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The ERP Components of Reward Processing Modulated by Status-Related Social Comparison

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Background: Although social status is closely related to income distribution, few studies have focused on social comparisons caused by income distribution based on social status.

Purpose: The neural indices of status-related social comparisons were investigated by modifying the classical social comparison task with the incorporation of event-related potentials (ERPs).

Methods: The study employed a total of 29 subjects (15 females), the status scores of whom were initially obtained through the utilization of classical measurements of objective (7 items) and subjective (2 items) socioeconomic status. Subsequently, the subjects were required to complete a dot-estimation task. To induce status-related and response-related (upward, equal, and downward) social comparisons, subjects were informed that rewards were distributed based on whether their status score or their response was superior to that of a selected competitor.

Results: The behavioral results demonstrated that status-related social comparisons were perceived as more unfair than response-related social comparisons. The ERP results indicated that the cue-P3 amplitude was lower under status-related cues than response-related cues. Additionally, the amplitude of feedback-related negativity was larger under status-related equal comparisons than response-related equal comparisons. Furthermore, the P3 amplitude was larger under status-related upward comparisons relative to response-related upward comparisons.

Conclusion: The findings indicated that status-related comparisons may contribute to the development of unfair consideration (enhanced FRN) and a reduction in task motivations (lowered cue-P3). Additionally, the status-related upward comparison may serve as a significant factor in the onset of relative deprivation (enhanced P3). It would therefore be beneficial to gain further insight into the neural basis of social comparisons.

Keywords: social comparisons, social status, ERP, FRN, P3

Introduction

Social status can be defined as the respect, admiration and importance that an individual earns from society and closely related to the divisions of interests.[1–3] The process of social comparison entails individuals evaluating their own interests in relation to those of others, taking into account factors such as abilities, rewards, and social status. This process can be classified into three main categories: upward comparison (compared with others better than us), equal comparison (compared with others similar to us), and downward comparison (compared with others inferior to us).[4–6] While social comparisons have been extensively examined through the lens of task responses (eg, reaction time and accuracy),[7–9] these comparisons remain largely confined to the domain of responses or abilities. It remains unclear whether status-related comparisons differ from response-related comparisons, in which interests are divided according to social status. Therefore, it is essential to investigate the mechanisms, particularly the neural mechanisms, of status-related social comparisons, as they may provide more insights into the nature of social comparisons.

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The status-related comparisons may entail processes pertaining to reward processing, which differentiate them from response-related comparisons. Prior research indicates that the reward division is perceived as unfair when individuals allocate greater financial compensation to individuals with the same identity, as opposed to those with different identities.[10–12] Given that rewards are determined in accordance with status-related identity under status-related comparisons, it is possible that the divisions may be perceived as more unfair under status-related comparisons than under response-related comparisons. Furthermore, research has demonstrated that relative deprivation can be elicited by unfair upward comparisons.[13,14] Given that status-related comparisons are perceived as unfair, it seems reasonable to hypothesize that relative deprivation may be induced by status-related upward comparison. In addition, social comparisons play an important role in motivation, enabling individuals to regulate their behaviors in order to obtain rewards.[15–17] However, it has been found that the motivational functions can be reduced when rewards cannot provide information for behavioral regulations.[18,19] From this perspective, status-related comparisons may have a detrimental effect on motivation, as they do not provide any valid information that can be used to regulate current behavior.

The aforementioned evidence suggests that status-related comparisons may be associated with greater unfairness and diminished motivational functions in comparison to response-related comparisons. Moreover, the relative deprivation may be more pronounced when a status-related upward comparison is made than when a response-related upward comparison is undertaken. In the absence of direct neural evidence to support these opinions, a dot-estimation task was used to investigate the neural mechanisms of status-related comparisons with event-related potentials (ERP) considering that this task has been widely used to investigate the neural basis of the response-related comparisons.[7,20–23]

The dot-estimation task is widely to investigate the neural basis of social comparison, as evidenced by previous studies.[7,20–23] In the dot-estimation task, participants were initially requested to indicate whether the dots represented a quantity that was less than or greater than a specified number (eg, 24) within a given image. Subsequently, they were provided with feedback that informed them about the monetary rewards of both themselves and other participants, with the aim of inducing upward, equal, and downward comparisons.[7,20] In contrast with the conventional dot-estimation task, the subjects were initially requested to evaluate their social status by utilizing the established measurements of objective and subjective socioeconomic status,[24–27] and subsequently, to undertake the dot-estimation task.[7,20] The subjects were informed that the experimenters would distribute the rewards (40 yuan) between them and another individual based on their respective social status scores (status-related cues) and performances on the dot-estimation task (response-related cues). The social comparisons were induced by offering rewards in accordance with the following comparisons: upward (you 10 vs anther 30), equal (you 20 vs another 20), and downward (you 30 vs another 10).

