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ORIGINAL RESEARCH

# The Effect of Positive Emotions on Prosocial Behavior During Ego-Depletion: Evidence From fNIRS

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**Purpose:** The psychological and neural mechanisms between relieving ego depletion and prosocial behavior have yet to be clearly explored. To address this, we combined behavioral experiments and fNIRS to explore how positive emotions promote prosocial tendencies under ego depletion.

**Methods:** In Experiment 1, 119 college participants ($M_{age}$=19.7±1.46) completed a dual-task self-control paradigm, confirming that ego depletion negatively impacts prosocial behavior. Experiment 2 involved 48 college participants ($M_{age}$=20.26±2.06) and combined behavioral tasks with functional near-infrared spectroscopy (fNIRS) to examine how positive emotions mitigate ego depletion and enhance prosocial behavior.

**Results:** Experiment 1 showed that participants in the low ego depletion group had a significantly higher bonus allocation amount than the high ego depletion group (t (62) =−2.24, p < 0.05). Experiment 2 showed that after both groups completed the ego depletion task, participants in the positive emotion group allocated significantly higher bonus amounts than those in the neutral emotion group (t (46) =2.06, p <0.05). And the $\beta$ values for channel ch15 (right dorsolateral superior frontal gyrus) and channel ch20 (right medial superior frontal gyrus) were significantly higher in the positive emotion group compared to the neutral emotion group ($p < 0.05$). The $\beta$ value for channel ch7 (left medial superior frontal gyrus) was also higher in the positive emotion group, approaching statistical significance ($p = 0.068$).

**Conclusion:** Those findings revealed that high ego depletion reduced prosocial behavior. Additionally, positive emotions alleviated ego depletion and promoted prosocial behavior by activating the medial superior frontal gyrus (SFGmed) and right dorsolateral superior frontal gyrus (SFGdor) negatively.

**Keywords:** prosocial behavior, ego depletion, self-control, positive emotions, medial superior frontal gyrus, right dorsolateral superior frontal gyrus

## Introduction

Prosocial behavior—voluntary actions aimed at benefiting others—serves as a cornerstone of societal functioning and individual psychological well-being.[1,2] Empirical evidence confirms that ego depletion (the transient exhaustion of self-control resources following cognitive effort reduces prosociality, yet the mechanisms underlying this impairment remain poorly specified.[3] Conversely, although positive emotions are known to enhance prosocial tendencies, their capacity to mitigate depletion-induced prosocial deficits constitutes an unresolved theoretical paradox. The current study aim to addresses this dual ambiguity by integrating behavioral paradigms with fNIRS to achieve three objectives: (a) establish the causal pathway through which ego depletion diminishes prosocial behavior, (b) identify the moderating role of positive emotions in replenishing self-regulatory resources, and (c) examining the brain activity associated with positive emotions promoting prosocial decision-making under ego depletion.



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## Ego Depletion and Prosocial Behavior

Prosocial decision-making inherently requires resolving the tension between immediate self-interest and delayed collective benefits—a regulatory challenge demanding self-control resources.[4] According to the self-control resource model, individuals consume a certain amount of psychological resources during self-control, and these resources are limited.[5] After exerting self-control in the previous task, individuals' resources diminish. The residual resources, when scarce, could lead to self-control failure in the subsequent task (ie ego-depletion).[6] Research has shown that ego depletion results in increased negative emotions,[7] decreased attention control,[8] and diminished prosocial behavior.[2,9,10]

## The Relieving Effects of Positive Emotions and Its Neural Mechanisms

Can the ego depletion after-effect be relieved? Studies have found that the ego depletion after-effect can be modulated by evoking high self-efficacy,[11] self-affirmation,[12] and triggering guilt emotions.[13] Notably, there is no unified view on whether positive emotions have a relieving effect on the ego depletion after-effect.[14] Some studies have found that inducing positive emotions in participants attenuated the negative after-effect of ego depletion.[15–17] Positive emotions can prompt individuals to pay more attention to human kindness and mutual aid, which in turn improves individuals' prosocial behavior.[3,18] The Broaden and Build theory of positive emotions suggests that positive emotions are effective in expanding individuals' scope of cognition and action,[19,20] promoting more decision-making for the benefit of others and society. In addition, in a positive emotional state, individuals may be more likely to think positively, increasing the likelihood of carrying out prosocial behavior.[3,21] However, Bray et al[22] did not find, and study even found a positive effect of negative emotions on cognitive control.[23] This inconsistency underscores the need to investigate not just behavioral outcomes, but the n brain regions governing emotion-depletion interactions.

