ($M$ = 9.28, $SD$ = 9.44; $F(1,24) = 66.80$, $p < .001$, $\eta_p^2 = .736$) and “no response” ($M$ = .44, $SD$ = .92; $F(1,24) = 418.54$, $p < .001$, $\eta_p^2 = .946$), and the ratings of happiness were significantly higher than the ratings of other emotions, all $F$s > 6.25, all $ps$ < .020, all $\eta_p^2s$ > .207. These results demonstrated that we induced target emotion in each condition.

**[Insert Figure 2 about here]**

### ERP/ERSP results

**P2.** A one-way ANOVA indicated a significant Emotion effect on the P2, $F(2,48) = 6.17$, $p = .004$, $\eta_p^2 = .205$ (Figure 3). Pairwise comparisons with Bonferroni correction showed that the P2 amplitudes were significantly larger in the shame condition (10.29 ± 3.16 μV) than in the guilt (8.79 ± 3.36 μV; $F(1,24) = 12.36$, $p = .006$, $\eta_p^2 = .340$) and happiness (8.81 ± 3.38 μV; $F(1,24) = 6.53$, $p = .050$, $\eta_p^2 = .214$) conditions. There was no significant difference between the guilt and happiness conditions, $F(1,24) < .01$, $p > .999$, $\eta_p^2 < .001$.

**N2.** A one-way ANOVA showed that the Emotion effect on the N2 was not significant, $F(2,48) = .66$, $p = .532$, $\eta_p^2 = .027$.

**P3.** A one-way ANOVA revealed a significant emotion effect on the P3, $F(2,48) = 8.99$, $p = .001$, $\eta_p^2 = .272$. Pairwise comparisons with Bonferroni correction indicated that the P3 amplitudes were significantly smaller in the happiness condition (11.65 ± 4.26 μV) than in the guilt (14.16 ± 5.78 μV; $F(1,24) = 11.49$, $p = .006$, $\eta_p^2 = .324$) and shame (13.83 ± 4.31 μV; $F(1,24) = 13.09$, $p = .003$, $\eta_p^2 = .353$) conditions. There was no significant difference between the shame and guilt conditions, $F(1,24) = .34$, $p > .999$, $\eta_p^2 = .014$.

**[Insert Figure 3 about here]**

**Theta oscillation.** A one-way ANOVA on the theta power showed a significant effect of Emotion, $F(2,48) = 11.58$, $p < .001$, $\eta_p^2 = .325$ (Figure 4). Subsequent pairwise comparisons with Bonferroni correction showed that the theta synchronization was significantly smaller in the happiness condition (1.81 ± .79 dB) than in the guilt (2.52 ± 1.03 dB; $F(1,24) = 23.92$, $p < .001$, $\eta_p^2 = .499$) and shame (2.52 ± .81 dB; $F(1,24) = 17.45$, $p < .001$, $\eta_p^2 = .421$) conditions, and there was no significant difference between the shame and guilt conditions, $F(1,24) < .01$, $p > .999$, $\eta_p^2 < .001$.

**Alpha oscillation.** A one-way ANOVA on the alpha power revealed a significant effect of Emotion, $F(2,48) = 6.99$, $p = .005$, $\eta_p^2 = .226$. Subsequent pairwise comparisons with Bonferroni correction showed that the alpha desynchronization was significantly larger in the guilt condition (-1.14 ± 1.71 dB) than in the shame (-.606 ± 1.55 dB; $F(1,24) = 7.02$, $p = .042$, $\eta_p^2 = .226$) and happiness (-.30 ± 1.35 dB; $F(1,24) = 8.99$, $p = .019$, $\eta_p^2 = .272$) conditions. No significant difference was found between the shame and happiness conditions, $F(1,24) =$

2.61, $p = .359$, $\eta_p^2 = .098$.

**[Insert Figure 4 about here]**

## Discussion

The present study investigated the time course of shame and guilt processing using an interpersonal paradigm. In the pilot and formal studies, participants' choice during the experiment and their ratings after the experiment suggested that shame and guilt were successfully evoked in intended conditions. The EEG results showed that the P2 was larger in the shame condition than the guilt and happiness conditions and the alpha desynchronization over the parietal region was larger in the guilt condition than the shame and happiness conditions. No significant difference was found in the N2. The P3 and theta synchronization were larger in the shame and guilt conditions than the happiness condition, but showed no significant difference between the shame and guilt conditions.