The ERP results indicated that the social comparisons are associated with the ERP components of feedback-related negativity (FRN), P3, and the late positivity potential (LPP),[7,23] which could prove beneficial in elucidating the distinction between status-related and response-related social comparisons. The FRN is a negative deflection in the frontocentral regions, with a peak in the time window of 200–300 ms.[28,29] In social comparisons, the FRN amplitude was found to be modulated by the feedback valence, with the upward comparison (negative outcomes) eliciting a larger FRN amplitude than the downward comparison (positive outcomes).[8,9,30] However, previous studies have also identified a relationship between FRN and fairness considerations, with the FRN amplitude being higher in response to unfair than fair outcomes.[31–33] Despite our initial assumption that status-related comparisons would be perceived as more unfair than response-related comparisons, the FRN amplitude may be larger in response to a status-related downward comparison (equal outcome) than a response-related downward comparison (equal outcome), given that the FRN amplitude can also be enhanced by upward comparisons.

P3 is also a significant ERP component associated with social comparison, which represents a positive deflection in the parietal regions with a peak occurring at approximately 300–500ms.[9,34] It has been demonstrated that individuals allocate a greater proportion of their attentional resources to downward comparisons than to upward comparisons, as evidenced by the enhanced P3 amplitude observed in the context of downward comparisons.[35–37] Nevertheless, it has been proposed that the experience of relative deprivation may be accompanied by negative emotional states, including anger and resentment.[38–40] Prior research has demonstrated that individuals allocate greater attentional resources to angry stimuli in order to cope with potential threats, which is evidenced by higher P3 amplitudes in response to angry stimuli compared to positive stimuli (eg, happiness).[41–43] Therefore, the P3 amplitude may be enhanced by status-related upward

comparison due to relative deprivation, which could potentially reduce the discrepancy in P3 between upward and downward comparisons under status-related conditions, while simultaneously increasing the divergence between status-related and response-related upward comparisons.

Based on the aforementioned reasons, we postulated that individuals might perceive status-related comparisons as more unfair than response-related comparisons. Additionally, we hypothesized that the FRN amplitude elicited by an upward (equal) comparison under a status-related comparison might be larger than under a response-related comparison. Similarly, we predicted that the P3 amplitude elicited by an upward comparison under a status-related comparison might be larger than under a response-related comparison. Furthermore, research has demonstrated that the cue-P3 has a larger amplitude when cues are perceived as motivational.[44,45] Given that response-related rewards can convey more motivational information than status-related, it can be postulated that the cue-P3 amplitude may be larger when response-related cues are presented than when status-related cues are presented.

Method

Experiment Design and Subjects

In this study, a 2 (reward division: status-related and response-related) × 3 (social comparison: upward, equal, and downward) within-subject design was used. The minimum sample size was calculated using G*power (V3.1.9.4) with the following parameters: $\alpha = 0.05$, effect size $f = 0.25$, and power = 0.8. Based on these parameters, 24 participants were required to meet the minimum sample size. Thus, 30 right-handed participants (15 females) from Xinxiang Medical University were included in this study. All methods were carried out in accordance with relevant guidelines and regulations or declaration of Helsinki. All of the subjects signed informed consent forms and were approved by the ethics committee of the Xinxiang Medical University. Data from one participant were excluded because of excessive artifacts in EEG recordings (See Table S1).

Experiment Procedure

In this study, participants were first asked to fill out a questionnaire of social status and then completed the dot-estimation task. Moreover, for the sake of inducing social comparison, the subjects were told that the experimenters would determine whether they could acquire extra rewards according to their social status or performance relative to the other subjects.

To measure social status, the participants were asked to complete the objective socioeconomic status (OSES) and subjective socioeconomic status (SSES). According to previous studies,[24,46] the OSES was used to measure 5 scores of social status based on individual's household income, parental education, and occupation. The SSES was measured using the MacArthur Ladder,[25,26] where individuals had to imagine that the 10-rung ladder represented people's position in Chinese society and their school.

After social status measurements, the participants completed the social comparison task. In the social comparison task, the stimulating font is white and the background is black. The stimulus set consists of ten dot pictures with a very number, and the participants were required to judge whether the points were odd or even and press the corresponding key. Prior to the experiment, every participant was informed that they would concurrently complete a basic numerical judgment task with the other participant in the adjacent laboratory, and that he/she could earn extra rewards that were dependent on their performance or one of the items on the social status questionnaire relative to the other subjects in each trial. The other person was a faux subject, meaning that both his/her social standing and performance were preset. At the conclusion of the trial, they were given additional funds in addition to the original show-up fee.