Neuroimaging studies provide an essential frame of reference for understanding how ego depletion influences prosocial behavior. Previous studies have shown that the same brain regions are activated in when individuals practice self-control, experience positive emotions, and conduct prosocial behavior. Self-control mainly involves brain areas such as dorsolateral prefrontal cortex (DLPFC) and ventromedial prefrontal cortex(VMPFC).[24–26] DLPFC participates in self-control processing in cross-term decision-making,[27] and VMPFC contributes to long-term goal implementation and is negatively correlated with characteristic self-control.[28] These brain areas are structurally separated and functionally related.[24,26,29] Similarly, ego depletion induces activity in a range of components of the PFC, such as the DLPFC, ventral lateral prefrontal cortex (VLPFC), and medial frontal cortex (MFC).[30–32]

The generation of prosocial behavior requires the integration of different sources of information, weighing choices, and decision-making so that it may involve the activities of the PFC. It has been found that regions such as DLPFC, lateral prefrontal cortex (LPFC) may be involved in self-control activities during the decision-making phase of prosocial behavior.[33,34] The production of prosocial behavior is also associated with enhanced activation of the medial prefrontal cortex (MPFC) and VMPFC.[35,36] Regarding the brain mechanisms underlying the cognitive effects of positive emotions, Herrington et al,'s[37] Emotional Stroop Experiment found that positive pleasant words activated the DLPFC bilaterally, with the left side being activated more. An fMRI study found that brain regions such as the medial orbitofrontal cortex (MOFC) and PFC have a close relationship with positive emotions and that positive emotion pictures activate the MOFC, middle frontal gyrus (MFG), and other brain regions.[38] Similarly, Gray et al's[39] fMRI study found that positive emotions selectively affect neural activity in the LPFC related to cognition by video evoking different emotions in a working memory task. It is evident that positive emotions may activate activity in relevant brain regions of the PFC, which decreases the potential for reduced prosocial behavior of individuals in ego-depleted states.

With the brain imaging technological maturity of fNIRS, continuous changes in oxy-hemoglobin and deoxy-hemoglobin can be obtained during brain activity, which allows for a finer exploration of the brain mechanisms that enhance and relieve the after-effects of ego depletion. fNIRS technology is widely used in the field of cognitive control research. It has high temporal and spatial resolution, making it particularly suitable for examining differences in activation timing and intensity in the prefrontal cortex during task performance.[40] fNIRS optimally detects sustained prefrontal hemodynamic changes (≥5 seconds in duration), which are characteristic of emotion regulation processes.[41] Additionally, compared to fMRI, fNIRS is less sensitive to motion and noise.[42]

## Present Study

Emerging evidence indicates that positive emotions might mitigate the effects of ego depletion, but three critical ambiguities limit theoretical progress. First, existing research findings exhibit significant inconsistencies. Second, the neural mechanisms linking positive emotions, ego depletion recovery, and prosocial behavior remain unexplored. Third, although fMRI studies have associated prefrontal regions (eg, DLPFC and VMPFC) with self-control and prosocial behavior, no study has used time-sensitive fNIRS to capture dynamic prefrontal hemodynamics during ego depletion and emotion regulation. The current study advances this discussion through two methodologically integrated experiments. Experiment 1 used a self-control dual-task paradigm and examined the level of prosocial behavior through a dictator task to verify whether ego depletion reduced participants' level of prosocial behavior. Experiment 2 continued with the same ego-depletion task, induced positive emotions in the form of a video, and used the dictator task to measure the level of prosocial behavior, while monitoring the changes in oxyhemoglobin concentration in the prefrontal area, thus exploring the relieving effect of positive emotions on the after-effects of ego depletion as well as changes in prefrontal cortex blood oxygenation concentration during the performance of the task. In the present study, we hypothesized that prosocial behavior would be significantly less in the ego depletion state (**Hypothesis 1**); there was a significant difference between the prosocial behavior of the positive emotions and neutral emotions groups in the ego depletion, with the prosocial behavior was significantly more common in the positive emotion group than in the neutral emotion group (**Hypothesis 2**); and that the brain of the positive emotions group was more relaxed and had lower levels of brain activation in comparison to that of the neutral emotions group (**Hypothesis 3**).