To the best of our knowledge, this is the first study using an electrophysiological method to explore shame and guilt processing. Taking advantage of the high temporal resolution of the electrophysiological method, we found that the difference between shame and guilt processing occurred in a rather early stage (P2 component, 140–220 ms) or started from an early time (alpha desynchronization, 240 ms), which is consistent with previous ERP studies which suggest that moral processing happens early in the brain (Decety & Cacioppo, 2012; Gan et al., 2016; Gui et al., 2015; Yoder & Decety, 2014).

Our findings showed that the difference between shame and guilt processing occurred in the P2 component, which is associated with early attentional selection and perceptual processing (Hillyard & Anllo-Vento, 1998; Martin & Potts, 2004). It has been found the P2 is larger for the self-relevant information compared with the non-self-relevant information, as the self-relevant information is more arousing and attention-capturing (Chen et al., 2011; Hu, Wu, & Fu, 2011; Meixner & Rosenfeld, 2010). The enhanced P2 found in the shame condition of our study could be caused by the self-relevant information involved in the shame condition (e.g. in the shame condition it was implied that the participants were less capable than the confederate). Our results are consistent with the theoretical claim that shame is more related to the self-referential processing than guilt (Tangney & Dearing, 2003). Considering that the P2 is an early component, our results suggested that the wrongdoers could quickly become aware of information which has adverse effects on their self-concept and self-esteem in a shame situation. The quick identification of negative information regarding the self may facilitate people to deal with their damaged self-image in a timely manner. Shame has been proposed as an emotional mechanism to protect individuals' self-image (de Hooge et al., 2010; Sznycer et al., 2016). Our findings here further suggested that this emotional mechanism can identify information that may threaten one's self-concept in an early stage.

The difference between shame and guilt processing were also found in the alpha oscillations over the parietal region, which is related to attentional orienting (Benedek et al., 2011, 2014; Klimesch, 2012; Rowland et al., 1985). Benedek et al. (2014) found that orienting attention to external information (compared to internal information) could elicit larger alpha desynchronization over the parietal region. Thus, our findings might suggest that in the state of guilt compared with shame, people are more inclined to orient attention to others instead of internal self. The results, to some extent, were consistent with the theoretical claim that guilt compared to shame is more related to the empathetic processing (concerning about others' thoughts and feelings) (Tangney & Dearing, 2003).

The quick distinction between shame and guilt is vital for wrongdoers to achieve guilt-related or shame-related interpersonal goals. It is believed that shame and shame-related behaviors (e.g. hide and escape) guard wrongdoers' self-image and social reputation (de Hooge, Breugelmans, & Zeelenberg, 2008; de Hooge et al., 2010; Sznycer et al., 2016), while guilt and guilt-related behaviors (e.g. apology, compensation, and self-punishment) maintain wrongdoers' interpersonal relationships (Baumeister, Stillwell, & Heatherton, 1994; Carnì et al., 2013; Zhu et al., 2017; Zhu et al., 2017). However, to achieve the interpersonal goals of shame and guilt, wrongdoers should not only act rightly but also act quickly. In terms of shame, quick withdrawal protects wrongdoers against devaluation (Gausel & Leach, 2011; Sznycer et al., 2016). When wrongdoers' inability or immorality is accidently exposed in public, wrongdoers can avoid being directly criticized and limit the extent to which others know and spread reputation-damaging information by hiding themselves quickly. In terms of guilt, compared to people who reach a moral decision slowly (a sign of doubt and uncertainty), people who reach a moral decision quickly receive more positive moral evaluations (Critcher, Inbar, & Pizarro, 2012; Evans & van de Calseyde, 2017; Jordan, Hoffman, Nowak, & Rand, 2016; Van de Calseyde, Keren, & Zeelenberg, 2014). When an accident is caused, wrongdoers are more likely to be forgiven if an apology is made immediately than some time later. Thus, the quick distinction between shame and guilt, which facilitates quick performance of the guilt- or shame-related behaviors, is conductive to the achievement of the corresponding interpersonal goals.