Figure 1 displays the time flow of each experiment. In the beginning, the fixation point showed up in the middle of the screen for 0.5 seconds. Later that time, various amounts of black dots were displayed for 2s, where the subjects were asked to judge whether the points were odd or even and to press the corresponding keystroke. After selecting (0.8–1.5s) and a short delay (0.5–0.7s), a division of status/response was observed, indicating that an extra reward was allocated accordingly. The award feedback screen told the subject about the reward amount distribution plan after a brief pause of 0.5–0.7 seconds. Lastly, they had to rate their level of satisfaction, and press "1" means very dissatisfaction to "5" means

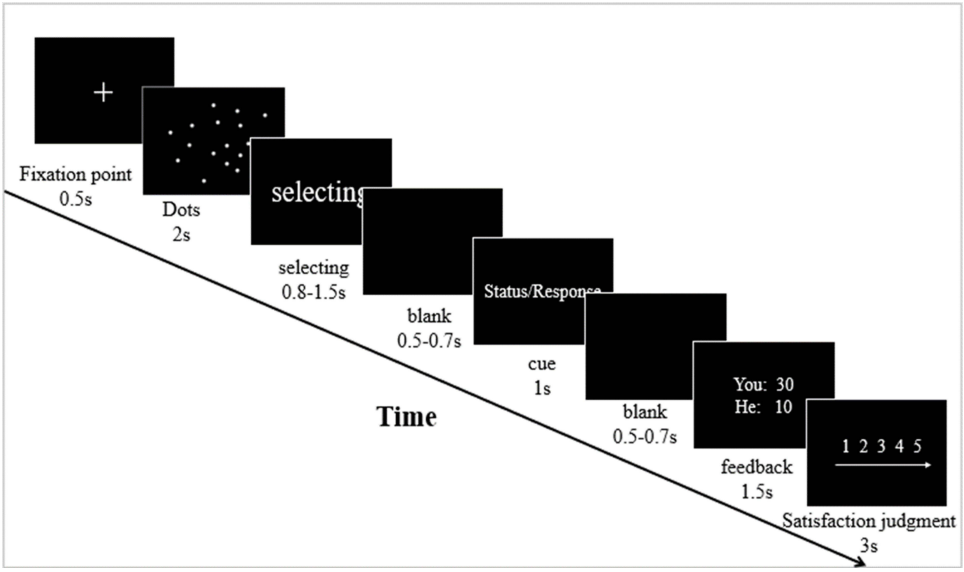

Figure 1 The time course of each trial in social comparison task.

very satisfaction. In addition, considering that unfair consideration could be induced under status-related social comparisons, the fairness score was measured using a 4-point scale (1= very unfair, 2 = unfair, 3 = fair, and 4 = very fair) after completing the social comparison task.

The experiment was split into two phases: practice and test, with the purpose of acquainting the volunteers with the task's procedure and the answer buttons. There were six types of trials. In the practice test, each trial was repeated 3 times. The official examination phase was comprised 216 trials, with each trial repeated 36 times.

EEG Data Collection and Preprocessing

64 Ag–AgCl scalp locations had their brain electrical activity monitored using an elastic cap (Neuro Scan Product). The left supraorbital and infraorbital rows of electrodes were used to record eye blinks. Two external canthi, 1.5 cm lateral to each other, were the sites of a row of electrodes used to capture the horizontal electro-oculogram (EOG). The electrode recordings' rows were all cited online. They were offline and re-referenced to the mean of the data for the left and right mastoids. Feedback-locked ERPs were obtained by extracting the division EEG epochs, which were 1000 ms, and the social comparison ERP epochs, which were 1500 ms (with a 200 ms pre feedback baseline). A 0.01–30 hz band-pass filter was used to amplify the biosignals, and 500 hz/channel of continuous sampling was done for off-line analysis. Blinks and eye movements were rejected offline as eye movement artifacts.

Statistical Analysis

According to our hypotheses, we analyzed cue-P3 in the cue stage, and FRN and P3 in the social comparison stage. The cue-P3 mean amplitudes were calculated in the 320–420ms time window across the medial parietal electrodes (Pz and POz) according to previous studies.[47,48] Based on previous studies,[49–51] the FRN was analyzed by first calculating the difference wave between the status-related equal comparison and response-related equal comparison, and then the peak latency (258ms) of the FRN was obtained in the time windows (228–288ms); finally, the FRN mean amplitudes were calculated in the time window across the medial frontocentral electrodes (Fz and FCz). P3 was analyzed in the time windows of 330–390ms across the parietal electrodes (P1 & Pz) based on the collapsed localizer (See Figure S1) as previous studies.[52–54] In addition to the FRN and P3, the late positivity potential (LPP) was also analyzed in the 450–550ms time window across the parietal electrodes (P1 & Pz) according to the collapsed localizer (See Figure S1) considering the roles of the LPP in the social comparison.[55,56]

The statistical analysis of the behavioral and ERP data was conducted with SPSS software (version 26, SPSS Inc)., with a statistical threshold of 0.05 for all analyses. Specifically, a 2 (reward division: status-related and response-related) × 3 (social comparison: upward, equal, and downward) two-way ANOVA of the within-subject design was used to analyze the satisfaction scores and mean amplitudes of the FRN, P3, and LPP. In addition, a paired *T* test was used to analyze the mean amplitude of cue-P3 and the fairness score.