# Experiment 1

## Methods

### Participants

119 Chinese college students participated in this experiment voluntarily, 82 girls (68.91%). Most participants were from the College of Education, where female students outnumber male students. There were 61 in the high ego depletion group, 18 boys and 43 girls, with an average age of 19.8; 58 students in the low ego depletion group, 19 boys and 39 girls, with an average age of 19.6. All participants' native language is Chinese, who can understand the experimental instructions and are not color blind or color weak. All participants voluntarily signed an informed consent form related to this study. Our study was approved by the Institutional Review Board of the School of Education, Guangzhou University.

### Experimental Design

Experiment 1 utilized a one-factor, between-subjects experimental design. The study adopts a univariate two-level design, with high and low ego depletion as the independent variables and prosocial behavior level as the dependent variable. Determine the level of prosocial behavior by measuring the allocation amount in the dictator game.

### Evaluation Tools

#### Brief Self-Control Scale (BSCS)

The scale was used to evaluate the trait self-control level of individuals.[43] The scale consists of 13 questions, with a Likert 5-point scoring system. From 1 to 5, it represents a transition from "completely inconsistent" to "completely consistent". The higher the total score, the higher the individual's level of trait self-control. The scale has good credibility in this experiment, and Cronbach α is 0. 79 in the present study.

#### Prosocial Tendencies Measure (PTM)

The scale mainly measures the prosocial tendencies of individuals towards friends, relatives and strangers.[44] The scale uses Likert's 5-point scoring system, with values ranging from 1 to 5 representing a transition from "completely non-compliant" to "completely compliant." The higher the average score, the higher the prosocial tendency. The scale has reasonable confidence in this experiment, and Cronbach α is 0.87 in the present study.

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### Positive and Negative Affect Schedule (PANAS)

The scale mainly evaluates the current emotional state of the participants during the experiment. The scale includes five adjectives for positive emotions and five negative emotions.[45] Positive emotional words are happy, joyful, excited, delighted, and cheerful; negative emotional words include anger, fear, sadness, nervousness, and upset. This scale uses Likert 5-point scoring (1 point indicates none at all, 5 points indicates very strong). In the present study, Cronbach α in the total table is 0.80, and Cronbach α in the positive and negative mood scales, respectively, is 0.90 and 0.72.

## Experimental Tasks

### Cognitive Ego Depletion Task

Researchers often use cognitive tasks to investigate ego depletion, with the Stroop color-word naming task being the most classic experimental option.[46] This task has been demonstrated to require participants' effortful control to complete.[46–48] And the experimental program is programmed using E-prime 2.0. The high ego-depletion condition is that the high character meaning is inconsistent with the color, of which 140 are inconsistent trials and 20 are consistent. The low ego-depletion condition is that the high character meaning is consistent with color, including 140 consistent trials and 20 inconsistent trials. The meaning includes words of red, green, and blue, and the colors also include red, green, and blue. Participants need to suppress the automatic response to the meaning of the words. They need to respond to the color of the word as soon as possible under the condition of ensuring the correct rate. The three colors of red, green, and blue correspond to the letters "B", "N", and "M" on the keyboard, respectively. The experiment includes the practice stage and the formal experimental stage. The formal experimental process was the fixation point 250ms, followed by 2000ms of semantic-color stimulus words, followed by feedback on whether the stimulation interface was correct (500ms), followed by the next test. If you press correctly in time, you will be prompted with green correct feedback. If you miss the response time of 2000ms, you will be prompted with no response. If you press incorrectly, you will be prompted with red error feedback. The process is shown in Figure 1.

### Dictator Game

Prosocial behavior adopts the direct selection dictator experimental game, which is a classic paradigm for measuring prosocial behavior.[4] The Dictator Game provides a direct and relatively pure assessment of altruistic and self-interested behaviors, and is thus sometimes referred to as a measure of unconditional kindness.[49] Although the game is abstract, the decision to share resources in the game reflects real-world prosocial decisions, such as charitable donations, cooperation, and fairness in social interactions.[4,9] In order to prevent the participants from doubting the authenticity of the experiment, the dictator game was appropriately adapted. The paradigm includes the distributors and the recipients, and the role of the task was determined by drawing lots. The participants were informed that the probability of winning the distributors or the recipients was 50%, so both the distributors and the recipients were the participants participating in the experiment.

