

The Effect of Empathic Concern on Fairness Decision-Making: Evidence from ERP

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Abstract

This study utilized event-related potential (ERP) technology and the ultimatum game (UG) paradigm to examine the effect of empathic concern on fairness decision-making. The experiment employed a 2 (state empathic concern: with empathic concern vs. without empathic concern) \times 3 (allocation fairness: fair vs. disadvantageous unfair vs. advantageous unfair) within-subjects design, with 37 participants completing the experiment. Participants served as responders and decided whether to accept allocation proposals from proposers. Behavioral results demonstrated that under disadvantageous unfair conditions, acceptance rates were higher in the empathic concern condition than in the no-empathy condition; conversely, under advantageous unfair conditions, the opposite pattern emerged. ERP results revealed: for advantageous unfair proposals offered by others, the no-empathy condition elicited a more negative anterior N1 (AN1) relative to the empathic concern condition, while the empathic concern condition evoked larger P2 amplitudes compared to the no-empathy condition; under the empathic concern condition, disadvantageous unfair proposals offered by others induced a more negative medial frontal negativity (MFN) than both advantageous unfair and fair proposals; P3 amplitude was greater under fair conditions than under disadvantageous unfair conditions and was not modulated by empathic concern. These findings indicate that empathic concern not only modulated fairness decision-making behavior but also regulated early attentional and motivational processes as well as subsequent cognitive and emotional processing in fairness evaluation; however, the higher-level cognitive process indexed by P3 was solely modulated by fairness and unaffected by empathy level.

Full Text

The Influence of Empathic Concern on Fairness-Related Decision Making: Evidence from ERP

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Abstract

Recipients often reject unfair offers at the cost of their own interests in ultimatum games (UGs), reflecting their fairness preference. Yet fairness preference is not invariable. It is affected by various factors, among which empathy plays an important role. Individuals might, for example, sacrifice own interests to help others in need. This kind of behavior not only is contrary to the pursuit of self-interest maximization but also violates fairness principles. As individuals are not only concerned about fairness but also care for others, this study focuses on managing the relationship between the two potentially conflicting goals. We explored individuals' behaviors and time dynamic processes of brain activities when fairness conflicted with empathy. It was hypothesized that empathy could modulate fairness-related decision making behaviors and ERPs.

Thirty-seven college students (26 females, 21.00 ± 2.07 years) participated in this study and completed multiple ultimatum games. EEG signals were recorded during play. In the task, the proposers were underprivileged students (empathy condition) and ordinary children (non-empathy condition). Each proposer distributed 10 yuan between themselves and one recipient. The participants played as recipients who would choose to accept or reject distribution offers (fair, disadvantageous unfair, advantageous unfair) by the proposers. The proposers and recipients would get the assigned money only if participants accepted the distribution offers. They received nothing if participants rejected the offer.

The behavioral results showed that the acceptance rate in the empathy condition was greater than that in the non-empathy condition for the disadvantageous unfair condition, while the opposite result occurred in the advantageous unfair condition. The EEG results showed that in the non-empathy condition, the advantageous unfair offer induced more negative anterior N1 (AN1) than it did in the empathy condition, but there was no difference between the disadvantageous unfair versus fair conditions. In the advantageous unfair condition, the P2 amplitude of the empathy condition was significantly more positive than that for the non-empathy condition, while in the disadvantageous unfair condition, P2 amplitude of the non-empathy condition was slightly positive than that of the empathy condition. The disadvantageous unfair offer induced more negative medial frontal negativity (MFN) in the empathy condition, while no difference was found between fair versus unfair offers in the non-empathy condition. Additionally, the amplitude of P3 was larger in the fair versus the unfair conditions as it was not modulated by empathy.

These findings suggest that experimentally-induced state empathy modulates fairness-related decision making behaviors and accompanying neural activity. Behavioral results indicate that state empathy takes priority in guiding people's behavior when it conflicts with the fairness criterion. For EEG results, empathy mainly modulates the early stage of the fairness concern and affects early attention and motivation as well as cognition and emotion. In later stages, the higher cognitive process represented by P3 is modulated only by fairness, not empathy. In conclusion, our study systematically explored and compared behavior patterns of fairness processing with temporal dynamic characteristics of brain activities by modulating empathy. The findings provide further insight into fairness-related decision making behaviors. They indicate the potential to influence individuals' behaviors and cognition by manipulating empathy.

Keywords: fairness-related decision making, empathic concern, AN1, P2, MFN

Classification Code: B845: C91

1.1 Definition and Research Paradigm of Fairness-Related Decision Making

As society and the nation increasingly emphasize fairness and justice, fairness norms play an increasingly critical role in various social and economic decisions. Fairness-related decision making refers to the process of making decisions that follow principles of justice and equality to obtain benefits and assume responsibilities (Qi et al., 2017). The ultimatum game (UG) paradigm is a classic paradigm for studying fairness-related decision making, involving two roles: proposer and responder. The proposer must make a distribution proposal for a certain amount of money, and the responder chooses whether to accept it. If accepted, the distribution is implemented; if rejected, both parties receive nothing (Guth et al., 1982). Research using UG has found that individuals generally exhibit inequity aversion in decision-making (Fehr & Schmidt, 1999), manifested as negative emotions triggered by unfairness and behavior that rejects unfair distributions at the cost of sacrificing one's own interests (Camerer, 2003; Polezzi et al., 2008; Sanfey et al., 2003), reflecting individuals' concern for fairness.