Results

Behavioural Results

The results demonstrated that the fairness score of the status-related division (2.0357 ± 0.141) was lower than that of the response-related division (3.3214 ± 0.155) [t (1, 28) = −5.229, $p < 0.001$, d= −0.988]. The repeated-measures ANOVA findings for the satisfaction scores indicated that the main effects of both reward division [F (1, 28) = 10.606, $p = 0.003$, $\eta^2 = 0.275$] and social comparison [F (2, 56) = 92.248, $p < 0$ 0.001, $\eta^2 = 0.767$] were significant. Moreover, the interaction effect was also significant [F (2, 54) = 5.817, $p = 0.005$, $\eta^2 = 0.1172$]. The simple effect test demonstrated that the satisfaction score under the status-related division was lower than that under the response-related division when downward social comparison was induced [F (1, 28) = 13.519, $p < 0.001$, $\eta^2 = 0.326$], whereas satisfaction scores were not significantly different between status-related and response-related divisions when upward and equal social comparisons were induced.

ERP Results

The Results of Cue-P3

The results showed that the response-related cue elicited a larger cue-P3 amplitude (4.221 ± 3.868) than the status-related cue (3.0312 ± 4.833) [t (1, 28) = −2.181, $p < 0.05$, d = −0.405] (See Figure 2).

The Results of the FRN

The results showed that the main effects of reward division and the social comparison were not significant, while the interaction between reward division and the social comparison was significant [F (2, 56) = 3.811, $p < 0.05$, $\eta^2 = 0.120$].

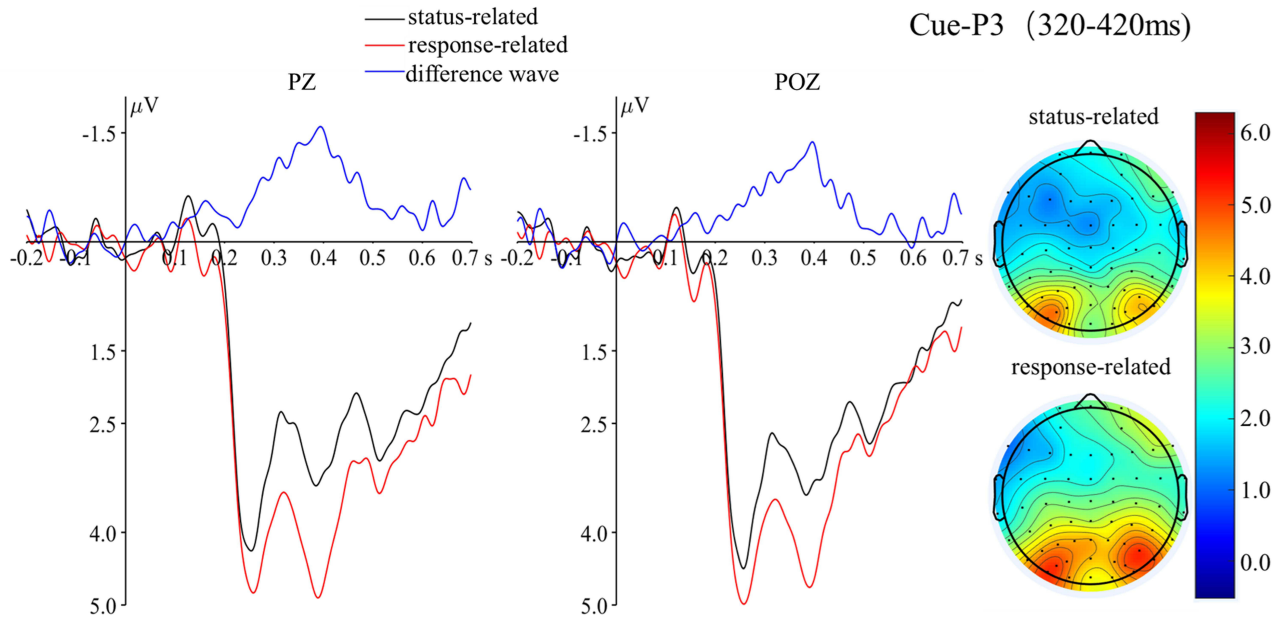

Figure 2 Grand-averaged ERPs and the difference wave (status-related cues minus response-related cues) at Pz and POz, as well as the topographic maps of the cue-P3 in the time window 320–420ms.

