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Social value orientation modulates context-based social comparison preference in the outcome evaluation: An ERP study

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ABSTRACT

Social value orientation (SVO) is a personality trait that is closely associated with social comparison preference. However, little is known about how the different types of SVO (i.e., proself vs. prosocial) modulate the behaviour and neural underpinnings of its interaction with social context. In the present study, we examined electrophysiological correlates captured when individuals with different SVOs engaged in a gambling game with two other players (a socially disliking player, person A, vs. a socially liking player, person B). Three main findings are reported in our study. 1) Social comparison effects were manifested in feedback-related negativity (FRN) (the most negative FRN was expressed in the large difference condition, and the least negative FRN was expressed in the even condition), and this effect was modulated by both the win/loss context and SVO. That is, in a self-win context, FRN exhibited a social comparison effect for both prosocials and proselfs. In the self-loss condition, only prosocials displayed this effect. 2) Both groups displayed an enhanced FRN to person A's (the disliked player's) loss compared with the FRN to A's win in the self-win context, whereas only prosocials displayed a more negative FRN to A's win compared to A's loss in the self-loss context. 3) There was a social liking effect, but not a social comparison effect, on the P300, showing that for prosocials only, winning with a socially liking player elicited an increased P300 compared to winning with a disliking player. These findings suggest that the influences of SVO on social comparison are automatic and context dependent, which is reflected by a semi-automatic FRN in which prosocials are sensitive to others' wins or losses in both the self-win and self-loss contexts, whereas proselfs are not interested in others' outcomes in the self-loss context. Furthermore, interpersonal relationships affected the P300 for prosocials when they won but had no effect on the proselfs. This work sheds light on the neural basis of outcome evaluation in multiple social contexts and its individual differences in automatic social comparison situations.

1. Introduction

Social comparison exists universally in social life because humans tend to compare their personal interests, abilities or opinions with others in relevant fields to understand themselves (Festinger, 1954). Despite the diversity of types of social comparison, upward and downward comparison represent two typical types in daily life; these are negatively and positively valenced comparisons, respectively (O'Brien et al., 2009; Summerville and Roese, 2008). That is, people form a positive self-belief through downward social comparison, which produces a sense of superiority and pleasure, whereas upward social comparison threatens the individual's self-belief and produces inferiority and sadness (Brickman and Bulman, 1977). Social comparisons in diverse contexts are known to modulate situation evaluation (Collins, 1996; Fardouly et al., 2015). For example, research suggests that even with an identical payoff, people are less satisfied if they earn less than their colleagues or people in the same occupation at other firms (Clark and Oswald, 1996).

Theoretical discussions have identified some specific motives underlying comparison, such as self-evaluation, self-improvement and self-enhancement (Gibbons and Buunk, 1999; Wood, 1989). Regarding the self-evaluation motivation, people with more uncertainty about themselves (Lee, 2014), for example, individuals with lower self-esteem (Wayment and Taylor, 1995) and higher neuroticism (Van der Zee et al., 1998), are more inclined to engage in social comparison. For self-improvement or self-enhancement motivation, people who pursue better performance than others are more social comparison-seeking (Suls et al., 2002). Therefore, people display different motivations for social comparison preference that are related to their personal traits.

Social value orientation (SVO) is a personality trait that has been

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found to modulate social comparison preference in dependent contexts (De Dreu and Boles, 1998; Van Lange, 1999). SVO reflects varied motivation orientations in people who can be identified as individualists, competitors and co-operators, measured by the Three Dominance Test (Van Lange, 1999) or the Slider Test (Murphy et al., 2011). It is common to combine individualists and competitors into the "proself" group, whereas co-operators are labelled "prosocials" (see review Bogaert et al., 2008; Van Lange and Liebrand, 1991). Prosocial individuals tend to maximize joint interests, whereas proself individuals tend to maximize self-interest (McClintock and Liebrand, 1988; Van Lange, 1999; Van Lange and Kuhlman, 1994). Based on social motivation differences, it is hypothesized that proselfs may seek more social comparison than prosocials with the goal of identifying the self in an advantageous condition during outcome evaluation. However, little is known about the behavioural and neural responses from social comparison during outcome evaluation with regard to the interplay between SVO and social context.

Using the event-related potential (ERP) technique, a large amount of work has identified outcome evaluation-related components, such as FRN and P300. It has been consistently found that negative outcomes (e.g., lost money) elicit a more negative FRN, with a negative-going deflection maximal at frontocentral scalp electrode sites approximately 250 ms post feedback (Gehring and Willoughby, 2002; Hajcak et al., 2006; Hauser et al., 2014). Furthermore, the FRN is thought to reflect an early evaluation of expectancy towards outcomes, with unexpected outcomes eliciting a more negative-going FRN (Cao et al., 2015; Holroyd and Coles, 2002; Nieuwenhuis et al., 2004), or a rapid evaluation of motivational significance (Gehring and Willoughby, 2002). Interestingly, previous studies have shown that social context, such as interpersonal distance and responsibility for outcomes, has an effect on FRN amplitude (Kimura and Katayama, 2016; Leng and Zhou, 2014; Li et al., 2010; Ma et al., 2011a, 2011b). Another ERP component that is closely associated with outcome evaluation is P300, which is considered to reflect attentional allocation (Gray et al., 2004; Linden, 2005; Zhang et al., 2017) or motivational/affective salience (Donchin and Coles, 1988; Nieuwenhuis et al., 2005; Wu and Zhou, 2009). P300 is also modulated by social contexts, such as interpersonal relationships (Leng and Zhou, 2010; Ma et al., 2011) and the level of personal responsibility for an outcome (Li et al., 2010).

In recent years, attempts have been made to explore the impact of social comparison on the ERPs of outcome evaluation; however, inconsistent results have been observed (Qiu et al., 2010; Wu et al., 2012). For example, in one study where subjects performed a simple dot estimation task during which correct responses were rewarded in three conditions (self:other = 1:2, self:other = 1:1; and self:other = 2:1), the results showed that both the "1:2 condition" and the "2:1 condition" elicited a more negative ERP deflection than the "1:1 condition" in 350 − 550 ms (i.e., N350–550, similar to ERN), suggesting a lack of differentiation between upward and downward social comparisons (Qiu et al., 2010). Other researchers have employed a similar experimental task, showing that loss vs. gain FRN was not modulated by social comparison but that the P300 showed an effect of social comparison independent of feedback valence such that the 1:1 payoff and the 2:1 payoff elicited a larger P300 than the 1:2 payoff (Wu et al., 2012).