1.2 The Influence of Empathic Concern on Fairness-Related Decision Making

In fact, fairness-related decision making is influenced by various factors, and the final outcomes are not absolute equality but relative and slightly biased fairness. These influencing factors encompass individual, situational, and social aspects, including social value orientation, gain-loss framing, social distance, and group identity (Bieleke et al., 2017; Wang et al., 2014; Wu & Zhou, 2012). Among these, empathy is a very important factor affecting fairness processing and is closely related to our real life. For example, in resource allocation processes, if

others need help, we face both the need to maintain fairness and the need to care for others and protect their interests. In such situations, does our fairness processing still focus only on fairness? Or is it affected by empathy? Empathic concern (also called empathy concern or sympathy) is an emotional and motivational state characterized by helping and promoting others' welfare (Bernhardt & Singer, 2012; Light et al., 2015). Specifically, when people observe or imagine that others are facing misfortune and suffering, they experience a state of empathic concern that triggers a series of emotional reactions directed toward others, including sympathy and compassion, thereby stimulating individuals' altruistic motivation to reduce others' suffering and promoting altruistic behavior (Batson et al., 2007). Previous studies have examined the influence of empathic concern on fairness-related decision making in situations unrelated to self-interest (Leliveld et al., 2012; Pfattheicher et al., 2019), but no research has focused on how empathy affects fairness processing when individuals are directly involved as stakeholders (directly encountering unfairness). Specifically, considering empathy may create a conflicting situation: empathic concern induces individuals' altruistic motivation, prompting them to care for others (Batson et al., 2007), while individuals also value fairness and are even willing to sacrifice their own interests to punish unfairness (Camerer, 2003; Fehr & Gächter, 2002). When these two goals or motivations conflict in decision-making, how do individuals handle the relationship between them? That is, for unfair proposals made by others that evoke individuals' empathic states, will individuals prioritize altruism or still adhere to fairness principles? Exploring this question helps us understand individuals' behavioral patterns in specific situations.

1.3 Temporal Characteristics of Fairness Processing

Based on the above discussion, we hypothesized that empathic concern would affect individuals' fairness-related decision making behaviors. To further determine which stages of fairness processing empathy affects, we employed event-related potential (ERP) technology with high sensitivity and temporal resolution, hoping to reveal the temporal dynamics of how empathy influences fairness-related decision making from a time dimension. According to previous research, ERP components related to fairness processing include anterior N1 (AN1), P2, medial frontal negativity (MFN), and P3 (Boksem & De Cremer, 2010; Hu & Mai, 2021; Wang et al., 2014).

AN1 and P2 are early components reflecting early automatic processing (Eisenberger, 2015; Horat et al., 2016). AN1 is a negative wave appearing approximately 100 ms after visual stimulus presentation, peaking around 120 ms, and distributed over frontocentral regions (Boudreau et al., 2009). AN1 is related to early automatic attention, with attended stimuli eliciting larger AN1 than unattended stimuli (Duzcu et al., 2019). Stimuli that violate expectations typically attract more attention, so novel (unexpected) stimuli also elicit larger AN1 amplitudes (Annic et al., 2014; Bouwer et al., 2020). AN1 effects have also received attention in social decision-making research: decision situations

with conflicting interests elicited more negative AN1 than those with aligned interests (Boudreau et al., 2009). In fairness-related decision making research, group identity can modulate AN1 amplitude by adjusting individuals' expectations of distribution proposals from in-group versus out-group members, with larger AN1 amplitudes reflecting the degree of expectancy violation for different distribution proposals (Wang et al., 2014). In summary, AN1 is modulated by stimulus characteristics and interaction partners. P2 is a positive component peaking around 200 ms after stimulus presentation, typically appearing in frontal and central regions (Horat et al., 2016). Like AN1, P2 is also related to early attention allocation (Luck & Hillyard, 1994). However, P2 is additionally modulated by motivational relevance or emotional significance, with stimuli having stronger motivational salience prompting individuals to allocate more attentional resources, thereby eliciting larger P2 amplitudes (Carretie et al., 2004). In interpersonal decision-making, situations with aligned interests have stronger motivational and perceptual salience for individuals, thus eliciting larger P2 amplitudes than conflict-of-interest situations (Boudreau et al., 2009). UG studies have found that fair proposals elicit larger P2 amplitudes than unfair proposals, reflecting individuals' intrinsic goals and motivations to pursue fairness (Hu & Mai, 2021; Yin Wu et al., 2011). Previous research on AN1 and P2 effects has mainly been demonstrated in pain empathy processing, reflecting early effects in response to pain scenarios and the automatic processing of pain empathy, serving as important indicators of early emotional automatic activation and sharing mechanisms (Decety et al., 2010; Fan & Han, 2008). Although no studies have found AN1 and P2 effects of empathy in social contexts, numerous studies have found that physical pain and social pain share common underlying neurophysiological mechanisms, including dorsal anterior cingulate cortex and right ventrolateral prefrontal cortex (DeWall et al., 2010; Eisenberger, 2015; Eisenberger et al., 2003; Kross et al., 2011), and encountering unfairness causes individuals to experience social pain (Campanha et al., 2011). Therefore, considering the similar processing patterns of physical and social pain, we hypothesized that in social contexts, empathy would also affect AN1 and P2 effects during fairness processing.