The simple effect test showed that there were no significantly different between status-related and response-related upward comparison [F (1, 28) = 1.839, $p = 0.186$, $\eta^2 = 0.062$], as well as status-related and response-related downward comparison [F (1, 28) = 0.182, $p = 0.673$, $\eta^2 = 0.006$], but the status-related equal comparison elicited a larger FRN than the response-related equal comparison [F (1, 28) = 6.371, $p < 0.05$, $\eta^2 = 0.185$] (See Figure 3).

The Results of the P3

The results showed that the main effects of reward division and the social comparison were not significant, while the interaction between reward division and the social comparison was significant [F (2, 56) = 5.654, $p < 0.05$, $\eta^2 = 0.168$]. The simple effect test showed that the status-related upward comparison elicited a larger P3 than the response-related upward comparison [F (1, 28) = 5.728, $p < 0.05$, $\eta^2 = 0.170$], while there was no significantly different between status-related and response-related comparisons when downward [F (1, 28) = 3.550, $p = 0.070$, $\eta 2 = 0.113$] and equal [F (1, 28) = 2.924, $p = 0.098$, $\eta^2 = 0.095$] comparisons were induced. Moreover, there were significant differences among the response-related upward, equal, and downward comparisons [F (2, 28) = 5.439, $p < 0.05$, $\eta^2 = 0.287$], but there was no significant difference among status-related upward, equal, and downward comparisons [F (2,28) = 0.541, $p = 0.588$, $\eta^2 = 0.039$]. The paired T test showed that the P3 amplitude was significantly or marginally significantly lower under response-related upward comparison than equal comparison ($p = 0.008$) and downward comparison ($p = 0.052$), but no significant difference between downward and equal comparisons (See Figures 4 and 5).

The Results of the LPP

Repeated measures ANOVA revealed that the main effect of division was not found, but the main effect of social comparison was found [F (2, 56) = 6.105, $p < 0.05$, $\eta^2 = 0.179$]. We also not find interaction effect of division and social comparison. The results of the post hoc test show that the upward comparison induces a smaller LPP than the equal and downward comparison. There was no difference between equal and downward, whether they were status-related or response-related (See Figures 4 and 5).

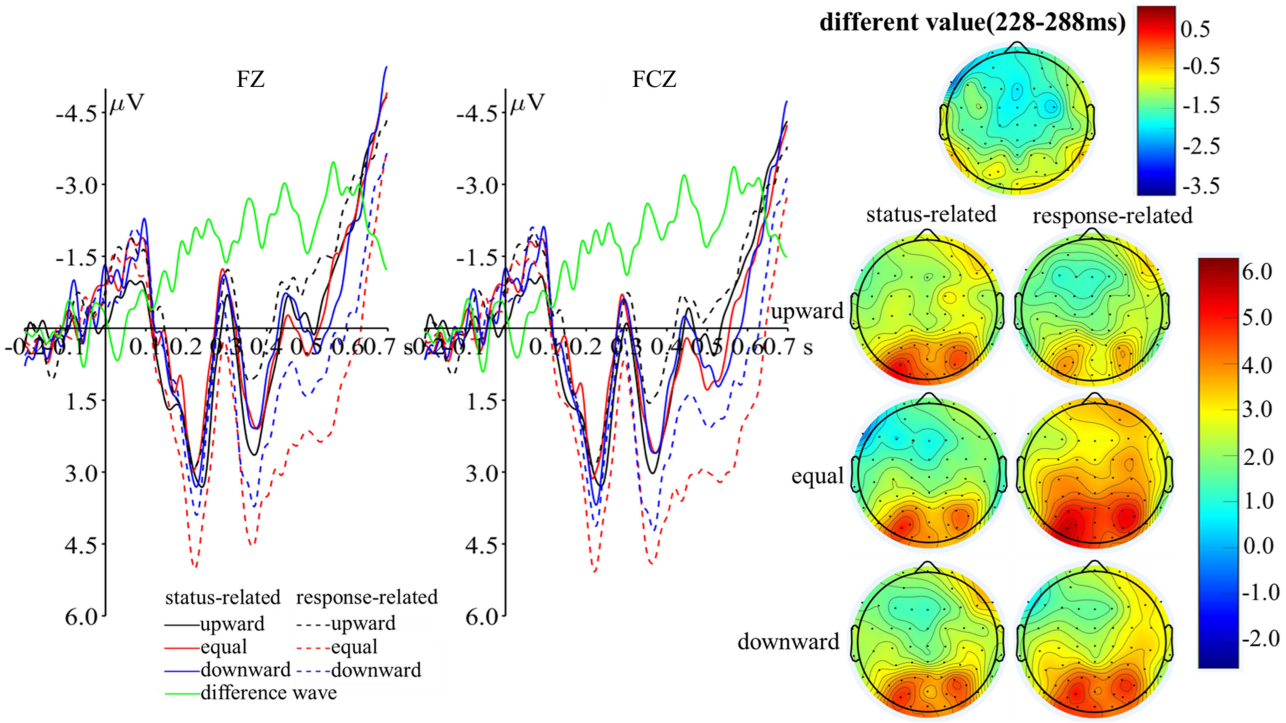

Figure 3 Grand-averaged ERPs at Fz and FCz for the social comparisons and the difference wave (status-related equal comparison minus response-related equal comparison); the topographic maps of the difference value and the social comparisons in the time windows 228–288ms.