However, a mixed factor in the above two studies is that the outcome evaluation is likely to trigger both fairness and comparison considerations in that FRN was found to be more negative when the result was unfair (Qu et al., 2013; Yu et al., 2015). By excluding the interference of fairness with the feedback received on their own and their partners' performance, a more negative FRN was found when the subjects' own outcomes were worse than those of their partners' (Boksem et al., 2011). Luo et al. (2015) adopted a three-person gambling game in which the results were of three types: a large difference outcome, a medium difference outcome, and an even outcome. The FRN showed sensitivity to social comparison such that both the large difference and the medium difference outcomes elicited larger amplitudes than the even outcome.

To further investigate the relationship between SVO and social comparison preferences, in the current study, we adopted the same paradigm as Luo et al. (2015) to examine the ERP effects of SVOs on outcome evaluation when each payoff is independent. In addition, considering that interpersonal relationships influence both FRN and P300 in the outcome evaluation (Leng and Zhou, 2010, 2014; Yang Wang et al., 2014; Yiwen Wang et al., 2014), we manipulated the relationship between subjects and others in this experiment: one player was the socially liking player, and the other was the socially disliking player (see details in Section 2). We then asked an open question about behavioural and neural responses to outcomes in various social contexts, and we questioned how the social comparison effect is modulated by SVO and interpersonal relationships. Similar to the existing studies showing a relationship between empathy and SVO (Declerck and Bogaert, 2008), we measured empathic traits using the Interpersonal Reactivity Index (IRI, Davis and Association, 1980), which has four subscales (i.e., perspective taking, fantasy, empathy concern, and personal distress),[1] to investigate the possible relationship between SVO, empathy trait, the social comparison effect and ERP responses. On the basis of prior research, we hypothesized that during outcome evaluation, proselfs would exhibit more social comparison preference than prosocials, which would manifest in FRN. We were interested in the differences in social comparisons between the self-win context and the self-loss context because people mainly show a downward comparison in the self-win context but an upward comparison in the self-loss context. Additionally, we predicted that prosocials would express less schadenfreude in response to the negative outcomes of others because of their altruistic motivation orientation.

2. Materials and methods

2.1. Participants

Forty-one undergraduate and graduate students ranging in age from 19 to 28 years (17 female, *M*age = 22.34 years, *SD* = 2.3) participated in the experiment. All participants were right-handed, had normal or corrected-to-normal vision, and reported no red-green colour blindness. The participants were told that the points that they earned during the experiment were relevant to their own gain or loss. At the end of the experiment, each participant received approximately 80 Yuan for participation. The study protocol was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences, and written informed consent was obtained from all participants before the experiment.

2.2. Procedure

2.2.1. Social liking manipulation: a trust game

After arriving in the laboratory, the participants were told that they would play two games with two other students who were sitting in the adjacent room. Initially, they would complete a revised trust game to induce affective preferences (social liking vs. social disliking) in the other two students, named A and B (Singer et al., 2006). During the game, the participants acted as investors and chose between a high or low proportion of money to invest. Then, the amount of money was tripled. Afterward, confederate A or B pressed a button to pretend to make a distribution. One of the investment agents (socially liking:

[1] The perspective-taking scale assesses spontaneous attempts to adopt the perspectives of other people and see things from their point of view. The fantasy items measure the tendency to identify with characters in movies, novels, plays and other fictional situations. The empathy concern and personal distress scales explicitly tap respondents' chronic emotional reactions to the negative experiences of others (Davis and Association, 1980).

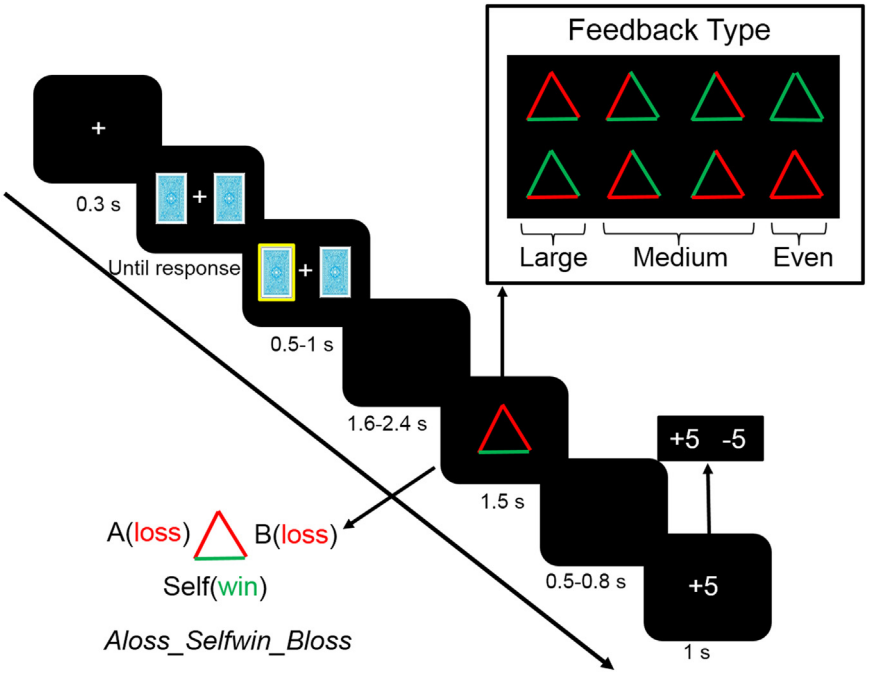

Fig. 1. Schematic representation of the three-person gambling task. A, socially disliking player; B, socially liking player.

player B) returned a fair (large) amount, and the other (socially disliking: player A) returned an unfair (small) amount. At the end of the game, the participants were asked to estimate the fairness, trustworthiness, attractiveness, and likeableness of the investment agent using a 7-point scale.

2.2.2. *Gambling task with EEG recording*

The second game was a gambling task, which was used previously by Luo et al. (2015). In each trial (Fig. 1), the participants were presented with two cards displayed on both sides of a fixation cross. This pair of cards remained on the screen until the participant chose one by pressing the "F" or "J" button on the keyboard with his/her left or right index finger. Then, the chosen card was highlighted for 500 − 1000 ms. After a 1600- to 2400-ms interval in which the other two participants were purportedly making their decisions, an equilateral triangle was displayed on the screen. The triangle size in the visual angle was equal to 4.5°. The colour of each edge of the triangle represented the valence of each player's outcome (Fig. 1). The participants were informed that in each trial, one card led to a win and the other led to a loss, and there was no relation between the location of the cards and the outcomes. The outcome of the participant's decision would not affect the interests of the other players and vice versa.