MFN is a negative wave distributed over frontocentral regions, peaking within 250-450 ms after stimulus presentation, reflecting rapid semi-automatic processing of current stimuli and representing the middle stage of fairness processing (Leng & Zhou, 2010). MFN is believed to be related to negative outcomes (Boksem & De Cremer, 2010), violation of social norms, and expectancy violation (Hewig et al., 2011; Van der Veen & Sahibdin, 2011; Yin Wu et al., 2011). In UG, unfair proposals elicit more negative MFN than fair proposals, whether disadvantageous or advantageous unfairness (Boksem & De Cremer, 2010; Hewig et al., 2011; Spape et al., 2019). Meanwhile, MFN also reflects negative emotional evaluation, as unfair proposals are typically considered more norm-violating and result in more unfavorable outcomes, triggering individuals' negative emotional experiences (Moser et al., 2014). Importantly, MFN is modulated by empathy level. For example, Liu et al. (2018, 2020) studied the influence of empathic

concern on outcome evaluation in different contexts and found that neural responses evoked by self-gains and losses were modulated by empathy level: in non-conflict-of-interest situations, empathy for others prompted participants to evaluate high-empathy others' outcomes consistently with self-outcomes, showing consistent MFN effects that were both larger than low-empathy conditions; in conflict-of-interest situations, winning money for low-empathy others meant self-loss, eliciting larger MFN, while MFN effects in high-empathy conditions remained consistent with non-conflict-of-interest situations.

The later cognitive evaluation stage of fairness processing is represented by P3. P3 is a positive wave appearing in parieto-occipital regions within 300-600 ms after stimulus presentation, believed to be closely related to selective allocation of attentional resources and other advanced cognitive processes, as well as fine processing of the emotional significance contained in outcomes (Hu & Mai, 2021; Leng & Zhou, 2010; Sanfey et al., 2003; Yu et al., 2015). P3 is affected by outcome valence and magnitude, with positive feedback and larger rewards eliciting larger P3 (Bellebaum et al., 2010). In UG tasks, fair proposals better conform to fairness criteria and provide greater benefits to individuals than unfair proposals, thus eliciting larger P3 amplitudes (Yin Wu et al., 2011; Yan Wu & Zhou, 2009). However, Liu et al. (2018, 2020) found that empathy level did not modulate P3 amplitude, and valence effects of P3 only appeared in self-conditions, suggesting that P3 may only be related to self-relevant information processing.

1.4 Research Content and Hypotheses

This study employed the UG paradigm combined with ERP technology to simulate real interpersonal interaction situations, inducing participants' state empathic concern to examine the influence of empathic concern on fairness-related decision making and the temporal characteristics of underlying brain activities. Based on the empathy-altruism hypothesis, people experience strong empathy for those in need or distress (Batson & Ahmad, 2001; Batson & Moran, 1999). Therefore, in this study, proposers in the empathy condition were set as impoverished left-behind children (i.e., people in need of help), while proposers in the non-empathy condition were ordinary children (i.e., people not in need of help). This manipulation was adapted from Liu et al. (2018, 2020) high and low empathy contexts, and its effectiveness has been verified. Meanwhile, participants as responders needed to choose among fair, advantageous unfair, and disadvantageous unfair distribution proposals made by different proposers. At the behavioral level, we hypothesized that there would be differences in behavior and subjective ratings between empathy and non-empathy contexts under different levels of distribution fairness. At the EEG level, AN1 is modulated by interaction partners (Wang et al., 2014), and this study induced empathy by manipulating proposers' identities. Therefore, we expected empathy to modulate AN1 amplitudes under different fairness conditions. Meanwhile, empathy induced individuals' altruistic motivation, making motivations differ between

empathy and non-empathy contexts across fairness conditions, thereby modulating P2 amplitude. Furthermore, previous research has shown that MFN is modulated by both empathy level and fairness. Considering that empathy level affects individuals' degree of attention to outcomes, we expected that different fairness conditions would elicit different MFN in the empathy context, but no differences in the non-empathy context. Finally, consistent with previous research (Liu et al., 2018, 2020), we still expected P3 not to be modulated by empathy level, only showing effects of distribution fairness.

2.1 Participants

Forty-two non-economics, non-psychology college students participated as participants, all right-handed, healthy, with no history of neurological diseases or brain injury, and normal or corrected-to-normal vision. All participants voluntarily participated in the experiment and signed informed consent forms. Five participants were excluded due to excessive EEG artifacts, and data from 37 participants were included in the final statistical analysis (26 females, aged 18-24 years, $M \pm SD = 21.00 \pm 2.07$ years). Sample size estimation was performed using G*Power v.3.1 (Faul et al., 2009). According to the analysis ($f = 0.25$, $\alpha = 0.05$, $\beta = 0.95$, ANOVA: repeated measures, within-subjects factors), a total sample size of 28 participants was needed to detect a reliable effect size, and the sample size in this study met this requirement.