No significant difference was found in the N2 among the shame, guilt, and happiness conditions. The N2 is related to controlled attention (see a review, Folstein & Van Petten, 2008). Our results might suggest that the controlled attention paid to the outcome of the confederate was same among three conditions in the N2 stage. The results are out of our expectation that the N2 would be smaller in the shame condition than the guilt condition, which was based on the consideration that more self-relevant information might be involved in the shame condition than the guilt condition (Tangney & Dearing, 2003) and self-relevant information compared to non-self-relevant information might be processed more easily and consume less cognitive resources (Campanella et al., 2002; Chen et al., 2011). One possible explanation for this no significant results is the paradigm we used. In our paradigm, the participants, whose aim was to help the confederate, might especially care about the social meaning of the feedback. After the early information processing (the P2 stage), the high-level social meaning of the feedback in different conditions was still unclear. Thus, in the N2 stage, a temporal stage which is between automatic and completely controlled information processing phases, the participants might try their best to allocate a (same) large amount of attention to the preliminarily processing of the social meaning of the feedback in different conditions.

Additionally, it has been found that N2 amplitudes become larger for negative feedback than for positive feedback (Hajcak, Moser, Holroyd, & Simons, 2006; Yeung & Sanfey, 2004). Some might suppose that larger N2 amplitudes would be elicited in the guilt condition than the shame condition, as the confederate lost money in the guilt condition, whereas the confederate gained money in the shame condition. It is the fact that a stranger's gains and losses could affect the N2, but the effect exists only when people act as observers (Yu &

Zhou, 2006). The study of Ma et al. (2011) showed that when participants themselves or friends of the participants were also involved in a game, the stranger's gains and losses would not influence the N2 anymore. Considering that the participants in the present study played an important role in the game and received both the feedback of their own advice and the feedback of the confederate's decision, it is not surprising to find that no significant difference was found in the N2. It is worth noting that we do not imply that the outcome value of the confederate's feedback was not processed. Our results just suggested that the N2 might not be sensitive enough to reflect the outcome value of the feedback here.

Our results showed that the P3 amplitudes were smaller in the happiness condition than in the shame and guilt conditions, but there were no significant difference between the shame and guilt conditions. The P3 is related to many elaborate cognitive processes (Ito, Larsen, Smith, & Cacioppo, 1998; Polich, 2007, 2012). Some studies has revealed that the P3 could reflect attentional resource allocation (Isreal et al., 1980; Wickens et al., 1983). Ullsperger et al. (1988) found a positive correlation between the P3 amplitudes and effort in a task, which means that the more the attentional resource is allocated to the current task, the larger the P3 amplitudes would be. Our results suggested that people allocate more attentional resource to the shame and guilt situations, in which the participants may be devalued or punished by others, than the happiness situation. In addition, other studies have indicated that the P3 is linked with emotional processing (Carretié, Iglesias, Garcia, & Ballesteros, 1997; Ito et al., 1998; Kestenbaum & Nelson, 1992). The larger P3 amplitudes are found for the more emotionally negative stimuli (Ito et al., 1998; Olofsson et al., 2008). Thus our results suggested that shame and guilt compared to happiness are more emotionally negative.

Our results also showed that the theta synchronization was significantly smaller in the happiness condition than in the shame and guilt conditions, but there were no significant difference between shame and guilt conditions. Theta oscillations over the frontal region are associated with emotional processing (Basar, 1998, 1999). There is a positive correlation between theta power and emotional arousal (Knyazev, Slobodskoj-Plusnin, & Bocharov, 2009; Knyazev, Bocharov, Savostyanov, & Slobodskoy-Plusnin, 2015; Krause, Viemero, Sillanma, & Teresia, 2000). Our results might suggest that shame and guilt compared to happiness are more emotionally arousing.

The results of the P3 component and theta oscillations, suggesting that shame and guilt are similarly negative and arousing, are in line with the previous fMRI findings (Basile et al., 2011; Michl et al., 2014; Roth et al., 2014; Wagner et al., 2011). However, these neural results seem inconsistent with the behavioral results of Tangney (1993) in which shame was reported to be more psychologically painful than guilt. A possible reason is that psychological pain, unlike physical pain, is more of an abstract and unfamiliar concept, so people are not capable of accurately rating how much psychologically pain they feel. When it comes to such a complex emotional state, neural indicators may provide more objective evidence (Otten & Jonas, 2014).