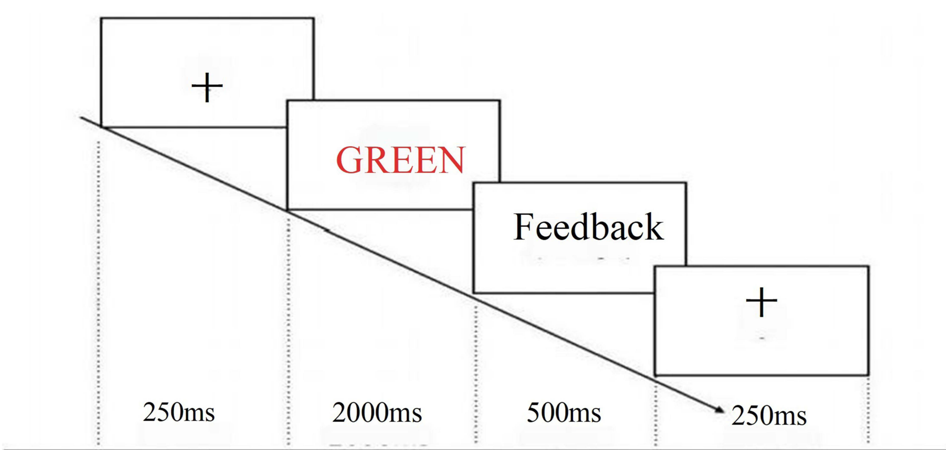


**Figure 1** Stroop Color Word Naming Task Program Diagram.

The winner had the right to distribute additional bonuses. The primary test will match the distributors and the recipients one by one. The recipients needed to make an additional 10 minutes of simple computer critical reaction, while the bonus came from the bonus assigned by the matching distributors, and they could only accept it and had no right to refuse. Each participant was completed in a separate space and drew lots after understanding the experimental task. At the end of the draw, the drawn roles were displayed (each participant showed the distributors). The distributors needed to allocate an additional bonus of 15 yuan(RMB). A total of 20 identical 15 yuan(RMB) allocation tasks were carried out. The final average distribution amount to the other party is used as an indicator of prosocial behavior. The higher the average distribution amount, the higher the prosocial behavior. The basic fees of the participants and the additional bonuses in the direct dictator game were paid to the participants in cash after the end of the experiment. The process is shown in Figure 2.

### Procedure

Participants arrived at a separate behavioral laboratory and first signed an informed consent form for the experiment. After participants understood the experimental instructions, they began completing the ego depletion task, followed by completing the validity check questionnaire on ego depletion and the PANAS emotion scale. Then, the Direct Dictator game was played, and at the end of it, the experimental purpose measures, the Self-Control Scale, and the Prosocial Tendencies Scale were completed. After completing the questionnaires, participants were informed of the additional bonuses and filled out the labor payment bill. Using SPSS 23.0 for descriptive statistical analysis and *t*-test of experimental data.

## Results

### Ego Depletion Task Control Test

An Independent sample *t*-test was carried out, as shown in Supplementary Table 1, and the main effect of the participants' effort level, fatigue level, and energy loss was significant ($t$ (62) ≥2.82, $p$ < 0.01). The results show that the participants under high ego-depletion conditions needed more capacity depletion and prove the effectiveness of ego-depletion manipulation.

### Bonus Allocation Amount in Different Ego Depletion Groups

In order to control the influence of trait self-control and prosocial behavior tendency on the experimental results. An Independent sample *t*-test was conducted on the trait self-control and prosocial behavior tendency of the participants in the high and low depletion groups. The results showed that there was no significant difference in trait self-control ($t$ (62)