2.2 Experimental Procedure

First, participants were informed that the experimental task was to decide whether to accept distribution proposals for 10 yuan made by proposers. Participants were told that the proposers were from a rural left-behind children school and an urban ordinary middle school, respectively, with left-behind students having relatively poorer family conditions and school infrastructure compared to ordinary students. Participants were presented with textual materials and pictures describing the family conditions, school infrastructure, teaching staff, and college admission rates of left-behind students and ordinary students, and were asked to read the materials and view the pictures thoroughly to induce a state of empathic concern (Liu et al., 2018, 2020). To test the effectiveness of the empathy manipulation used in this study, we additionally recruited 22 participants. After undergoing the same empathy manipulation procedure, they were asked to complete the Empathic Response Questionnaire for manipulation check (Batson et al., 1997, 2002). A 7-point scale was used to measure the degree to which participants felt sympathetic/concerned/touched (Pfattheicher et al., 2019). The three items showed high internal consistency reliability (Cronbach's $\alpha = 0.88$), and the three ratings were averaged to obtain state empathy scores. A one-way repeated measures ANOVA on state empathy scores in the two contexts revealed that state empathy ratings in the left-behind student context were significantly higher than in the ordinary student context (5.56 ± 0.95 vs. 2.39 ± 1.35 , $F(1, 21) = 129.68$, $p < 0.001$, $\eta^2 = 0.86$), indicating that the

left-behind student context successfully induced individuals' state empathy.

To increase experimental credibility, we emphasized to participants that each distribution proposal was made by a different proposer. However, since it was impossible to conduct the game simultaneously at a unified time and place, all distribution proposals were collected in advance. We also informed participants that we would calculate and distribute earnings for both participants and proposers based on their choices, ensuring participants believed their choices would genuinely affect others' interests. The proposers' earnings depended on participants' choices: if participants accepted, proposers received the corresponding amount; if participants rejected, proposers received nothing. Participants' own earnings consisted of three parts: in both empathy and non-empathy conditions, 15 trials were randomly selected from the distribution proposals that participants chose to accept, the amounts participants should receive were accumulated and added to the base payment for participating in the experiment. This earnings structure meant that if participants wanted to obtain as much payment as possible, they needed to reject fair and disadvantageous unfair distributions and only accept advantageous unfair distributions. Unlike previous research, this manipulation could distinguish whether participants' acceptance of disadvantageous unfair proposals was based on self-interest considerations or purely altruistic motivation, while also examining whether individuals would abandon self-interest maximization to pursue fairness by their acceptance or rejection of fair proposals. Overall, this manipulation could comprehensively examine participants' behavioral motivations. The setting of participants' earnings in the experiment was to make participants believe their choices were linked to their real experimental payment, thereby ensuring participants could make more authentic choices. In reality, each participant received 75 yuan as experimental payment, which we provided based on the total duration of the experiment, but participants were not informed that everyone's experimental payment was the same.

The experiment used a 2 (state empathic concern: empathy vs. non-empathy) \times 3 (distribution fairness: fair vs. disadvantageous unfair vs. advantageous unfair) within-subjects design. Ten types of distribution proposals were set: fair condition (4/6, 5/5, 6/4, 25 trials each); disadvantageous unfair condition (8/2, 9/1, 30 trials each); advantageous unfair condition (2/8, 1/9, 30 trials each); filler condition (3/7, 7/3, 30 trials each). The number before the slash indicates the amount the proposer allocated to themselves. The setting of distribution fairness conditions was consistent with Wu and Zhou (2012). The dependent variables were participants' acceptance rates, subjective ratings, and ERP components under different conditions. The experiment was conducted separately for empathy and non-empathy tasks, each containing 5 blocks with 51 trials per block. The entire experiment included 10 blocks and 510 trials, lasting approximately 50 minutes. The order of the two tasks was counterbalanced across participants.

During the experiment, participants needed to rate their emotional experience

and fairness perception of current distribution proposals. Emotional experience rating used a 9-point scale (Bradley et al., 2001; Hewig et al., 2011; Hu & Mai, 2021), where “5” indicated calm and mild mood; from “5” to “9” indicated increasingly positive emotional experiences, and from “5” to “1” indicated increasingly negative emotional experiences. Fairness perception rating used a 7-point scale (Leliveld et al., 2012; Pillutla & Murnighan, 1996), where “4” indicated uncertainty, “1” indicated very unfair, and “7” indicated very fair.

2.4 Experimental Process

The experimental stimuli were presented and behavioral data were recorded using E-Prime software (Version 3.0). The experimental procedure is shown in Figure 1 [Figure 1: see original paper]. Before each block, the proposer’s identity was presented on the screen. At the beginning of each trial, a white fixation cross was presented at the center of the screen for 800-1200 ms, followed by a 500 ms blank screen. Then the distribution proposal was presented in a top-bottom structure, with the top number indicating the amount the proposer allocated to themselves. After the distribution proposal was presented for 1200 ms, it disappeared. Following a 500 ms blank screen, the decision screen was presented, and participants could press “F” to accept or “J” to reject the proposal. In each block, each type of distribution proposal would randomly appear once for emotional experience rating and fairness perception rating.