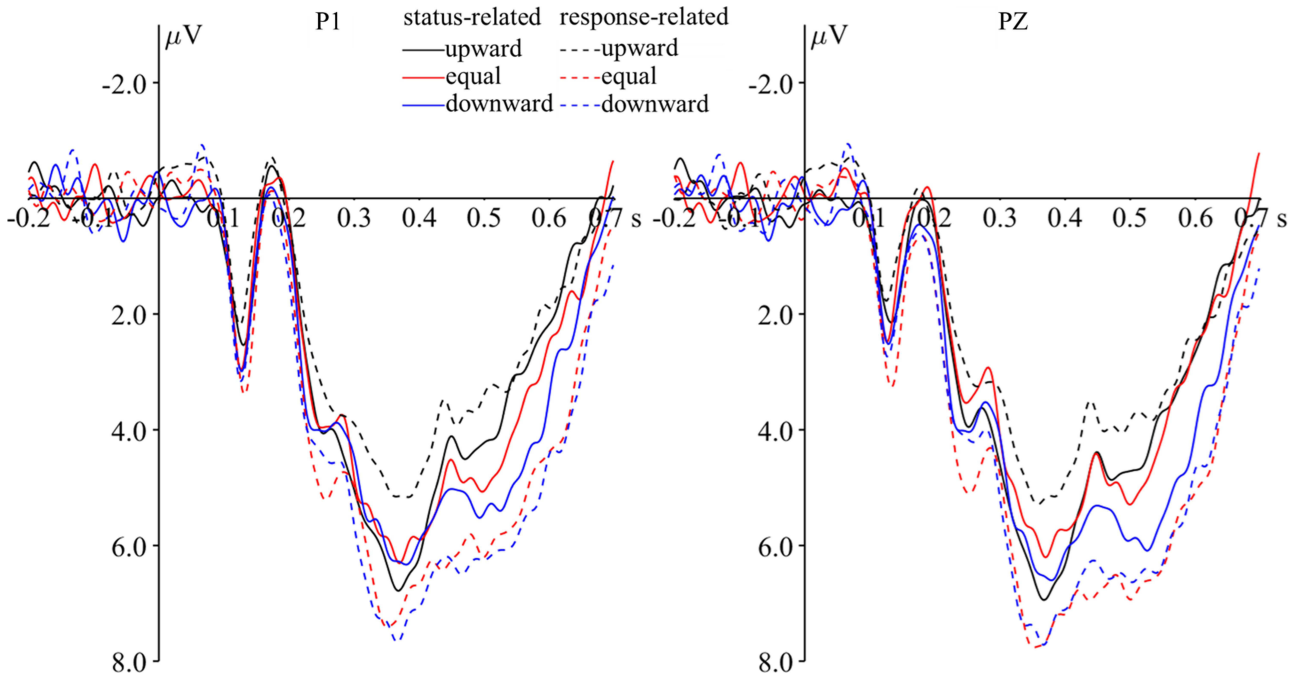

Figure 4 Grand-averaged ERPs at P1 and Pz for the social comparisons.

