

MODULATION OF FORGIVENESS ON PROCESSING HURT SITUATIONS: A STUDY OF EVENT-RELATED POTENTIALS

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To explore the neuro-mechanism of the time course of processing a hurt situation, we analyzed event-related potentials (ERPs) generated in the brain in response to stimuli in individuals with different degrees of forgiveness. Participants were 216 university students. Of the early ERP components, the negative-deflecting N1 was modulated neither by degree of forgiveness nor by the hurt situation, and the positive-deflecting P2 was larger for low-forgiveness than for high-forgiveness participants, and for low-hurt than for high-hurt situations. The N2, which identifies and encodes stimulus, was enhanced in the high-forgiveness group and for high-hurt situations. Importantly, the late positive component (LPC) stage of stimulus evaluation was larger in the high-forgiveness group for high-hurt situations, but in the low-forgiveness group was evident for low-hurt situations. These data indicate that the modulation of forgiveness on processing hurt situations occurs at the late stage of information processing.

Keywords: forgiveness, hurt situation, event-related potential, late positive component.

As a cognitive, emotional, and behavioral response to interpersonal conflict, *forgiveness* generally refers to absolving another person of blame, or giving up claims on another of debt, loan, obligation, or other claims, which is different from condoning, excusing, forgetting, pardoning, and reconciliation (e.g., Eaton

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& Struthers, 2006; Ryan & Kumar, 2005; van der Wal, Karremans, & Cillessen, 2016). Generally, the offended individuals can use forgiveness as an effective coping strategy to promote their happiness and well-being (Worthington & Scherer, 2004).

Although three main methods (narrative, questionnaire, and experimental) are usually applied in forgiveness research, a few scholars have explored the neurological basis relevant to forgiveness (e.g., Farrow et al., 2001; Young & Saxe, 2009). For example, using functional magnetic resonance imaging, Farrow et al. detected brain regions relevant to judging others' emotional states and forgiveness of their crimes. They found that although both empathic and forgiveness judgments activated left superior frontal and orbitofrontal gyri and precuneus, other different regions were activated by empathic judgments (left anterior middle temporal and left inferior frontal gyri) and forgiveness judgments (posterior cingulate gyrus).

It has been proposed that the nature of the hurt situation plays an important role in the degree of forgiveness judgments (e.g., Brose, Rye, Lutz-Zois, & Ross, 2005; Koutsos, Wertheim, & Kornblum, 2008). McCullough, Fincham, and Tsang (2003) found evidence that initial ratings of transgression severity and empathy did not increase forgiveness over time, but in a situation related to forbearance of a special agreement between a borrower and a lender to delay a foreclosure, whereas initial responsibility attributions were inversely related to forbearance, they did directly increase forgiveness over time. Moreover, in one recent study the researchers investigated subjective and objective perspectives on forgiveness in which participants who were in love were asked to describe how they had been hurt by their lover. The results revealed that the severity of the hurt event could predict the degree of forgiveness, regardless of subjective or objective ratings (Fincham, Jackson, & Beach, 2005).

In neuroimaging studies (e.g., Young & Saxe, 2009), the results have shown that forgiveness relies on brain regions such as the frontal lobes, the temporo-parietal junction, and the anterior cingulate cortex, whereas processing hurt situations involves the inferior frontal gyrus of the brain in inhibiting negative emotion. Little has been known about the time course of processing hurt situations. Krämer, Büttner, Roth, and Münte (2008) have explored the modulation of ERP components related to provocation and evaluation during aggressive interaction. They found a larger frontal negativity during the decision stage under strong provocation as compared to weak provocation, and this condition was positively correlated with the ability to avoid retaliation. Moreover, during the outcome stage, they detected medio-frontal negativity in loss over win conditions. They recorded a result that we find interesting in that, different from the pattern in aggressive participants, among nonaggressive participants this ERP component was slightly smaller in win than in loss conditions, indicating that when these

people were punishing their opponent they had a negative valence similar to when they were being punished. In addition, physiological researchers have assessed the relationship of forgiveness to health by analyzing the heart rate and blood pressure of individuals who were forgiving another person and revealed that forgiveness was indeed associated with the individual's health (Lawler et al., 2003; Lawler et al., 2005).