Figure 1 Schematic diagram of the ultimatum game task

During the experiment, EEG data were recorded using a Biosemi EEG recording system with a 32-channel electrode cap. The filter bandpass was 0.01-100 Hz, and the sampling rate was 512 Hz per channel. Electrodes were placed at the outer sides of both eyes to record horizontal eye movements, and above and below the left eye to record vertical eye movements. Scalp resistance under all electrodes was maintained below 5 k Ω . The left mastoid electrode was used as reference during recording, and offline analysis used the average of both mastoids for re-referencing. The collected EEG data were preprocessed using the eeglab toolbox (Version 12.0.2.6b) in Matlab (2013a). Since this study focused on participants’ processing of different distribution proposals during stimulus presentation, the segmentation of raw EEG data ranged from 200 ms before stimulus (distribution proposal) onset to 800 ms after stimulus onset. After segmentation, ocular artifact correction was performed using the ocular artifact removal algorithm (Gratton et al., 1983). Data were low-pass filtered below 30 Hz, and trials with amplitudes exceeding ± 75 V were considered artifacts and rejected, followed by averaging across conditions.

Based on the characteristics of grand-averaged waveforms, we extracted AN1 (minimum peak value at 100-200 ms), P2 (average amplitude at 230-280 ms), MFN (average amplitude at 300-450 ms), and P3 (average amplitude at 250-350 ms). In preprocessing, according to the topographical distribution of ERP components and previous research (Yeung & Sanfey, 2004), AN1, P2, MFN, and

P3 were calculated through 9 electrode sites (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4). Results showed that AN1, P2, and MFN amplitudes were largest at the Fz electrode, while P3 amplitude was largest at the Pz electrode. Therefore, we selected Fz and Pz electrodes where these ERP components reached maximum amplitudes for further statistical analysis.

2.6 Temporal-Spatial PCA

Since P2, MFN, and P3 may overlap in ERP waveforms, we used principal component analysis (PCA) to decompose ERP components (Foti et al., 2011). This study employed the Evoked ERP/EPO toolbox based on Matlab for temporal-spatial PCA (Zhang et al., 2020). First, temporal PCA with Promax rotation was performed on all time points of each participant' s averaged ERPs. Then, components of interest were selected and projected to the electrode field based on three factors: (a) polarity and latency of temporal components; (b) polarity and location of spatial component activation regions; (c) similarity of topographic maps of components of interest across conditions. Finally, P2 (average amplitude at Fz electrode at 200-225 ms), MFN (average amplitude at Fz electrode at 360-400 ms), and P3 (average amplitude at Pz electrode at 460-510 ms) components were selected for statistical analysis.

To confirm the identification of PCA factors, we calculated Pearson correlations between PCA factor amplitudes and corresponding ERP components from traditional time-domain analysis. Results showed that P2 was highly correlated with PCA-P2 ($r = 0.84$, $p < 0.001$), and MFN was highly correlated with PCA-MFN ($r = 0.99$, $p < 0.001$). However, considering that the latency of P3 obtained from traditional time-domain analysis was inconsistent with PCA-P3, and the temporal and spatial characteristics of PCA-P3 better matched the features of our component of interest, we focused mainly on PCA-P3 results and did not examine the correlation between them.

2.7 Statistical Analysis

SPSS 25.0 statistical software was used for data analysis. Behavioral data, EEG data, and PCA factors were analyzed using 2 (state empathic concern: empathy vs. non-empathy) \times 3 (distribution fairness: fair vs. disadvantageous unfair vs. advantageous unfair) within-subjects repeated measures ANOVA. When the sphericity assumption was violated, degrees of freedom for F-ratio were corrected using the Greenhouse-Geisser method. Bonferroni correction was used for post-hoc tests of significant main effects, and simple effects analysis was used to test significant interactions. Descriptive statistics are presented as mean \pm standard deviation ($M \pm SD$). The significance level for all statistical analyses was set at 0.05, and effect sizes for all ANOVAs were reported using partial eta-squared (η^2), where 0.01 represents a small effect size.

3.1.1 Acceptance Rate

The main effect of empathy was significant, $F(1, 36) = 4.87$, $p = 0.034$, $p^2 = 0.12$, with acceptance rates in the empathy condition significantly higher than in the non-empathy condition (0.67 ± 0.21 vs. 0.62 ± 0.16). The main effect of fairness was significant, $F(2, 72) = 90.89$, $p < 0.001$, $p^2 = 0.72$. Post-hoc tests showed that acceptance rates in fair (0.84 ± 0.26) and advantageous unfair (0.88 ± 0.23) conditions were significantly higher than in the disadvantageous unfair condition (0.20 ± 0.29 , $ps < 0.001$), with no significant difference between fair and advantageous unfair conditions ($p > 0.1$). The interaction between empathy and fairness was significant, $F(1.64, 59.12) = 14.04$, $p < 0.001$, $p^2 = 0.28$. Simple effects analysis showed that in the disadvantageous unfair condition, acceptance rates in the empathy condition were significantly higher than in the non-empathy condition (0.30 ± 0.40 vs. 0.11 ± 0.25 , $p < 0.001$), while in the advantageous unfair condition, acceptance rates in the empathy condition were significantly lower than in the non-empathy condition (0.84 ± 0.31 vs. 0.92 ± 0.20 , $p = 0.025$). No significant difference was found in the fair condition ($p > 0.1$), as shown in Figure 2 [Figure 2: see original paper]A.