A total of 400 trials were divided into 5 blocks, and a short break was given between blocks. To familiarise the participants with the procedure, a practice with 10 trials was used before the formal experiment. Based on the valences of the participant's outcome (win/loss) and the two other players' outcomes (win/loss), there were 8 types of feedback. Regarding the social comparison factor, there were a total of three conditions: "large", "medium" and "even". In the large difference condition (*"large"*), the valence of the participant's outcome was different from the valence of the two other players' outcomes (e.g., the participant won and the other two lost). In the medium difference condition (*"medium"*), the valence of the participant's outcome was the same as the valence of one player. Finally, in the even condition (*"even"*), the participant and the other two players had the same outcome (Fig. 1). At the end of the gambling task, each participant provided a happiness rating regarding the eight types of feedback presented in the task using a 5-point scale, with "1" indicating very unhappy and "5" indicating very happy.

After the formal experimental procedure, the participant's SVO was measured using the Slider measurement (Murphy et al., 2011). We also measured the empathy trait using the IRI (IRI, Davis and Association, 1980) and self-esteem using the Self-Esteem Scale (SES, Rosenberg, 1965). Debriefing questions concerning the extent to which the subjects believed that our manipulation was true (ranging from 1 to 5) were administered, and the results indicated an overall high level of belief that they were playing with A and B (mean = 3.89).

2.3. *Data recording and analysis*

The participants were comfortably seated 80 cm in front of the computer screen in a dimly lit and sound-attenuating room. The electroencephalogram (EEG) was recorded during the gambling task using an elastic cap with a set of 64 electrode sites placed according to the extended international 10–20 system (Brain Product, GmbH, Germany). The vertical electrooculogram was recorded using an electrode placed on the right infraorbital area. The raw EEG data were online referenced using FCz and then re-referenced offline with the average of the left and right mastoids (Luck, 2014). The data were sampled at 500 Hz/channel with impedance lower than 5 kΩ. The online continuous data were digitised using a bandpass filter of 0.5–70 Hz.

The EEG data were preprocessed and analysed using MATLAB 2013a and the EEGLAB toolbox (Delorme and Makeig, 2004). The EEGs were filtered with a low pass of 30 Hz (24 Db/oct). EOG artefacts were removed from the EEG signal using the independent component analysis (ICA) method (Delorme and Makeig, 2004; Jung et al., 2001). Epochs began 100 ms before the stimulus and continued for 500 ms, with the activity from −100 to 0 ms serving as the baseline. The artefacts were removed using ± 80 μV as the threshold.

According to the grand-averaged waveforms and topographic maps (Figs. 2 and 3), the FRN was extracted as the base-to-peak difference to determine the maximum negative amplitude in the 230- to 280-ms time window (Rigoni et al., 2010) at Fz, which was identified with the maximum amplitude (Gehring and Willoughby, 2002). P300 was defined as the average amplitude in the 320–450-ms time window pooled from Cz, Pz and CPz (Linden, 2005).

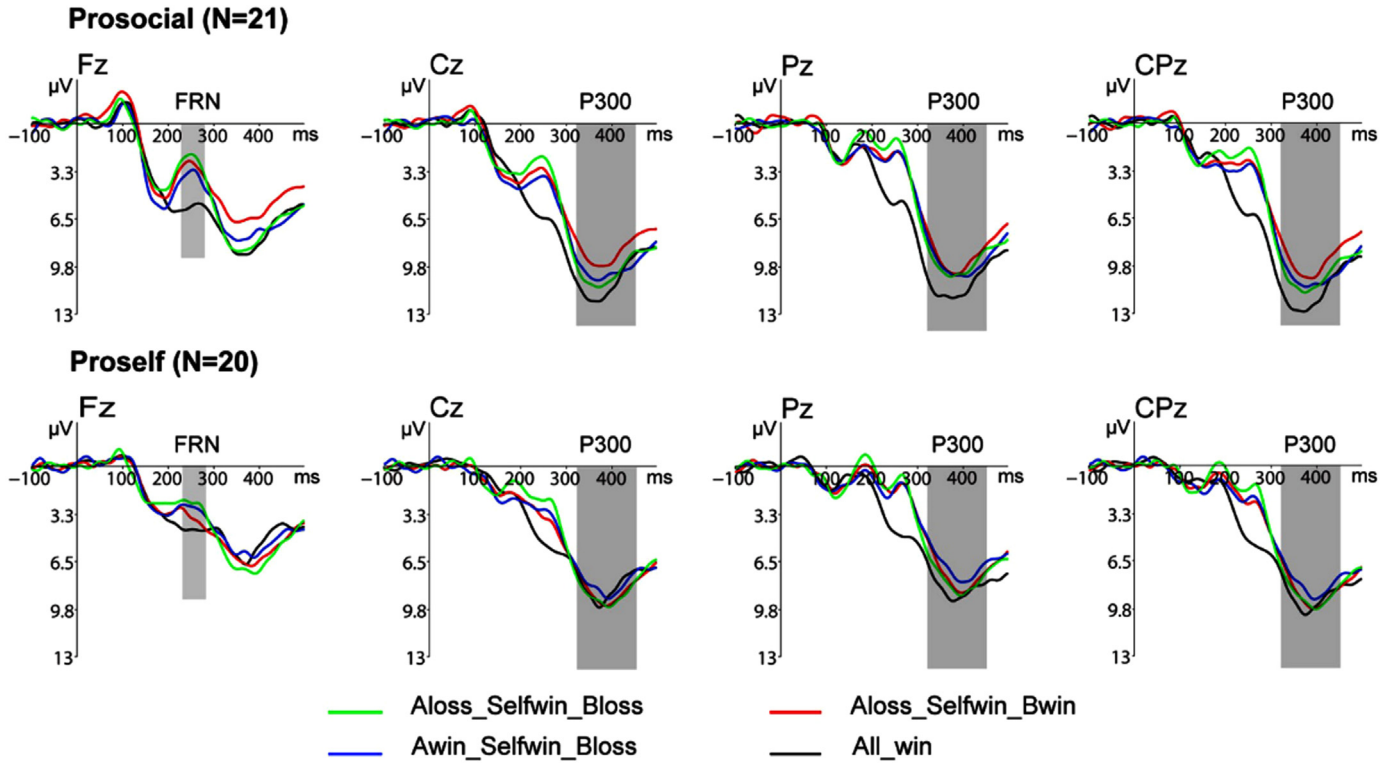

Fig. 2. Grand-average ERP waveforms following self-win feedback for proself and prosocial individuals at Fz, Cz, Pz and CPz. At Fz, the shaded areas depict the time window of the FRN; at Cz, Pz and CPz, the shaded areas depict the time window of P300. A, socially disliking player; B, socially liking player.