The current study has some limitations. First, only two emotional words were offered for the participants to choose in each trial. It looks like a forced choice, which might force the participants to select an emotion that they did not feel. But, as has been emphasized in the Method section, it is actually not a forced choice since the participants were clearly told that they could choose not to respond if neither word described their current feelings. In addition, the post-task questionnaire provided the participants a second chance to freely rate on different emotions for different conditions, including sadness, shame, happiness, guilt, anger, and pride. The rating results showed that we did successfully induce target emotion in each condition. Secondly, in the behavioral results, the feelings of shame and guilt were somehow mixed in the shame and guilt conditions without a pure distinction. This is because shame and guilt naturally coexist (Tangney & Dearing, 2003). Previous studies also found guilt stimuli evoked shame feelings and vice versa (Michl et al., 2014; Takahashi et al., 2004). Even when people were asked to recall a guilty experience, they still reported feelings of shame (Wagner et al., 2011). Thus, it is unlikely to induce pure guilt or shame. Consistent with previous studies, here we ensured the ratings of target emotion in each condition were significantly higher than any other emotion. Moreover, because the present study focused on the neural difference between shame and guilt, the mixed shame and guilt feelings in the shame and guilt conditions actually weakened our experimental effects. So the results reported here might be conservative to some extent.

## Conclusion

Inducing shame and guilt in an interpersonal context, our results of the P2 and alpha oscillations supported previous findings that shame compared to guilt involves more self-referential processing, while guilt compared to shame involves more empathetic processing. No significance difference was found in the N2, P3, and theta oscillations between the shame and guilt conditions. The high temporal resolution of the EEG technique enables us to find that the shame and guilt processing could be dissociated in an early stage (P2 component, 140–220 ms and alpha oscillation, started from 240 ms). The quick distinction between shame and guilt may facilitate quick performance of the subsequent guilt- or shame- related behaviors, which is conductive to the achievement of the corresponding interpersonal goals.

## Acknowledgements

We thank Dandan Zhang and Zheng Li for constructive and helpful comments. This work was supported by the National Key R&D Program of China (2017YFC0803402), the National Basic Research Program of China (2013CB837300), the National Natural Science Foundation of China (NSFC) (31170971, 31400888, 31771206), the Major Project of National Social Science Foundation (12&ZD228), the Beijing Municipal Science & Technology Commission (Z151100003915122), the National Program for Support of Top-notch Young Professionals, and the Fundamental Research Funds for the Central Universities and the Research Funds of Renmin University of China (15XNLQ05).

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**Table 1.** Pairs of words which appeared following different outcomes.

| Role of the participants | Conditions | Outcomes | | Pairs of words |
|---|---|---|---|---|
| | | Advice | Decision | |
| Advisor | Guilt | wrong | wrong | guilt/shame |
| | Shame | wrong | right | guilt/shame |
| | Happiness | right | right | happiness/pride |
| | | right | wrong | happiness/pride |
| Decider | | wrong | wrong | sadness/anger |
| | | wrong | right | happiness/pride |
| | | right | right | happiness/pride |
| | | right | wrong | sadness /shame |