3.2.1 Emotional Experience

The main effect of fairness was significant, $F(1.34, 47.69) = 33.23$, $p < 0.001$, $p^2 = 0.48$. Post-hoc results showed that participants' emotional experiences in fair (5.61 ± 0.72) and advantageous unfair (6.02 ± 1.55) conditions were more positive than in the disadvantageous unfair condition (3.67 ± 1.17 , $ps < 0.001$), with no significant difference between fair and advantageous unfair conditions ($p = 0.471$). The interaction between empathy and fairness was significant, $F(2, 72) = 13.95$, $p < 0.001$, $p^2 = 0.28$. When others proposed disadvantageous unfair offers, participants experienced stronger negative emotions in the non-empathy condition than in the empathy condition (3.32 ± 1.23 vs. 4.02 ± 1.35 , $p < 0.001$). When others proposed advantageous unfair offers, participants experienced stronger positive emotions in the non-empathy condition than in the empathy condition (6.35 ± 1.55 vs. 5.68 ± 1.80 , $p = 0.002$). No significant difference was found in the fair condition ($p = 0.214$), as shown in Figure 2B. The main effect of empathy was not significant ($p = 0.509$).

3.2.2 Fairness Perception

The main effect of fairness was significant, $F(2, 72) = 58.64$, $p < 0.001$, $p^2 = 0.62$. Fairness perception ratings in the fair condition (4.88 ± 0.60) were significantly higher than in disadvantageous unfair (2.72 ± 1.08) and advantageous unfair (3.03 ± 1.25 , $ps < 0.001$) conditions, with no significant difference between disadvantageous and advantageous unfair conditions ($p = 0.528$). The interaction between empathy and fairness was significant, $F(1.70, 61.26) = 13.27$, $p < 0.001$, $p^2 = 0.27$. For disadvantageous unfair proposals made by others, participants' fairness perception ratings in the non-empathy condition were significantly lower than in the empathy condition (2.44 ± 1.08 vs. 2.99 ± 1.23 , $p <$

0.001), while no significant differences were found between empathy conditions in fair and advantageous unfair conditions ($p = 0.057$; $p = 0.083$), as shown in Figure 2C. The main effect of empathy was not significant ($p = 0.445$).

Figure 2 Mean acceptance rates, emotional experience ratings, and fairness perception ratings under different conditions. Note: Error bars represent standard error; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.3.1 AN1

The interaction between empathy and fairness was significant, $F(2, 72) = 3.83$, $p = 0.026$, $p^2 = 0.10$. In the advantageous unfair condition, AN1 amplitude in the non-empathy condition (-4.67 ± 2.55 V) was significantly more negative than in the empathy condition (-3.90 ± 2.05 V, $p = 0.030$). No significant differences were found between empathy conditions in fair and disadvantageous unfair conditions ($ps > 0.1$), as shown in Figure 3 [Figure 3: see original paper]. Neither main effect was significant ($ps > 0.1$).

3.3.2 P2

The interaction between empathy and fairness was significant, $F(2, 72) = 4.88$, $p = 0.010$, $p^2 = 0.12$. In the advantageous unfair condition, P2 amplitude in the empathy condition (-1.10 ± 3.13 V) was significantly larger than in the non-empathy condition (-1.84 ± 3.28 V, $p = 0.049$). In the disadvantageous unfair condition, P2 amplitude in the non-empathy condition (-1.08 ± 3.28 V) was slightly larger than in the empathy condition (-1.96 ± 2.78 V, $p = 0.096$). No significant difference was found in the fair condition ($p = 0.726$), as shown in Figure 3. Neither main effect was significant ($ps > 0.1$).

Figure 3 A shows grand-averaged waveforms at the Fz electrode for empathy and non-empathy conditions under different distribution conditions; B shows mean bar charts of AN1 and P2 amplitudes under different conditions. Note: Error bars represent standard error; † $p < 0.1$, * $p < 0.01$

3.3.3 MFN

The interaction between empathy and fairness was significant, $F(2, 72) = 3.97$, $p = 0.023$, $p^2 = 0.10$. As shown in Figure 4 [Figure 4: see original paper], in the empathy condition, MFN amplitude in the disadvantageous unfair condition (-4.02 ± 2.98 V) was significantly more negative than in the advantageous unfair condition (-2.79 ± 3.33 V, $p = 0.008$) and marginally more negative than in the fair condition (-3.20 ± 3.26 V, $p = 0.081$), with no significant difference between advantageous unfair and fair conditions ($p = 0.715$). In the non-empathy condition, no significant differences were found among the three conditions ($ps > 0.1$). Neither main effect was significant ($ps > 0.1$).

3.3.4 P3

Neither the main effects nor the interaction of empathy and fairness was significant ($p_s > 0.1$).