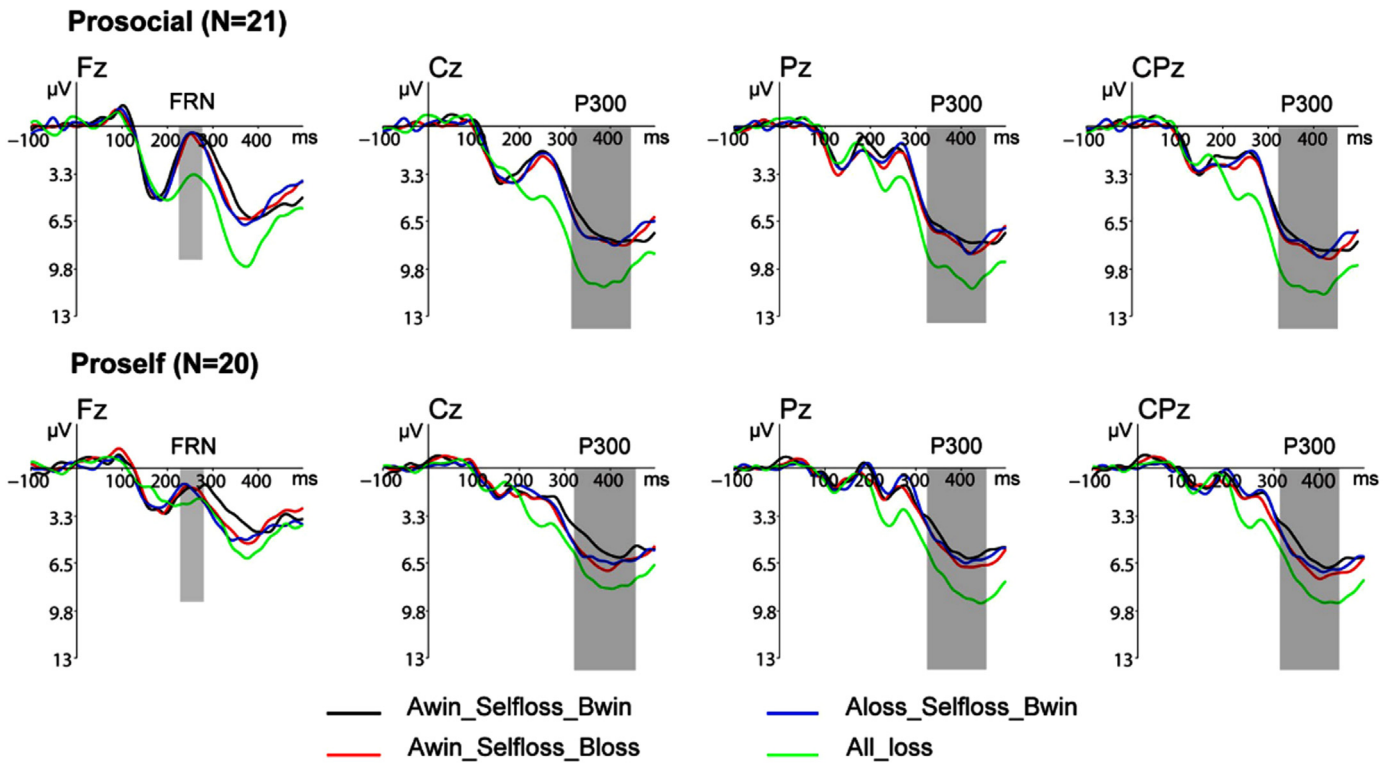

Fig. 3. Grand-average ERP waveforms following self-loss feedback for proself and prosocial individuals at Fz, Cz, Pz and CPz. At Fz, the shaded areas depict the time window of the FRN; at Cz, Pz and CPz, the shaded areas depict the time window of P300. A, socially disliking player; B, socially liking player.

2.3.1. Full ANOVA

All behavioural data and ERP amplitude data were statistically analysed using SPSS software (Version 18). For behavioural ratings, peak FRN and mean P300 amplitudes, we first conducted a *full analysis* with a 2 (SVO: prosocial vs. proself) × 2 (valence of A: win vs. loss) × 2 (valence of B: win vs. loss) × 2 (valence of self: win vs. loss) ANOVA to explore all the possible effects on the affective rating and ERP responses. The mean trial number for each condition was as follows: Awin_Selfwin_Bwin: 42; Awin_Selfwin_Bloss: 39; Aloss_Selfwin_Bwin: 37; Aloss_Selfwin_Bloss: 42; Awin_Selfloss_Bwin: 41; Awin_Selfloss_Bloss: 34; Aloss_Selfloss_Bwin: 38; Aloss_Selfloss_Bloss: 37.

2.3.2. Social comparison effects analysis

The social comparison effect, including the upward and downward comparison effects, should differ between the self-win and self-loss contexts. For social comparison-seeking participants, the most positive outcome was self-win, other two lose. The most negative outcome was self-loss when the other two both won. Therefore, we analysed the social comparison effect in the self-win and self-loss contexts to separate the upward and downward conditions, respectively. A 2 (SVO: prosocial vs. proself) × 3 (social comparison effect: large vs. medium vs. even) ANOVA was conducted. We collapsed the Awin_Bloss and Aloss_Bwin conditions in this investigation.

2.3.3. Social liking effect analysis within medium comparison conditions

Furthermore, we conducted a specific interest-driven analysis and compared the FRN and P300 amplitude when a subject won/lost with a socially liking player and a socially disliking player (i.e., Awin_Selfwin_Bloss vs. Aloss_Selfwin_Bwin and Awin_Selfloss_Bloss vs. Aloss_Selfloss _Bwin) to identify whether there is a difference between winning/losing with socially liking B and winning/losing with socially disliking A in the self- win or lose context. We believe this is one possible way to separate out the social comparison effect, similarity effect and our social liking manipulation effect in the two groups because in this case, the difference is exactly the same (i.e., 2:1), as is the triangle colour. Therefore, we can target the social liking effect by these comparisons because the only difference is which of the other players wins/loses with self. Therefore, a 2 (SVO: prosocial vs. proself) × 2 (winning/losing with the socially liking player B vs. winning/losing with the socially disliking player A) ANOVA was conducted to compare winning with A vs. winning with B in the self-win context and to compare losing with A vs. losing with B in the self-loss context for the FRN and P300 amplitudes separately.

The Greenhouse-Geisser correction was applied when the sphericity assumption was violated. The Bonferroni correction was used for multiple comparisons. The partial eta-squared (η_p^2) was also reported as a measure of the proportion between the variance explained by one factor and the total variance.