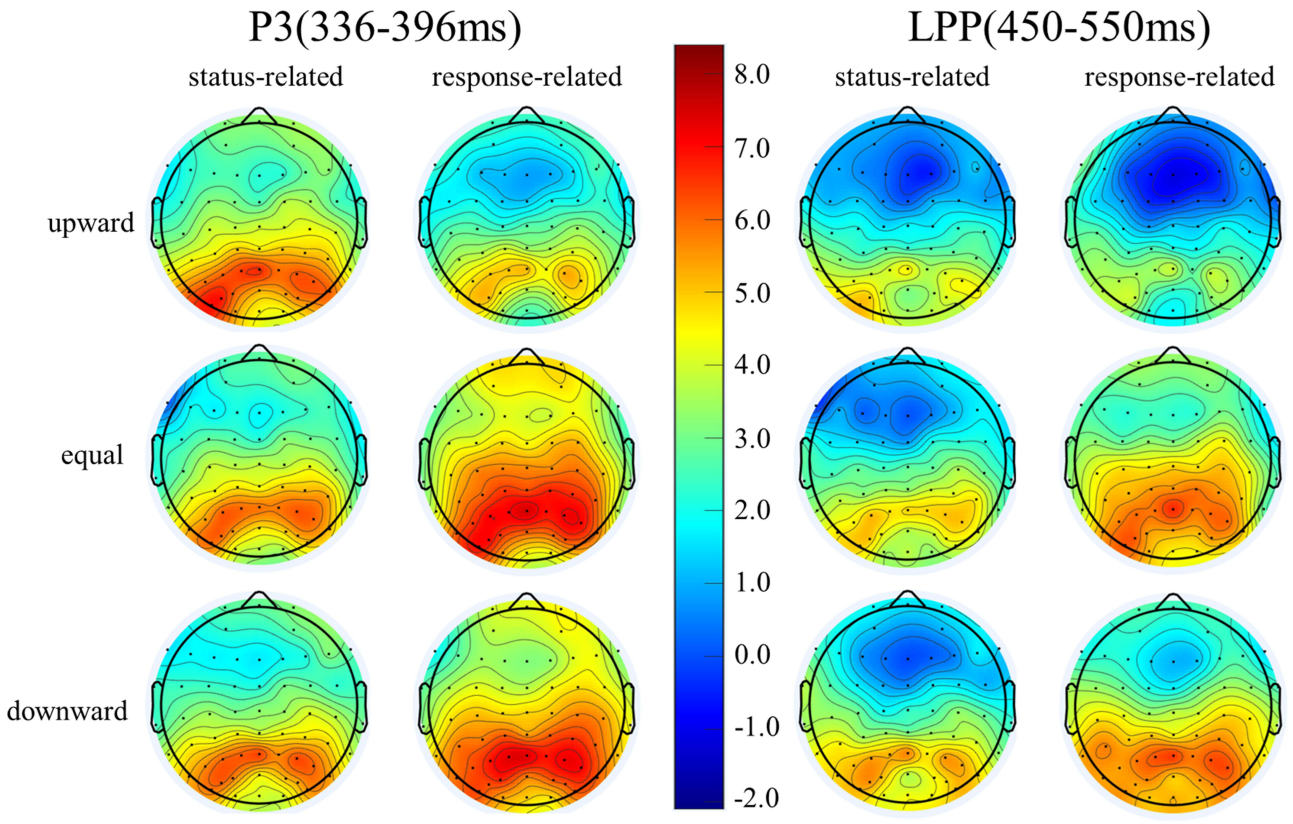

Figure 5 The topographic maps for the P3 and LPP under the social comparisons in the time windows of 336–396ms and 450–550ms respectively.

Discussion

In this study, electrophysiological indices of status-related social comparisons were investigated using a modified social comparison task combining with the ERP technique. In accordance with our hypotheses, the behavioral results showed that the individuals reported that the status-related comparisons were more unfair than the response-related comparisons. The ERP results showed that the status-related cue elicited a larger cue-P3 amplitude than the response-related cue; the status-related upward comparison caused a higher P3 amplitude than the response-related upward comparison; the status-related equal comparison elicited a larger FRN amplitude than the response-related equal comparison. Except for these results, we found that the upward comparison elicited a smaller LPP amplitude than both the equal and downward comparisons.

Our results revealed that the fairness score under the status-related comparison was lower than under the response-related comparison; the FRN amplitude was larger under status-related equal comparisons than under response-related equal comparisons. It was confirmed that the FRN amplitude can be moderated by the reward-division fairness, which showed that the FRN amplitude is larger under the unfair division than the fair division.[28,57] Furthermore, previous studies also define the reward division as unfairness when individuals give the persons with same identity more money than others with different identity.[10–12] Our results implied that unfairness could be observed by the larger FRN amplitude under the status-related equal comparison than the response-related equal comparison. Considering that the FRN amplitude can be also enhanced by other response-related comparisons based on previous studies,[58–60] it might be difficult to be observe the difference between response-related and status-related upward/downward comparisons because of the confusion of unfairness under the status-related division. Thus, it might be an important way to observe the unfairness using the enhanced FRN amplitude under the status-related equal comparison relative to the response-related equal comparison.

Our results also found that the P3 amplitude elicited by the upward comparison was larger under the status-related comparison than response-related comparison. It has been suggested that unfair upward comparison can induce relative deprivation accompanied by anger and resentful.[38–40] Furthermore, previous studies also found that P3 amplitude is larger under anger than happiness due to more attentional resources are assigned to the angry stimuli to cope with potential threat.[41–43,61] Considering that the status-related comparisons are more unfair than the response-related comparisons, the enhanced P3 under the status-related upward comparison might be related to the relative deprivation induced by the unfair upward comparison. Similar to the anger, the enhanced P3 amplitude also implied that the attentional system might also assign more resources to the relative deprivation induced by the status-related upward comparison.