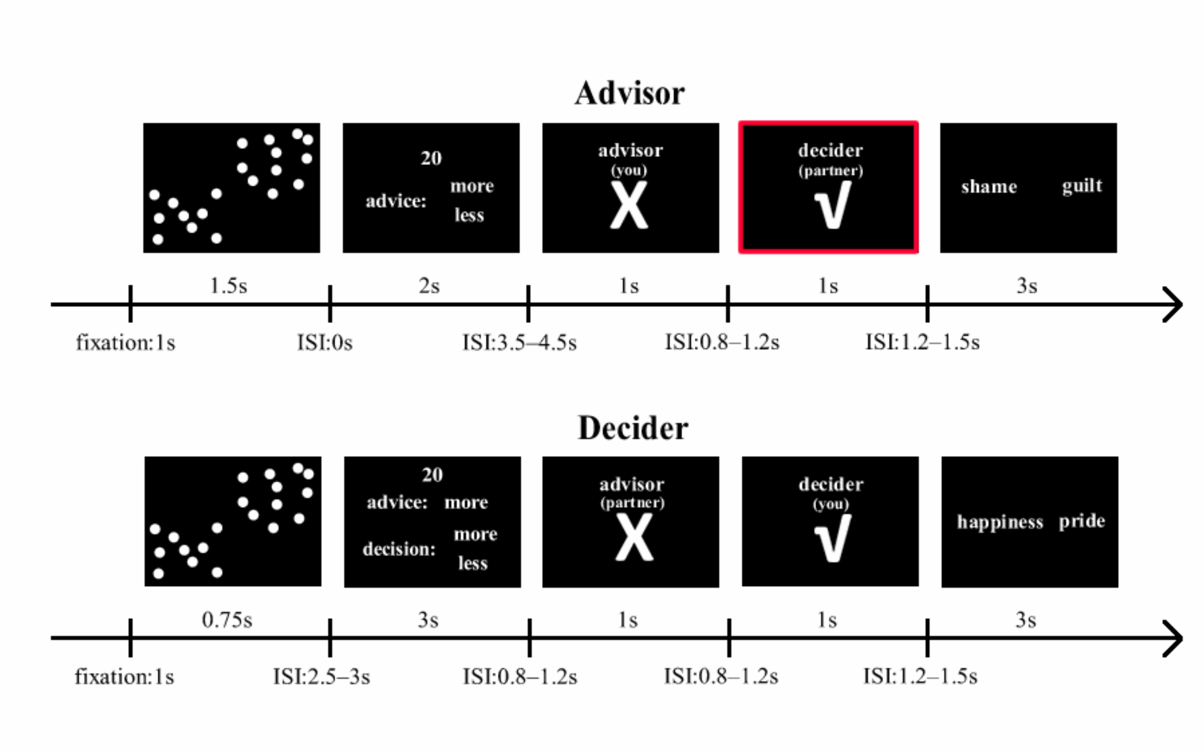



**Figure 1.** The sequence of events in a trial for the advisor and decider. The ERP and ERSP data were time-locked to the outcome of the decider's decision (marked with a red square in the figure) when the participants acted as the advisor. ISI: interstimulus interval.