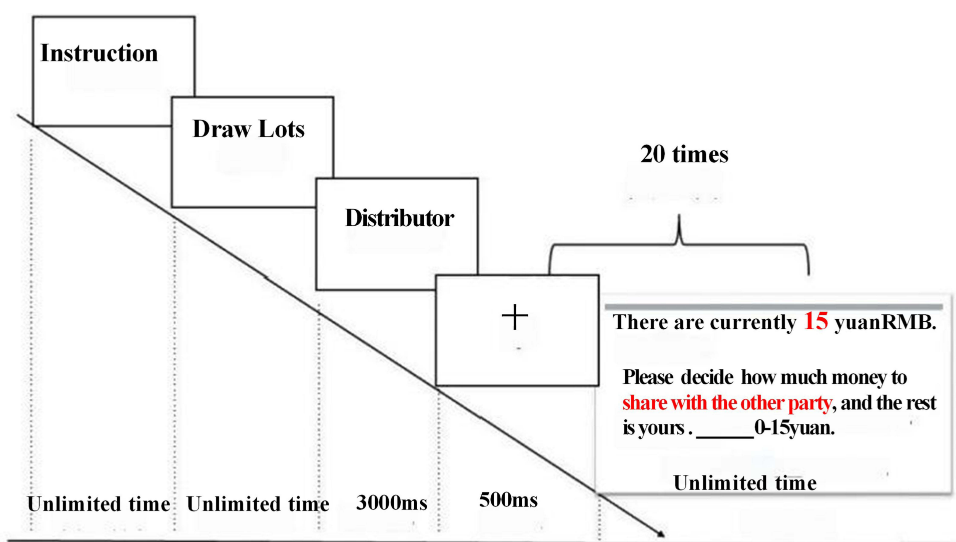


**Figure 2** Direct Dictator Experimental Task Program Diagram.

=−0.86, $p > 0.05$), positive emotions ($t$ (62) =−1.92, $p > 0.05$), negative emotions ($t$ (62) =- 0.96, $p > 0.05$) and prosocial behavior tendency ($t$ (62) =−0.25, $p > 0.05$) of the participants in the two groups. Therefore, the influence of trait self-control, current emotional state, and prosocial behavior tendency on the experimental results can be excluded.

In addition, there is a significant difference between the high and low ego-depletion groups in the level of prosocial behavior (allocation amount) ($t$ (62) =−2.24, $p < 0.05$, $d$=0.56), and the participants' prosocial behavior with low ego-depletion ($M_{\text{pro}}$=6.55, $SD_{\text{pro}}$=1.50) is significantly higher than with high ego depletion ($M_{\text{pro}}$=5.61, $SD_{\text{pro}}$=1.81).

## Discussion

In this study, the level of prosocial behavior of the high ego-depletion group was significantly lower than that of the low one, which is consistent with Hypothesis 1 of this experiment. Participants in the high ego-depletion group were required to inhibit dominant responses to cognitive processing of font color and to respond to non-dominant cognitive processing of font word meanings during the completion of the Stroop task, which in turn led to a depletion of self-control resources in the cognitive domain. As a result they showed lower bonus allocation, ie, lower prosocial behavior, in the subsequent bonus allocation for the Direct Dictator task.

Experiment 1 demonstrated that ego depletion reduces individuals' level of prosocial behavior. So, do positive emotions provide a relieving effect on the ego depletion after-effect? To answer that question, based on Experiment 1, we designed Experiment 2 to examine the effects of positive and neutral emotions in the ego-depleted state on the allocation of bonuses in the direct dictator experimental task. In addition, Experiment 2 used fNIRS to monitor changes in blood oxygen concentration in the prefrontal cortex of the brain while participants were completing the task, in order to reveal the brain mechanisms underlying the relieving effects of positive emotions.

# Experiment 2

## Method

### Participants

A total of 48 Chinese college student participants were tested in the experiment. The number of participants watching positive videos was 24, including six boys and 18 girls, with an average age of 21.17. The number of participants watching neutral videos is 24, including five boys and 19 girls, with an average age of 19.30. All participants' native language is Chinese, who can understand the experimental instructions and are not color blind or color weak. All participants voluntarily signed an informed consent form related to this study. Our study was approved by the Institutional Review Board of the School of Education, Guangzhou University.

### Experimental Design

A univariate two-level experimental design was used, with the independent variable being the type of emotional arousal (positive and neutral emotions), the dependent variables being the fNIRS metrics under arousal of positive or neutral emotions, and the metrics of prosocial behavior and f NIRS under high ego-depletion. fNIRS metrics: Changes in the concentration of oxy-hemoglobin in 22 channels in the prefrontal regions of the brain are monitored and are expressed as a $\beta$-value.

### Experimental Measurement

As in Experiment 1, participants in Experiment 2 were required to complete the Trait Self-Control Scale, the PANAS Scale, and the Prosocial Behavioral Tendencies Scale, with respective reliabilities of 0.82, 0.72, 0.90.

### Experimental Tasks

#### Cognitive Ego Depletion Task and Dictator Game

As in Experiment 1, all participants were required to complete.