To further explore the time course of the neuro-mechanism involved in the processing of hurt situations, in the current study we recorded and analyzed the ERPs of individuals with different degrees of forgiveness to test the following hypothesis:

Hypothesis 1: That if the modulation of forgiveness on the processing of the hurt situation occurred at the early stage of information processing, it will be reflected by event-related components, N1, P2, or N2; if not, it will be reflected by the late positive component.

The N1 is an early ERP component that is part of the normal response to visual stimulation and sensitive to selective attention (<https://en.wikipedia.org/wiki/N1>). The P2 event-related component is a positive-going electrical potential that peaks at about 200 milliseconds after the onset of external stimulus and represents some aspect of higher-order perceptual processing, modulated by attention (<https://en.wikipedia.org/wiki/P200>). The N2 event-related component is a negative-going wave with an anterior scalp distribution and a peak latency of 200–350 milliseconds poststimulus and is considered to reflect stimulus identification, attentional shifts, inhibition of motor responses, conflict monitoring (<https://wikipedia.org/wiki/N200>), maintenance of context information, detection of mismatch, and executive cognitive control (Buzzell, Roberts, Baldwin, & McDonald, 2013; Folstein & Van Petten, 2008).

As described by Friedman and Johnson (2000), the late positive component (LPC) is a positive-going wave after 400 milliseconds poststimulus onset with a distribution of medial and posterior scalp, reflecting the late stage of stimulus evaluation processes.

Method

Participants

We analyzed data that we obtained from responses to the Adolescent Forgiveness Questionnaire (Zhou, Lu, Zhang, & Wang, 2017). Participants were 216 students at Shanghai Normal University (109 women; $M_{\text{age}} = 21.6$ years, $SD = 1.8$ years), who were unfamiliar with psychological experiments. Based on their general forgiveness score, we selected 31 participants with either extremely high or extremely low values for an experiment using an electroencephalogram (EEG).

All these students reported that they were right handed, with normal or corrected-to-normal visual acuity, and did not have any history of psychiatric or neurological disorders. All students were paid US\$10 for participation and they signed an informed consent agreement to participate in this study as required by the Institutional Review Board of the Shanghai Normal University. Participants were divided into two groups, those with a high-forgiveness score (16 students, mean score 5.39 ± 0.16) and those with a low-forgiveness score (15 students, mean score 1.93 ± 0.39). The score in the high-score group was significantly higher than that of the low-score group, $t(29) = 33.02, p < .001$.

Stimuli

In the experiment, the participants were presented with a story and asked to imagine that they were the main character in it. The aim of the experiment was to investigate the students' forgiveness emotion by experiencing different feelings of hurt based on the actions of others. For example, one of the stories was as follows:

Miss Ran Zhu and you are good friends and you often play and eat together. You trust each other because you have such a good relationship and you would tell each other anything. The relationship is so good that you believe she would not tell anything that is a private matter to you to others, not even one word. But one day, when you were on the way to somewhere, you happened to hear that Mr. Man Fang and others were talking about something private to do with you that was serious, and that would be bad for your reputation, and would have a negative effect on your study and your life in the future. And you were sure that you had never told such things to anybody except Miss Ran Zhu, and that you had emphasized that she should not tell others about these things. So, you decided to ask her about this, but she said that she thought it was not important. She then told someone else the same information.

Before the story was presented, names of people of the same gender as the participant appeared on their computer screen, and the participant had to indicate whether or not these names were familiar to them. Based on these responses, we chose unfamiliar names of the same gender as the participants for the characters in the story. After reading the story, the participants were asked to identify names that were and were not used in the story from several names presented to them.