Figure 4 A shows grand-averaged waveforms of different distribution proposals at the Fz electrode for empathy and non-empathy conditions; B shows grand-averaged waveforms at the Pz electrode; C shows mean bar charts of MFN and P3 amplitudes under different conditions. Note: Error bars represent standard error; † $p < 0.1$, ** $p < 0.01$

3.4.1 PCA-P2

The interaction between empathy and fairness was significant, $F(2, 72) = 3.80$, $p = 0.027$, $p^2 = 0.10$. In the empathy condition, P2 amplitude in the advantageous unfair condition (-1.30 ± 2.59 V) was marginally larger than in the fair condition (-1.84 ± 2.70 V, $p = 0.066$), with no significant difference from the disadvantageous unfair condition (-1.99 ± 2.87 V, $p = 0.101$), as shown in Figure 5 [Figure 5: see original paper]A. In the non-empathy condition, no significant differences were found among the three conditions ($p_s > 0.1$). Neither main effect was significant ($p_s > 0.1$).

3.4.2 PCA-MFN

The interaction between empathy and fairness was significant, $F(2, 72) = 4.60$, $p = 0.013$, $p^2 = 0.11$. In the empathy condition, MFN amplitude in the disadvantageous unfair condition (-5.47 ± 3.57 V) was significantly more negative than in the advantageous unfair condition (-3.88 ± 4.15 V, $p = 0.007$) and marginally more negative than in the fair condition (-4.52 ± 3.99 V, $p = 0.090$), with no significant difference between advantageous unfair and fair conditions ($p = 0.478$). In the non-empathy condition, no significant differences were found among the three conditions ($p_s > 0.1$), as shown in Figure 5B. Neither main effect was significant ($p_s > 0.1$).

3.4.3 PCA-P3

The main effect of fairness was significant, $F(2, 72) = 5.73$, $p = 0.005$, $p^2 = 0.14$. P3 amplitude in the fair condition was significantly larger than in the disadvantageous unfair condition (4.86 ± 4.30 V vs. 3.92 ± 4.33 V, $p = 0.004$), with no significant difference from the advantageous unfair condition (4.46 ± 4.47 V, $p = 0.412$). No significant difference was found between disadvantageous and advantageous unfair conditions ($p = 0.238$), as shown in Figure 5C. Neither the main effect of empathy nor the interaction was significant ($p_s > 0.1$).

Figure 5 Average waveforms of PCA-P2 at the Fz electrode (A), PCA-MFN (B), and PCA-P3 at the Pz electrode (C)

This study used the UG paradigm combined with ERP technology to explore the modulating effect of empathic concern on individuals' fairness-related de-

cision making and the temporal dynamic characteristics of underlying brain activities. Results showed that empathic concern and distribution fairness interactively influenced individuals' fairness-related decision making behaviors and subjective ratings. Specifically, in the disadvantageous unfair condition, acceptance rates, emotional experience ratings, and fairness perception ratings in the empathy condition were higher than in the non-empathy condition, while the opposite pattern was found in the advantageous unfair condition, with no significant differences between empathy conditions in the fair condition. EEG results showed that in the non-empathy condition, advantageous unfair proposals made by others elicited more negative AN1 than in the empathy condition, while no differences were found between empathy conditions in disadvantageous unfair and fair conditions, indicating that empathic concern level can affect early attentional processes in fairness-related decision making. Additionally, compared to the non-empathy condition, advantageous unfair proposals made by others elicited larger P2 amplitudes in the empathy condition, while the opposite trend appeared in the disadvantageous unfair condition, reflecting the influence of empathic concern on motivational levels during fairness processing. In the empathy condition, disadvantageous unfair proposals elicited more negative MFN amplitudes, while no significant differences were found in the non-empathy condition, reflecting the modulation of empathic concern on cognitive and emotional processing. We also used PCA to separate potentially overlapping ERP components. Results showed that PCA-P2 and PCA-MFN exhibited similar patterns to traditional ERP results. Notably, PCA-P3 was only affected by fairness and not modulated by empathy level.

4.1 Empathic Concern Modulates Fairness Perception, Emotional Experience, and Decision Behavior

Emotional experience and fairness perception are important factors that prompt individuals to make irrational behaviors that violate the principle of interest maximization (such as rejecting unfair distributions) (Fehr & Gächter, 2002; Matarazzo et al., 2016; Sanfey et al., 2003). In this study, individuals' emotional experience, fairness perception, and decision behavior were all modulated by empathy. Fairness perception, emotional experience ratings, and acceptance rates in the empathy condition were higher than in the non-empathy condition, reflecting that empathy increases individuals' tolerance for disadvantageous unfair proposals. Advantageous unfair proposals conflict with individuals' altruistic motivation, resulting in more negative emotional experiences compared to the non-empathy condition, with correspondingly reduced acceptance rates. These results also reflect that individuals' behavioral motivations in the empathy condition were more altruistic, indicating that when empathy conflicts with fairness criteria, individuals prioritize empathy to guide behavior. Furthermore, based on our manipulation of earnings, the interest-maximizing choice was to only accept advantageous unfair distributions and reject other distribution proposals. However, acceptance rates in the fair condition were as high as those in the advantageous unfair condition, reflecting individuals' motivation to pursue

fairness rather than merely self-interest maximization.