3. Results

3.1. Demographic and behavioural data

3.1.1. Demographic data

There were 21 prosocials and 20 proselfs participating in the study. We set up a cut-off with angles of 22.45; angles below 22.45 degrees indicated competitiveness and selfishness and greater angles indicated a more prosocial disposition (Murphy and Ackermann, 2014; Murphy et al., 2011). As shown in Table 1, the Slider measurement scores of prosocials (M = 29.97, SE = 7.06) were significantly higher than those of proselfs (M = 8.52, SE = 9.09): t (1, 39) = 8.463, p < 0.001, and there were no significant differences in age, gender, IRI and self-esteem scores between the two groups.

Table 1
Sample characteristics.

	Prosocial group (n = 21)	Proself group (n = 20)	*t*-test (*df* = 39)
Age, years (*SD*)	22.43 (2.25)	22.25 (2.40)	−1.349
Gender (% females)	38.10	45.00	0.201 (Chi-square)
SVO (*SD*)	29.97 (7.06)	8.52 (9.09)	12.606***
IRI (*SD*)	54.81 (8.11)	54.90 (8.23)	1.195
SE (*SD*)	31.43 (5.62)	29.85 (5.56)	− 0.195

SVO, Social Value Orientation; IRI, Interpersonal Reactivity Index; SES, Self-Esteem Scale.
*** p < 0.001.

Table 2
Participants' self-reported impression ratings for two partners.

	A (socially disliking player)	B (socially liking player)	F
Fairness *(SD)*	2.02 (0.11)	5.05 (0.13)	151.25***
Likeability (SD)	2.07 (0.18)	5.56 (0.18)	176.37***
Attractiveness *(SD)*	2.12 (0.18)	5.40 (0.19)	120.58***
Trustworthiness *(SD)*	1.95 (0.18)	5.46 (0.15)	187.20***

*** p < 0.001.

3.1.2. Elicitation of affective preference

A 2 (SVO: prosocial vs. proself) × 2 (partner: A vs. B) ANOVA was conducted to examine affective preference. A significant main effect of partner suggested that the rating scores for player B (socially liked) were significantly higher than those for player A (socially disliked) (Table 2). There were no interaction effects between SVO and the partner on fairness, likeability, attractiveness or trustworthiness, indicating that there was no modulating effect of SVO on ratings.

3.1.3. Behavioural results

Due to negligence in the experimental operation, 3 subjects' rating data were not collected. Therefore, 38 participants (18 proselfs and 20 prosocials) were included in the final analysis. The social comparison effect analysis showed that there was a significant main effect of valence, F(1, 36) = 239.47, p < 0.001, η_p^2 = 0.87, and that the rating score of win (M = 3.898, SE = 0.08) was significantly higher than the rating score of loss (M = 1.87, SE = 0.08). The significant interaction between valence and social comparison, F(1, 72) = 8.635, p = 0.002, η_p^2 = 0.19, indicated the highest happiness rating for a "large" win and the lowest rating for a "large" loss. A full condition analysis showed that there was a significant main effect of A's outcome, F(1, 36) = 32.20, p < 0.001, η_p^2 = 0.47, and the rating score of A-loss (M = 3.19, SE = 0.07) was significantly higher than the rating score of A-win (M = 2.56, SE = 0.07). We also observed a main effect of own outcome, F (1, 36) = 264.72, p < 0.001, η_p^2 = 0.88, such that the rating score of self-win (M = 3.86, SE = 0.08) was significantly higher than the rating score of self-loss (M = 1.89, SE = 0.08). However, in both analyses of the subjective rating, neither the SVO nor B's outcome-related effects were found.

3.2. Electrophysiological data

The grand-averaged ERP waveforms were separately displayed for all self-win conditions (Fig. 2) and all self-loss conditions (Fig. 3). In the following section, we report the statistical results of two ERP components: 1) the peak FRN from 230 ms to 280 ms in Fz and 2) the mean P300 from 320 ms to 450 ms pooled in Cz, Pz and CPz.

3.2.1. FRN

The full condition analysis showed that there was a significant main

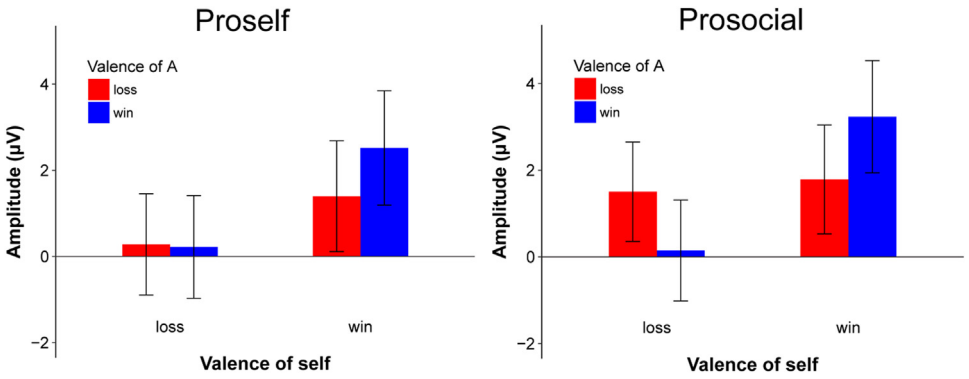

Fig. 4. Histogram displaying the interaction effect between SVO (social value orientation), self's valence and A's valence on the FRN value. Standard errors are also depicted. A, socially disliking player.

effect of own outcome, $F(1, 39) = 29.63$, $p < 0.001$, $\eta_p^2 = 0.43$; FRN was significantly more pronounced in the condition of self-loss ($M = 0.54\,\mu V$, $SE = 0.82$) than in that of self-win ($M = 2.23\,\mu V$, $SE = 0.90$). More importantly, there was a three-way interaction between A's outcome, own outcome and SVO, $F(1, 39) = 4.25$, $p = 0.046$, $\eta_p^2 = 0.10$, showing that when prosocials won, A-loss ($M = 1.79\,\mu V$, $SE = 1.26$) elicited a more negative FRN than A-win ($M = 3.23\,\mu V$, $SE = 1.30$), $p < 0.001$, whereas when prosocials lost, A-win ($M = 0.15\,\mu V$, $SE = 1.16$) elicited a larger FRN than A-loss ($M = 1.50\,\mu V$, $SE = 1.15$), $p = 0.001$. However, when proselfs won, similar to prosocials, a more negative FRN was elicited for A-loss than for A-win, $p < 0.01$, whereas when proselfs lost, FRN was no longer influenced by A's gambling result, $p > 0.05$ (Fig. 4).