Procedure

There were two blocks in the experiment, one presenting a high-hurt situation and the other a low-hurt situation, with multiple trials in each. Each block consisted of the participants reading a story, evaluating the emotions of the people in the story, and indicating whether they recognized the names in the story. Stimuli were presented by E-Prime 2.0.

The story was presented to participants on the computer screen for between 30 and 50 seconds, and they pressed the space bar on the keyboard when they had finished reading the story.

In the evaluation stage, participants answered questions such as, “What do you think about the injury?”, “Which do you think is more injurious to you?”, and “If you are the main character in the story, what are your feelings?”

In the recognition stage, some names appeared in the center of the screen and the participants were asked to judge whether or not each of these was the name of a character in the story. Names shown were the names of the injured party, unrelated names, and names not presented in the story, with 30 items for each category. In each trial, a ‘+’ was first presented from 400 to 600 milliseconds, and then the name was presented. Participants were asked to judge if it was a name in the story by pressing the relevant key. The name disappeared after the participants had pressed the key or, if there was no response, after it had been presented for 2,500 milliseconds. After a blank screen had been presented for 1,500 milliseconds, the next trial started. There was a short break between the two blocks.

Electroencephalogram recording and analyzing. EEG was recorded continuously with a set of 32 Ag/AgCl electrodes placed on participants’ scalps according to the 10/20 system. To monitor participants’ eye movements and blinks, an electrooculogram (EOG) was recorded via electrodes placed on the bilateral external canthi and the left infraorbital and supraorbital areas of the participants’ eyes. Both EEG and EOG signals were sampled at 500 Hz, with a 0.1-100 Hz band pass. During recording, the left mastoid was used as reference and a bimastoid average reference was calculated off-line. Electrode impedances were kept below 5 k Ω .

We corrected EOG artifacts off-line and then the EEG was segmented in epochs of 1,000 milliseconds, beginning 200 milliseconds prior to stimulus onset and averaged separately for each condition. Segments with an incorrect response or contaminated with peak-to-peak deflection exceeding $\pm 100 \mu\text{V}$ were excluded from averaging. After this procedure, averaged ERPs included at least 40 trials for each condition. The averaged ERP waveforms were low-pass filtered at 30 Hz (24dB/octave).

Based on the electrode montage, we measured the amplitudes and latencies of the N1, P2, N2, and LPC components at Fz, F3, F4, FCz, FC3, FC4, Cz, C3, C4, CPz, CP3, CP4, Pz, P3, and P4 sites. For N1 and P2 components, the peak amplitudes and latencies were measured automatically between 90 milliseconds and 160 milliseconds and between 150 milliseconds and 230 milliseconds, respectively. For N2 and LPC components, the mean amplitudes were measured between 280 milliseconds and 330 milliseconds and between 400 milliseconds and 650 milliseconds, respectively. These measurements were submitted to a

four-way analysis of variance (ANOVA) with a between-subjects factor of group (high-forgiveness score, low-forgiveness score), and the within-subject factors of situation (high-hurt, low-hurt; hurt measurements based on a median-split score from the Adolescent Forgiveness Questionnaire), hemisphere (left, midline, and right), and site (F3/Fz/F4, FC3/FCz/FC4, C3/Cz/C4, CP3/CPz/CP4, and P3/Pz/P4). Degrees of freedom (*d/f*) were corrected whenever necessary using the Greenhouse–Geisser epsilon correction factor.

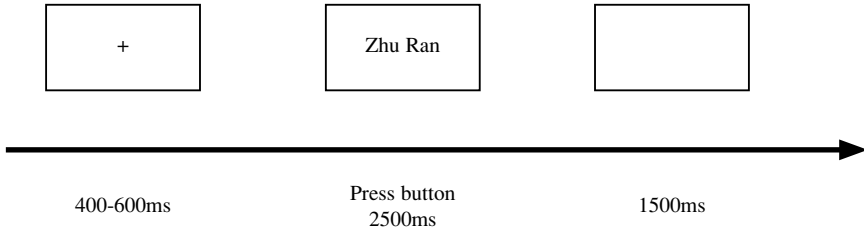


Figure 1. The sequence of on-screen steps in each trial.