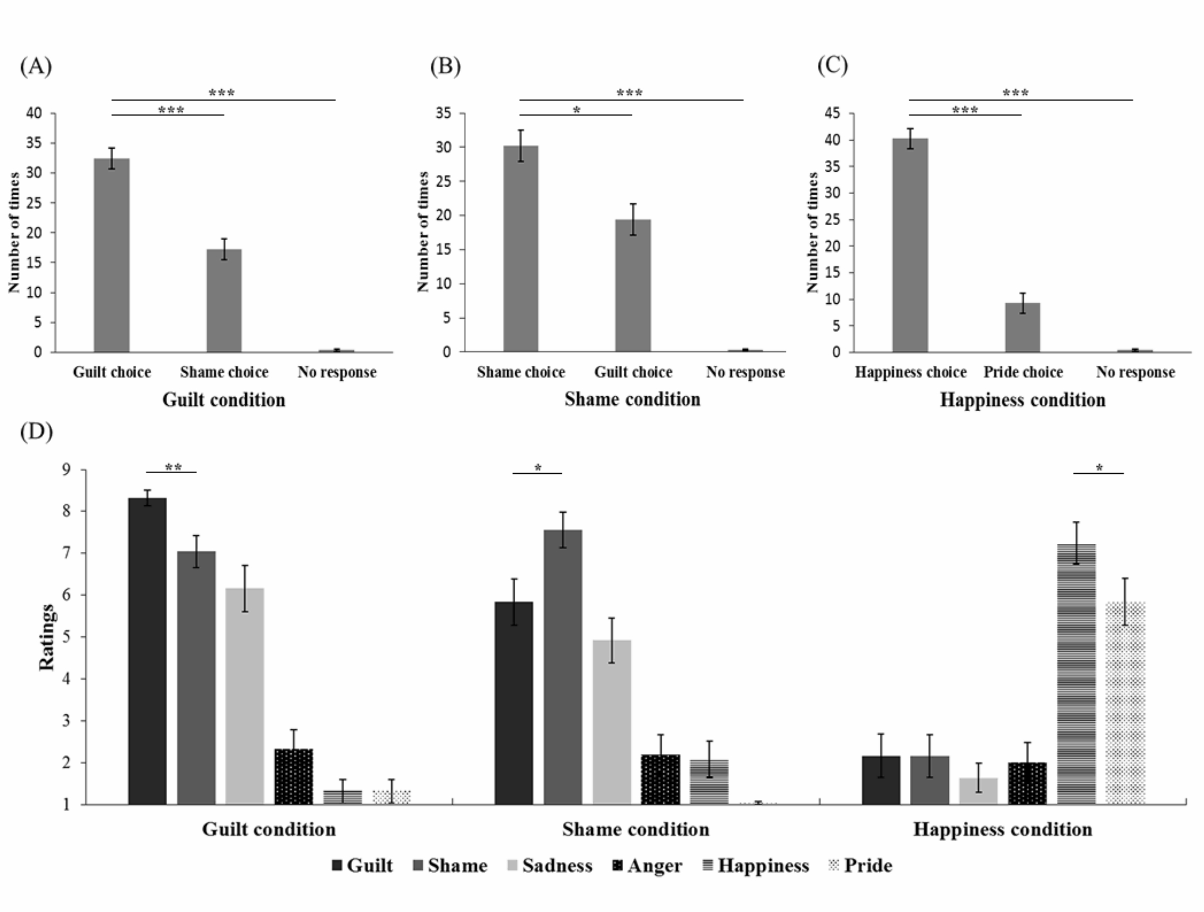
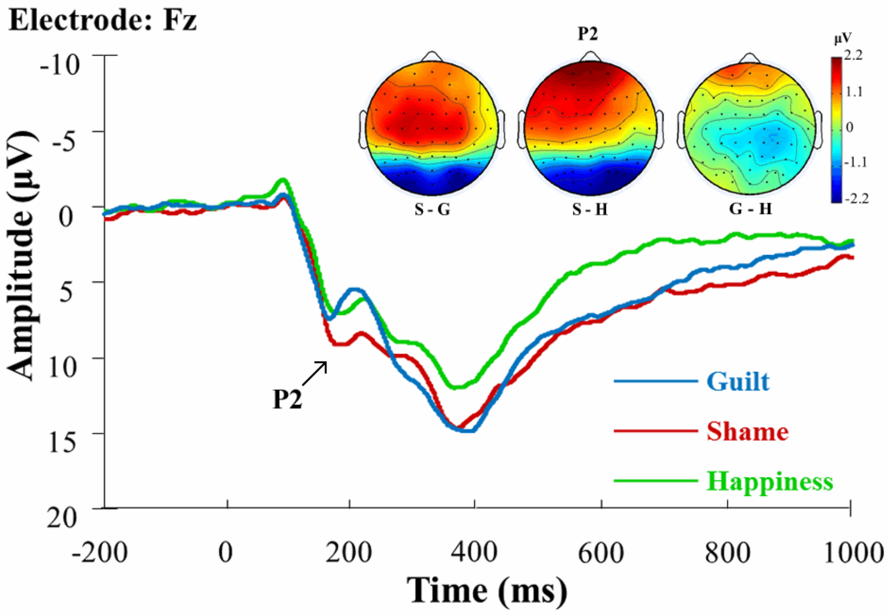



**Figure 2. A–C**, Behavioral results. Participants' choice of emotional words in the guilt (**A**), shame (**B**), and happiness (**C**) conditions. **D**, Participants' ratings of different emotions in the guilt, shame, and happiness conditions. *$p < .05$, **$p < .01$, ***$p < .001$.