4.2 Empathic Concern Modulates the Early Automatic Stage of Fairness Processing

Decision-making involves mentalizing processes, such as guessing and forming expectations about the other's goals and strategies (Polezzi et al., 2008; Wu & Zhou, 2012). AN1 is believed to be related to stronger expectancy activity (Boudreau et al., 2009; Bouwer et al., 2020), and experimental contexts and interaction partners can affect participants' attentional bias and expectations (Wang et al., 2014; Yin Wu et al., 2011). Therefore, modulated by empathy level, participants may make different inferences about different proposers' decisions and form decision expectations in advance. People are more inclined to help those who are helpful. In the empathy condition, when participants want to help a stranger, they typically assume the other is worthy of help and thus tend to believe the other is more cooperative and reciprocal, making fair and advantageous unfair distributions expected. In contrast, proposers in the non-empathy condition may be more inclined to pursue self-interest and competition, so advantageous unfair distributions exceed participants' expectations and are novel stimuli for them, enhancing visual attention and eliciting more negative AN1 (Kubota & Ito, 2007). According to this explanation, disadvantageous unfair distributions made by others in the empathy condition should elicit more negative AN1 than in the non-empathy condition. This trend existed numerically but did not reach statistical significance.

Empathy also modulated the P2 component representing motivational significance. For the advantageous unfair condition, apart from fairness level, participants in the non-empathy condition only focused on self-interest, while in the empathy condition participants focused on both self-interest and others' interests. Moreover, the inequality in self and other distribution in this condition violated individuals' altruistic motivation and fairness pursuit, giving it stronger motivational salience that was extracted and represented in P2, eliciting larger P2 amplitudes (Carretie et al., 2004; Luck & Hillyard, 1994). Conversely, in the disadvantageous unfair condition, participants in the empathy condition faced a conflict between accepting (violating self-interest maximization) and rejecting (harming the other's interests and conflicting with altruistic motivation), making it a conflict-of-interest situation. In the non-empathy condition, participants only focused on self-interest, and rejecting corresponding proposals did not affect their own earnings, making it an interest-aligned situation, thus eliciting larger P2 (Boudreau et al., 2009).

In summary, empathy level modulated the early automatic processing of fairness-related decision making by affecting individuals' expectations in corresponding contexts to regulate early attention represented by AN1, while also modulating P2 amplitude by influencing individuals' behavioral motivations.

4.3 Empathic Concern Modulates the Mid-Stage Semi-Automatic Stage of Fairness Processing

Current research generally suggests that MFN may reflect social pain, violation of social norms, cognitive conflict, emotional conflict, or worse-than-expected outcomes (Boksem & De Cremer, 2010; Polezzi et al., 2008; Spape et al., 2019; Van der Veen & Sahibdin, 2011). In this study, MFN only showed distribution fairness effects in the empathy condition, with no such effects in the non-empathy condition. A possible explanation is that our manipulation of participants' earnings differed from previous research: rejecting unfair proposals did not affect self-earnings, so participants in the non-empathy condition only focused on self-interest and did not care about others' earnings, reducing cognitive resources allocated to processing proposal fairness, thus MFN showed no differences (Wu & Zhou, 2012). In the empathy condition, participants would attend to others' earnings and therefore process distribution fairness levels, showing differences. Although MFN showed no differences in the non-empathy condition, it consumed cognitive resources, so the elicited MFN amplitude was not significantly different from the empathy condition. We thus speculate that MFN also reflects the investment and consumption of cognitive resources during decision-making (Polezzi et al., 2008).

Considering that participants in the empathy condition had higher altruistic motivation and were willing to sacrifice self-interest to maintain the other's welfare, they also hoped that the others they wanted to help would be more reciprocal and cooperative. Therefore, in the empathy condition, larger MFN in the disadvantageous unfair condition reflected expectancy violation on one hand, and on the other hand may reflect negative emotions elicited by this condition (such as disappointment, betrayal, etc.) (Moser et al., 2014). In any case, it is relatively clear that empathic concern indeed modulated the mid-stage rapid, semi-automatic processing represented by MFN in fairness-related decision making.

4.4 Research Limitations and Future Directions

This study has four limitations: First, in the empathy manipulation, background information about "left-behind children" and "ordinary children" should be described in a unified, standardized manner to avoid large individual differences caused by different people having different knowledge and understanding of these two groups based on their own experiences and backgrounds. Second, it is necessary to test whether participants believed their choices genuinely affected others' earnings. Additionally, this study had a large gender imbalance, and although statistical tests found no gender effects, gender factors should be balanced in future research. Finally, this study did not measure relevant trait variables such as trait empathy and fairness preferences, which should be considered in future research.

This study examined the influence of empathic concern on individuals' fairness-

related decision making behaviors and revealed the temporal dynamic characteristics of underlying brain activities through ERP. Results showed that empathic concern interferes with individuals' fairness-related decision making. When individuals develop empathic concern for others, their tolerance for unfair behavior increases, indicating that when empathy conflicts with fairness criteria, individuals prioritize processing empathy to guide behavior. The temporal course of this influence on brain activity is that empathic concern modulates both early automatic and mid-stage semi-automatic stages of fairness processing, indicating that empathy affects individuals' early attention allocation and behavioral motivations, as well as negative emotional experiences and cognitive resource investment and consumption. These findings provide new insights for explaining individuals' fairness-related decision making behaviors in specific contexts, suggesting that we can influence individuals' fairness perception and behavior by manipulating empathy levels, while also helping us further understand how empathic concern modulates fairness processing.

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