Results

There were no significant main effects and interactions for N1 measurements, regardless of latency or amplitudes ($ps > .05$).

For P2 amplitudes, the ANOVA revealed a significant main effect of group, $F(1, 27) = 10.20, p = .004, \eta^2 = 0.27$, showing larger P2 for low-forgiveness (4.99 μV) than for high-forgiveness (2.51 μV) participants. The main effect of situation was significant, $F(1, 27) = 7.61, p = .01, \eta^2 = 0.22$, showing that the P2 amplitude was larger for a low-hurt situation (4.26 μV) than for a high-hurt situation (3.24 μV). No other effects reached a level of significance ($ps > 0.05$). For the P2 latency, neither main effects nor interactions were significant ($p > .05$).

For the N2 component, there were significant main effects of group, $F(1, 27) = 7.47, p = .011, \eta^2 = 0.22$, and situation, $F(1, 27) = 5.25, p = .030, \eta^2 = 0.16$, showing that N2 was enhanced both in the high-forgiveness group (-4.22 μV) compared with the low-forgiveness group (-1.86 μV) and for the high-hurt situation (-3.41 μV) compared with the low-hurt situation (-2.67 μV). The main effect of hemisphere was also significant, $F(2,54) = 23.02, p < 0.001, \eta^2 = 0.46$, showing larger N2 at the midline sites (-4.11 μV) than in the left (-2.56 μV) or right (-2.44 μV) hemispheres. No other effects reached a level of significance ($ps > .05$).

For the LPC, there was a significant main effect of group, $F(1, 27) = 11.71, p = .002, \eta^2 = 0.30$, showing an enhanced LPC for the low-forgiveness group (3.52 μV) over the high-forgiveness group (2.05 μV). The main effect of situation

was also significant, $F(1, 27) = 15.61, p = .001, \eta^2 = 0.37$, showing a larger LPC for a high-hurt situation (3.67 μV) than for a low-hurt situation (1.90 μV). We found the result for the two-way interaction of group situation interesting, $F(1,27) = 4.39, p < .05, \eta^2 = 0.14$. Further analysis for this interaction revealed that the effect of situation was evident in the high-forgiveness group (0.70 μV and 3.41 μV for low-hurt and high-hurt situations, respectively; $p < .01$), but not in the low-forgiveness group (3.10 μV and 3.94 μV for low-hurt and high-hurt situations, respectively; $p = .75$). The group difference was significant for a low-hurt situation ($p < .02$) but not for a high-hurt situation ($p = .85$). No other effects reached a level of significance ($ps > .05$).