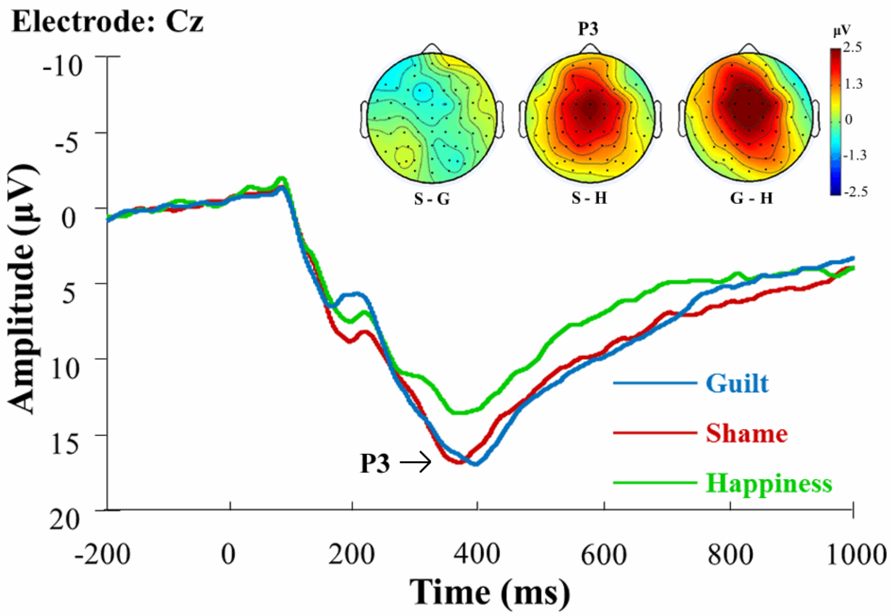




**Figure 3.** Grand-averaged ERPs time-locked to the outcome of the decider's decision in the guilt, shame, and happiness conditions at Fz and Cz. Topographic maps of difference waves are presented for the P2 and P3 for selected contrasts. Shame condition elicited larger P2 amplitudes over the frontal region than the guilt and happiness conditions did. S: shame condition, G: guilt condition, H: happiness condition.