The social comparison effect analysis in the self-win context showed a significant main effect of the social comparison effect, $F(2, 78) = 26.48$, $p < 0.001$, $\eta_p^2 = 0.40$, indicating an increasing FRN with the social comparison difference. Specifically, the all win condition ($M = 3.74\,\mu V$, $SE = 0.98$) and the medium difference condition ($M = 1.99\,\mu V$, $SE = 0.91$) elicited a significantly smaller FRN than the only self-win condition ($M = 1.22\,\mu V$, $SE = 0.89$), $p < 0.001$. Neither a significant main effect of SVO nor an interaction effect was found in the self-win context.

The social comparison effect analysis in the self-loss context showed a main effect of social comparison, $F(1, 39) = 9.49$, $p < 0.001$, $\eta_p^2 = 0.20$, and a significant interaction effect between SVO group and social comparison, $F(2, 78) = 3.73$, $p < 0.05$, $\eta_p^2 = 0.09$. Only prosocials exhibited a significantly smaller FRN in the all loss condition ($M = 2.62\,\mu V$, $SE = 1.25$) compared with the only me-loss condition ($M = 0.13\,\mu V$, $SE = 1.18$), $p < 0.001$ (Fig. 5).

Regarding the specific interest analysis of the social liking effect under the same social comparison level (medium condition) for the two groups, the ANOVA result indicated neither a main effect of social liking nor an SVO group-related effect, $Fs < 1.79$, $ps > 0.19$.

We also found correlations between FRN amplitudes and the fantasy scores of IRI. Fantasy is about "*respondents' tendencies to transpose themselves imaginatively into the feelings and actions of fictitious characters in books, movies, and plays*" (Davis and Association, 1980). As shown in Fig. 6, fantasy scores were significantly negative with FRN amplitudes under conditions of Aloss_Selfwin_Bwin ($r = -0.36$, $p < 0.05$), Awin_Selfwin_Bloss ($r = -0.32$, $p < 0.05$), Aloss_Selfwin_Bloss ($r = -0.32$, $p < 0.05$), Aloss_Selfloss_Bwin ($r = -0.33$, $p < 0.05$), and Awin_Selfloss_Bloss ($r = -0.34$, $p < 0.05$), which indicated that whether the self was in the win or loss condition, the higher the degree of fantasy, the more pronounced the FRN when faced with the negative outcome of others.

3.2.2. P300

The full condition analysis showed a significant main effect of the self's valence such that self-win ($M = 9.24\,\mu V$, $SE = 0.98$) elicited an increased P300 in comparison with self-loss ($M = 7.43\,\mu V$, $SE = 0.89$), $F(1, 39) = 55.78$, $p < 0.001$, $\eta_p^2 = 0.59$. There was also a main effect of A's valence, which was different from the self's pattern such that A-loss ($M = 8.61\,\mu V$, $SE = 0.95$) elicited a larger P300 in comparison with A-win ($M = 8.06\,\mu V$, $SE = 0.91$), $F(1, 39) = 12.78$, $p = 0.001$, $\eta_p^2 = 0.25$. B-loss ($M = 8.59\,\mu V$, $SE = 0.93$) also elicited an increased P300 in comparison with B-win ($M = 8.08\,\mu V$, $SE = 0.92$), $F(1, 39) = 17.33$, $p < 0.001$, $\eta_p^2 = 0.31$.

By analysing the social comparison effect on the P300 in the self-win context, we found a significant social comparison effect ($F(2, 78) = 21.44$, $p < 0.001$, $\eta_p^2 = 0.36$), indicating that the P300 amplitude of the even condition ($M = 9.94\,\mu V$, $SE = 1.07$) was significantly larger than that of the medium condition ($M = 8.84\,\mu V$, $SE = 0.96$) in the win context, $p = 0.016$.

By analysing the social comparison effect on the P300 in the self-loss context, we found a significant social comparison effect, $F(2, 78) = 30.36$, $p < 0.001$, $\eta_p^2 = 0.44$. The simple effect analysis showed

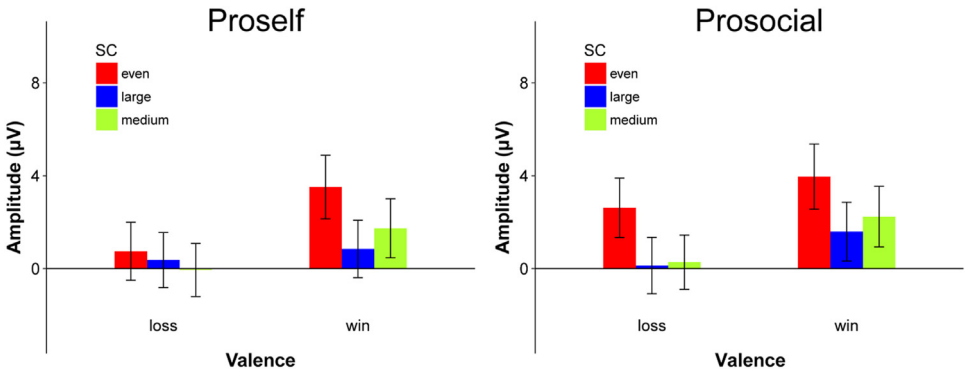

Fig. 5. Social comparison effect on peak FRN for prosocial and proself individuals in win and loss conditions.