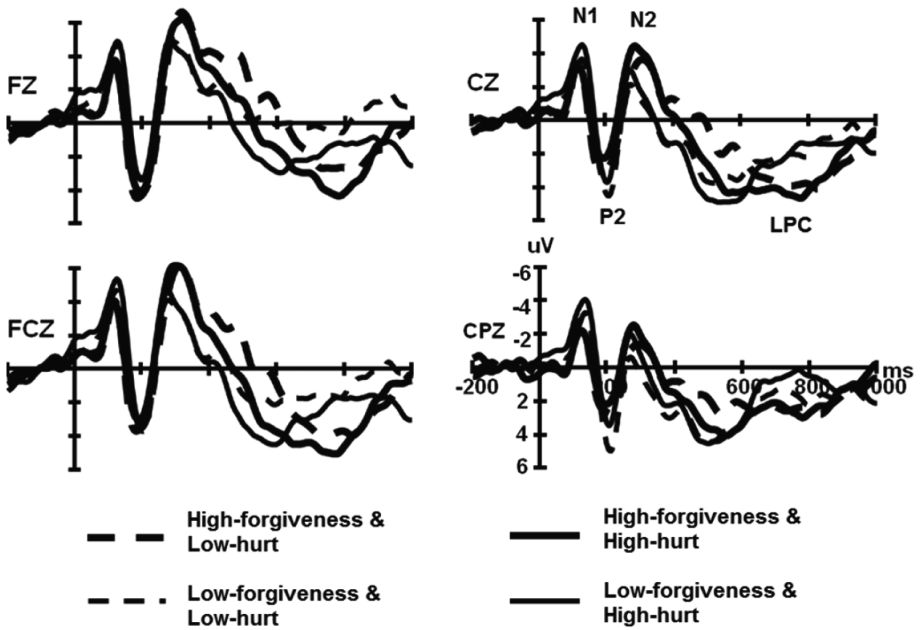


Figure 2. The event-related potential waveforms for four conditions in the two forgiveness-level groups.

Discussion

To explore the time course neuro-mechanism of the processing of a hurt situation, we recorded and analyzed the ERPs in individuals with different degrees of forgiveness. Although the early ERP component N1 was modulated neither by the forgiveness nor by the hurt situations, the P2 was larger for low-forgiveness than for high-forgiveness participants and for low-hurt than for high-hurt situations. However, the N2 was enhanced in the high-forgiveness

over that in the low-forgiveness group and for high-hurt over that for low-hurt situations. A result that we judged to be important was the significant two-way interaction of group situation for the LPC. In the high-forgiveness group, the LPC was larger for high-hurt than for low-hurt situations, but this situation effect was absent in the low-forgiveness group; the larger LPC in the low-forgiveness versus the high-forgiveness group was evident only for a low-hurt situation, not for a high-hurt situation. These data indicated that the modulation of forgiveness on the processing of a hurt situation occurred at the late stage of information processing.

The fact that the P2 was larger for low-hurt than for high-hurt situations indicates the early modulation of emotional content. In line with our findings, the emotional content may be divided automatically in the early stage of processing visual stimuli, based on the amplitude of the P2 component (Gootjes, Coppens, Zwaan, Franken, & Van Strien, 2011; Kanske, Plitschka, & Kotz, 2011; Trauer, Andersen, Kotz, & Müller, 2012). Generally, the ability of the injured party to forgive is related to his or her level of understanding of the motives and ideas of others, and individuals with a low capacity for forgiving are relatively poor in their ability to understand the motives of the hurter. We found that the emotional experiences of these people were more profound and resulted in an enhanced P2 component.

In addition to the P2 component, we also found that the N2 component was enhanced either for high-forgiveness participants or for high-hurt situations. The N2 component is also modulated by trait aggressiveness. For example, in a competitive-reaction-time task, Krämer and colleagues (2008) found N2 was enhanced in the condition of high provocation. In the present study, the high-hurt situation represented aggressiveness and, hence, enhanced the N2 component of the participants. Generally, an individual with high ability for forgiving shows behavior that is more prosocial than that of his or her peers (Mauger, Saxon, Hamill, & Pannell, 1996) and hence, in our experiment, for the students in the high-forgiveness-score group there could have been greater cognitive conflict when they were feeling for the main character in the hurt situations. Therefore, the increase in cognitive conflict could be the source of the enhanced N2.

Finally, we found a significant modulation of degree of forgiveness and situation on the LPC. After reading the story, the students were asked to identify and evaluate the people in the story. The group with high-forgiveness-ability scores showed less thinking repeatedly, so that the LPC amplitude related to their process of evaluating the hurter should be smaller than the group with the low-forgiveness-ability scores. On the other hand, the LPC in response to emotional words, pictures, and faces is also sensitive to the motivational relevance of the stimuli and reflects the postperceptual analysis of these stimuli, and it is this postperceptual analysis that is used to facilitate processing and encoding of the

emotional stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp et al., 2004). In our experiment, the high-hurt situation story presented more negative emotion and, therefore, resulted in a larger LPC for the high-forgiveness group. This result is in line with that of a recent ERP study relevant to processing emotional stimuli (Olofsson, Nordin, Sequeira, & Polich, 2008).

In sum, the present study investigated the neural basis of the modulation of forgiveness and indicated that this modulation on processing of hurt situations occurred at the late stage of information processing.

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