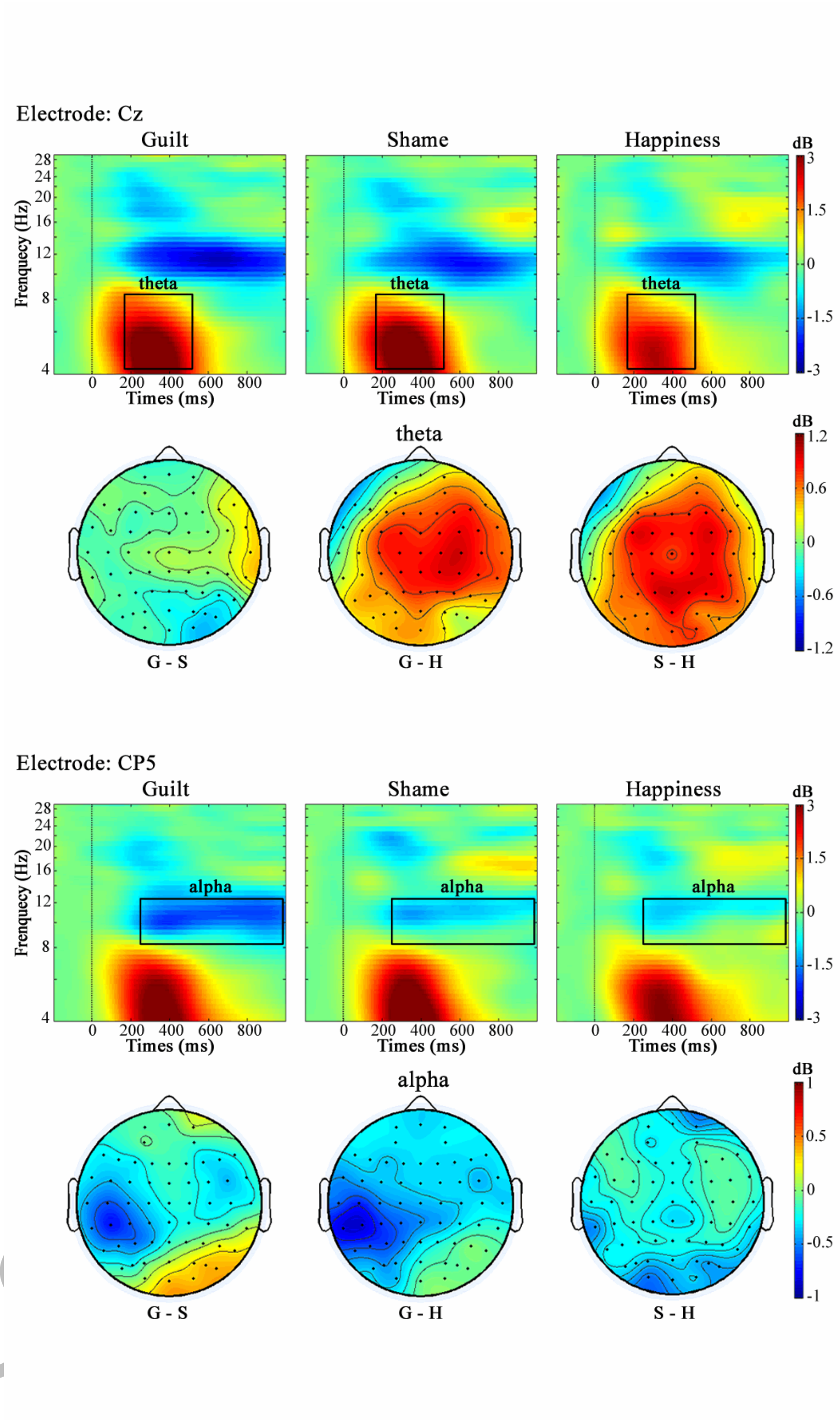



**Figure 4.** Group-averaged ERSP time-locked to the outcome of the decider's decision in the guilt, shame, and happiness conditions at Cz and CP5. Topographic maps of difference power are presented for the alpha and theta oscillations for selected contrasts. Guilt condition elicited larger alpha desynchronization over the left parietal region than the shame and happiness conditions did. S: shame condition; G: guilt condition; H: happiness condition.

# Supplementary Material

## Pilot study

### Procedure of the pilot study

Twenty-seven students from Beijing Normal University participated in the pilot study. Two participants were excluded due to misunderstanding the instructions, leaving 25 participants (12 females, $M_{age}$ = 22.52 years, *SD* = 2.58) in the analyses. The procedure of the pilot experiment was the same as the formal one, except that participants acted as the decider for 25 trials and as the advisor for 25 trials (shame condition: 8 trails, guilt condition: 8 trails, happiness condition: 7 trails, uncertain condition: 2 trails) without EEG recording.

### Results of the pilot study

In the shame condition, "shame" choice ($M = 5.28$, $SD = 2.17$) was more frequently chosen than "guilt" ($M = 2.72$, $SD = 2.17$; $F(1,24) = 8.70$, $p = .007$, $\eta_p^2 = .266$) and "no response" ($M = .00$, $SD = .00$; $F(1,24) = 147.98$, $p < .001$ , $\eta_p^2 = .860$), and the post-task ratings of shame were significantly higher than the ratings of other emotions, all *F*s > 4.22, all *p*s < .051, all $\eta_p^2$ s > .150. In the guilt condition, "guilt" ($M = 5.04$, $SD = 1.59$) was more frequently chosen than "shame" ($M = 2.84$, $SD = 1.62$; $F(1,24) = 11.81$, $p = .002$, $\eta_p^2 = .330$) and "no response" ($M = .11$, $SD = .32$; $F(1,24) = 227.50$, $p < .001$, $\eta_p^2 = .905$), and the post-task ratings of guilt were significantly higher than the ratings of other emotions, all *F*s > 9.71, all *p*s < .005, all $\eta_p^2$ s > .288. In the happiness condition, "happiness" ($M = 4.72$, $SD = 1.49$) was more frequently chosen than "pride" ($M = 2.28$, $SD = 1.49$; $F(1,24) = 16.84$, $p < .001$, $\eta_p^2 = .412$) and "no response" ($M = .00$, $SD = .00$; $F(1,24) = 252.02$, $p < .001$, $\eta_p^2 = .913$), and the ratings of happiness were significantly higher than the ratings of other emotions, all *F*s > 4.15, all *p*s

< .053, all $\eta_p^2$s > .147. These results demonstrated that we induced target emotion in each condition.