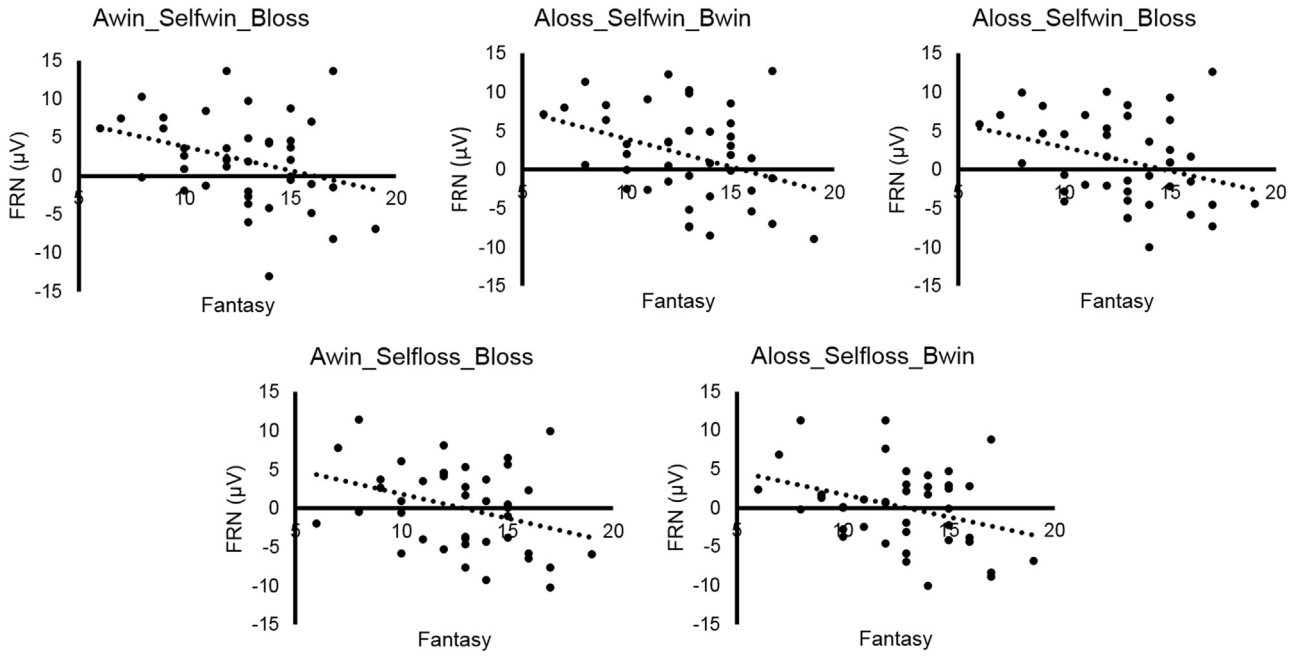

Fig. 6. Scatter plot depicting the correlations between fantasy scores for IRI and FRN amplitudes under the following conditions: Awin_Selfwin_Bloss, Aloss_Selfwin_Bwin, Aloss_Selfwin_Bloss, Awin_Selfloss_Bloss, and Aloss_Selfloss_Bwin. A, socially disliking player; B, socially liking player.

that the even condition (M = 9.21 μV, SE = 1.03) showed a greater P300 than both the medium (M = 7.02 μV, SE = 0.87), $p < 0.001$ and large difference (M = 6.47 μV, SE = 0.88) conditions, $p < 0.001$. We did not find a significant SVO group effect or two-way interaction between SVO group and social comparison, $ps > 0.45$.

The specific interest analysis result of the social liking effect under the same social comparison level (medium condition) for the two groups indicated an interaction effect between social liking and SVO in the self-win context, $F(1, 39) = 6.43$, $p < 0.05$, $\eta_p^2 = 0.14$, but not in the self-loss context. That is, a win with the socially liking player B (M = 9.91 μV, SE = 1.33) elicited a larger P300 than a win with the socially disliking player A (M = 9.11 μV, SE = 1.36) for prosocials but not for proselfs.

The correlation between the P300 and SVO score was not significant either for all of the conditions together or for each condition separately, $Ps > 0.078$ (uncorrected p value for multipole correlations). No significant correlation was found between the IRI subscales and the P300 amplitude.

4. Discussion

In the present study, we examined the relationship between SVO and social comparison in terms of outcome evaluation. With regard to the behavioural results, surprisingly, we did not find a modulation effect of SVO, although there was a social comparison effect. Such a result is inconsistent with the existing hypothesis or inference of the SVO effect on social comparison (Van Lange, 1999). This may be because the rating was insensitive to different conditions, as we measured behavioural ratings only once at the end of experiment instead of rating trial by trial. Another possible reason is that only one's own gains or losses impacted final payoffs in our experimental setup, which may also have led to the lack of a differential effect across conditions. While A (socially disliking player) did exhibit a main effect, we did not find the main effect of B's (socially liking player) gambling results. This result is likely to be due to the rating priority of the socially disliking player's gambling results. From the evolutionary view, the human attention system will give priority to threat information to protect themselves from potential harm (Koster et al., 2004; Öhman et al., 2001). Considering the survival-related intrinsic bias to negative information, the socially disliking player may represent a threat signal to the self's benefit during the interaction in the trust game, which would then lead to the differential affective ratings of A's gambling results.

Regarding the EEG results, we found an interaction between SVO and social comparison on FRN. Furthermore, we found that SVO influenced interpersonal relationship responses, which were reflected in the full condition analysis of FRN and the specific analyses of the P300 for the medium comparison conditions. Consistent with the findings of a previous study, we observed a social comparison effect on the FRN and an interpersonal relationship effect on the P300 (Wu et al., 2012).

4.1. SVO modulates the social comparison effect on FRN

Using a social comparison analysis, we found a more negative-going FRN to loss outcomes than to gain outcomes; this finding was also identified in earlier studies (Gehring and Willoughby, 2002; Hajcak et al., 2006; Miltner et al., 1997; Yeung and Sanfey, 2004). Consistent with the results of Luo et al. (2015), a significant hierarchical social comparison effect was found, with the most negative result being obtained for the “large” difference condition and the least negative result being obtained for the “even” condition. Notably, there was a significant three-way interaction between SVO, valence and social comparison such that when the participants won the game, both groups showed a social comparison preference. However, when the participants lost, only prosocials exhibited a social comparison effect; proselfs no longer expressed such a preference, which indicated that the modulation effect of SVO on FRN was context-based. This point is very important because we are concerned primarily with the social comparison in proselfs; however, it seems that only prosocials were concerned with others’ outcomes, even when they lost the game. Thus, we infer that when the subjects won the game, both proselfs and prosocials were motivated to concern themselves with others’ gambling outcomes. However, when the subjects lost, proselfs, whose motivation was to maximize self-benefit, were no longer concerned about the outcomes of others, whereas prosocials still paid attention to others’ outcomes because of their intrinsic tendency to care about joint outcome (Bogaert et al., 2008; Van Lange, 1999). Therefore, the FRN differential effect reflected an evaluation of the motivational significance of feedback stimuli in different social comparison contexts (Gehring and

Willoughby, 2002; Yeung et al., 2005). Another possible interpretation is that prosocials may be more sensitive to social norms (Eek and Gärling, 2008; Lange and Vugt, 1998; Van Lange et al., 2007) such that they prefer to be consistent with others in social interactions. An earlier study showed that expectancy modulates FRN; that is, unexpected results are associated with more negative FRN (Cao et al., 2015). Thus, regardless of their own gambling result, the motivation to maintain consistency with the majority may lead to a differential effect such that the least pronounced FRN occurs when all players obtain the same result, whereas the greatest FRN occurs when encountering the largest difference.