A substantial body of research indicates that relative deprivation is significantly associated with a range of adverse outcomes, including aggressive behavior, antisocial conduct and criminality.[39,62,63] The theory of relative deprivation posits that relative deprivation can be induced and may instigate aggressive behavior when individuals perceive that others are better off and that their own disadvantage is undeserved.[38,64] It has been demonstrated that aggressive behavior can be moderated by cognitive control, indicating that the aggressive behavior could be successfully inhibited if individuals possess sufficient cognitive resources to execute the cognitive control.[65–67] Our results indicate that the relative deprivation may require a significant number of cognitive resources due to the enhanced P3 amplitude observed in status-related upward comparisons relative to response-related upward comparisons. Therefore, it can be posited that the cognitive resources available may be insufficient to inhibit aggressive behaviors when the relative deprivation is induced by an unfair upward comparison.

Our results also demonstrated that the amplitude of the cue-P3 was diminished in response to status-related cues in comparison to response-related cues. The cue-P3 is responsive to incentive cues and is capable of conveying monetary contingencies under both loss and gain relative to neutral cues.[44,68–70] It has been proposed that an increased cue-P3 amplitude indicates that individuals have allocated a greater number of attentional resources to reward-predicting stimuli, which can stimulate the motivation to engage in reward-seeking behaviors.[69,70] Consequently, the reduced cue-P3 amplitude may suggest that status-related cues possess diminished motivational functions in comparison to response-

related cues. In other words, the response-related cues may exert a more pronounced motivational influence on individuals to engage in reward-seeking behaviors than the status-related cues.

This approach offers an effective method of influencing behaviors in a socializing context, whereby individuals are rewarded contingent on their ability to meet the behavioral standards valued by significant others (eg parents, teachers, elders).[71–74] Although this perspective implies that it is an important way to motivate behaviors by using the response-related division of reward, social status plays an important role in satisfying the psychological need for competence.[1–3,75] It may therefore be inevitable to distribute rewards on the basis of social status. It is important to note, however, that the motivation to receive a reward may be reduced when social comparisons are made on the basis of social status. Moreover, individuals may experience relative deprivation when they perceive status-related upward comparison, which could potentially result in adverse outcomes, including anger, resentment, and aggressive behaviors.[38–40] It is therefore important to strike a balance between response-related (eg performance-based rewards) and status-related divisions (eg salary rank) in practice, such as in management, education and other fields, where rewards are used to shape behaviors.

Conclusions and Limitations

The present study investigated the ERP components of status-based social comparisons using the modified dot-estimation task. The findings indicated that status-related comparisons were perceived as more unfair than response-related comparisons. This was evidenced by the observation of a higher FRN amplitude in response to status-based equal comparisons relative to response-based equal comparisons. Furthermore, the motivational impact of the rewards was diminished in the context of status-related comparisons, potentially linked to the reduced cue-P3 amplitude observed in status-related cues relative to response-related cues. Additionally, the P3 amplitude was elevated in the context of status-related upward comparisons compared to response-related upward comparisons, suggesting that individuals may have experienced a sense of relative deprivation in the context of an unfair upward comparison.

The findings presented here contribute to our understanding of the neural basis of status-related comparisons. However, it is also necessary to address some of the limitations of the present study in future research. Firstly, considering that status-related social comparisons were triggered by classical measurements of objective and subjective socioeconomic status, it was difficult to determine whether the responses were correct. Inconsistent with the classical dot-estimation task,[7,20,23] there was no correct or incorrect information in the feedback. Thus, it is necessary to study the electrophysiological indices of status-related social comparisons, in which social status can also be evaluated as right or wrong.

Secondly, our findings showed that the LPP amplitudes during upward comparisons were the smallest, whereas the LPP amplitudes were not different between equal and downward comparisons. Previous experiments have shown that LPP may reflect the detection of stimuli with motivational marker.[76] In previous studies, positive stimuli may enhance LPP, which is inconsistent with our experimental results.[7,23,54] However, we were unable to provide a reasonable explanation for this finding. One possible explanation is that in the case of downward comparison and equal comparison, it will have a stronger incentive function than in the upward comparison. They reinforced and motivated participants' feedback during the trial. Another possible reason is that downward and equal comparisons induce more emotion regulation strategies.[77,78] Further research is needed to provide a more reasonable explanation for the results of the LPP.

Thirdly, although our findings implied that relative deprivation might be related to the higher P3 amplitude elicited by status-related upward comparisons, but the relative deprivation was not directly measured in the current research. Thus, future research should examine the connection between P3 and relative deprivation, as well as its roles in aggressive behavior, antisocial conduct and criminality.

Data Sharing Statement

The data that support the findings of this study are available if necessary.

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Disclosure

The authors declared that they have no conflicts of interest with respect to the authorship or publication of this article.

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