4.2. SVO does not modulate the social comparison effect on the P300

We observed a stable social comparison effect on the P300 in which the even results evoked the largest P300; this is in line with the findings of Luo et al. (2015). A more positive P300 was found in response to a positive outcome compared with the response to a negative outcome, which is also consistent with previous research (Peterburs et al., 2013; Yeung et al., 2005). The full condition analysis showed that self-win elicited a more positive amplitude than self-loss, whereas regardless of interpersonal preferences, others' loss induced a larger P300 than others' win. According to the motivational/emotional salience hypothesis (Hajcak et al., 2005; Leng and Zhou, 2010; Linden, 2005; Nieuwenhuis et al., 2005), self-win is a positive outcome and attracts greater attention, and others' loss is a better result in comparison with others' win in a social comparison condition and thus also attracts more attention.

In contrast to the effects on FRN, no SVO or comparison interaction effects were found on the P300. Considering that an SVO modulation effect occurs on the FRN but not the P300, we infer that the SVO effect on social comparison may manifest in the semi-automatic phase but not in the late attention or outcome evaluation stages. Of note, an SVO modulation effect was not observed in the findings of Wang et al. (2017), who used a social dilemma game (i.e., chicken game). The attentional relevant outcomes in this stage may be similar for prosocials and proselfs. However, another recent study showed an SVO modulatory effect on the FRN, P300 and LPC (late positive component) because these components were sensitive to others' gains and losses in the prosocial group only and not in the proself group (Hu et al., 2017). We believe that the more complex manipulation (e.g., combined with interpersonal relationship) in the current study may have led to the null SVO effect on social comparison.

4.3. SVO modulates the social liking effect on both the FRN and P300

We also found a modulation effect of SVO on FRN in interpersonal responses. Specifically, in a self-win condition, both groups showed a more negative-going FRN to A-loss in comparison with A-win. However, in a self-loss condition, prosocials exhibited a larger FRN to A-win vs. A-loss, and proselfs' FRN was not affected by A's outcome. Based on previous studies (Yang Wang et al., 2014; Yiwen Wang et al., 2014 Wei et al., 2015), we can cautiously conclude that when the participants win, both groups show concern for the socially disliking player's gambling result. However, when they lose, prosocials express less empathy or even more schadenfreude towards the socially disliking player's loss. One explanation for this result may be that prosocial motivation enabled the participants to interpret the loss outcome as a reasonable punishment for their previous violation of fairness and the reciprocity norm in social interaction. In this case, proselfs are no longer concerned with the socially disliking player's win or loss, which is consistent with their independent proself motivation and with previous findings showing that the FRN amplitude can be influenced by self-processing (Kang et al., 2010; Zhu et al., 2015, 2017).

Furthermore, in a later stage, the P300 showed an interaction between SVO and the interpersonal relationship effects such that prosocials exhibited a social liking effect only when they won and not when they lost. Proselfs showed no social liking effect on the P300 amplitude in both the self-win and self-loss contexts. This result is partly consistent with a recent study that suggested that prosocials are sensitive to the others' outcomes only under the self-gain condition in the P300 stage (Hu et al., 2017). Our results provide further evidence that prosocials gave attention to the socially liking and socially disliking players' outcomes only when they won. Following existing explanations, we believe that in the P300 stage, people pay more attention to positive outcomes, which leads to more positive amplitudes for better outcomes and attention allocation to others' outcomes (Hu et al., 2017). Importantly, in our task, self-affect is mainly based on the self's gains/losses; the different effects under the self-win vs. self-loss contexts may also reflect the self-emotion effect on attention, as P300-related attention bias could be modulated by affective context (Smith et al., 2006). Social psychology studies have indicated that proselfs think and act in an individual manner (De Cremer and Van Lange, 2001); therefore, it is reasonable that they will pay more attention to their own outcomes regardless of the social liking effect.

These findings together indicate that the interaction effect between SVO and the interpersonal relationship in an outcome evaluation is processing stage- and context-based.

4.4. Expression of SVO starts from the semi-automatic stage

It has been suggested that there are two processes in outcome evaluation: an early (semi-automatic) process for motivational significance reflected by FRN and a later, top-down (intentional) process, which is influenced by the attentional resource assignment indexed by P300 (Goyer et al., 2008; Leng and Zhou, 2010, 2014; Wu and Zhou, 2009). Regarding SVO modulating the FRN but not the P300 for the social comparison effect, this may be because social comparison-seeking among people with distinct social orientations is driven more by intuition than by deliberate reflection (Haruno and Frith, 2010; Haruno et al., 2014). It has been demonstrated that prosocials spontaneously perform prosocial behaviours, whereas proselfs spontaneously perform selfish behaviours. In addition, proselfs require more reaction time when making a prosocial decision, conforming with more activity in the anterior cingulate cortex (ACC), which is related to cognitive control (Cornelissen et al., 2011; Kuss et al., 2015; Mischkowski and Glöckner, 2016; Yamagishi et al., 2017). Based on these findings, we infer that the modulation effect of SVO on social comparison preference is semi-automatic, as reflected by the FRN responses in the early stage but not the P300 in the later stage. However, SVO modulation of the social liking effect starts with the semi-automatic stage and shifts to the later, more motivational attention stage. As a measure of empathy traits to both the positive and negative outcomes of others, the fantasy score was correlated with the FRN but not the P300. This finding is partly consistent with the concept that the FRN reflects the valence of outcome and corresponds with existing studies finding that the FRN can index empathic response to others' outcomes (Cui et al., 2016; Ma et al., 2011a, 2011b; Yang Wang et al., 2014; Yiwen Wang et al., 2014).

Notably, the payoff of the subject was positively related to the gains or losses of one's self only in our experimental setting, which may facilitate the self-interest consideration and the implicit social comparison effect. Therefore, our results may not be generalized to other situations that include real money gains or losses in explicit social comparison. Following this manipulation, another limitation is that our ERP results were not supported by our behavioural results, which showed no SVO effect on the affective ratings. We believe that a replicated and concise design to examine real affective responses in multiple agent games is necessary.

In summary, the present study finds that SVO, an important personality trait, influences context-based social comparison preference in outcome evaluation, as mainly indexed by FRN. Specifically, in a win condition, both groups showed a social comparison effect in which the

most negative-going amplitude was found in the “large” difference condition. In a loss condition, prosocials still showed a social comparison preference in which the “large” difference condition elicited the most negative-going FRN, whereas proselfs were no longer affected by comparison information. Regarding the P300, we found a social comparison effect, and a generally larger P300 was related to better outcomes, although we did not find a modulation effect of SVO. These findings may provide additional insights into the neural mechanisms of social comparison in individuals with different SVOs and offer a new perspective for understanding the prosocial motivation in people with different SVOs.

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Conflict of interest

The authors declare no conflicts of interest.

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