#### Emotion Evocative Task

Editing humorous video clips as a video evoked positive emotions with low approach motivation, the video duration is 8 minutes. The laboratory culture video of microorganisms was selected as a neutral video, and the duration of the video was 8 minutes. Prior to the start of the formal experiment, we recruited 49 undergraduates to score the comprehensibility, hilarity, and emotional arousal of the two videos. Repeated-measures ANOVA results showed that there is no significant difference between the two videos in understanding ($F(1,48)$ =0.56, $p > 0.05$) and negative emotion arousal ($F(1,48)$ =0.419, $p > 0.05$),while significant difference in video humor ($F(1, 48) = 88.58$, $p < 0.001$, $\eta^2$=0.65) and positive emotions arousal ($F(1, 48) = 24.61$, $p < 0.001$, $\eta^2$=0.34), as shown in Supplementary Table 2. Therefore, the materials of positive emotional videos and neutral emotional videos meet the requirements of this experiment.

### fNIRS Channel Layout

This experiment used the LIGHTNIRS portable functional near-infrared spectrometer produced by Shimadzu Company, to monitor the change of hemoglobin concentration in the prefrontal cortex through a three-wavelength (780±5nm, 805 ±5nm, 380±5nm) near-infrared semiconductor laser, with a sampling rate of 8.33 hz. The experimental program is programmed with E-prime 3.0.

This experiment mainly detects the prefrontal lobe area, which consists of a 5*3 layout consisting of 8 transmitters and 7 receivers, 22 channels composed of 3 cm probe spacing, mainly covering the prefrontal lobe area, with a sampling rate of 8.33Hz. According to the international 10–20 EEG system placement probe, the middle line of the hat coincides with the CA-OZ line, mainly covering the prefrontal area. Previous studies have shown that the prefrontal cortex is an important brain region involved in cognitive control, emotion regulation, and pro-social decision-making.[24–26,37–39]The probe layout and channel position are shown in Figure 3. In the first picture, red is the light source, blue is the detector, and the number between the two For the channel.

After fNIRS data collection, 3D positioning (FASTRAK, Polhemus, Colchester, VT, USA) was used to calibrate the position of each probe, and four reference points (NZ, CZ, AL and AR) were respectively nasal concave, central center line, Left mastoid process of temporal bone, and right mastoid process of temporal bone. Through probability registration correspondence, Montreal Neurological Institute (MNI) and Automatic Anatomical Labeling (AAL) spatial coordinates was obtained, as shown in Supplementary Table 3. The reported channel location was based on the maximum coverage of each channel of AAL.

### Procedure

All the participants were completed independently in a separate near-infrared laboratory. The first step was recruiting participants. The process is the same as Experiment 1. The second step was randomly assigned to a positive emotional group or a neutral emotional group. Same as Experiment 1. The third step was to wear the instrument and adjust the light signal. The participant sat in a comfortable chair. The experimenter helped the participant wear a hat, open his hair, and plug in 15 probes of the near-infrared instrument. The fourth step was the ego-depletion task. All participants must complete the high-level ego depletion task, then complete the Ego Depletion Validity Testing Questionnaire and the PANAS Emotions Scale. The fifth step was emotion-induced. The participants of the positive emotion group watched an 8-minute funny video, and the participants of the neutral emotion group watched an 8-minute laboratory video of microbial culture. After watching the video, the PANAS scale was completed. In the sixth step, participants were required to complete the Direct Dictator Experiment task. When the participants pressed the key to start the draw, the recording of their fNIRS signal was started. This experiment was completed by turning off the fNIRS apparatus. Finally, participants needed to complete the corresponding questions (same as in Experiment 1). During the experiment, the experimenter paid constant attention to the status of the participants; if the participants reported discomfort, such as dizziness or headache, we would immediately turn off the fNIRS apparatus and stop the experiment.

## Data Analysis

### fNIRS Data Pre-Processing

Collecting signaling changes in hemoglobin concentration in the participants' prefrontal cortex of the brain. Based on previous studies, oxy- hemoglobin has better signal quality than deoxy-hemoglobin and is more sensitive to changes in cerebral blood flow.[50] Therefore, only data on the change in concentration of oxy-hemoglobin were analyzed in this study. The convert program package of NIRS_SPM software for Matlab R2013 version was used to convert the optical

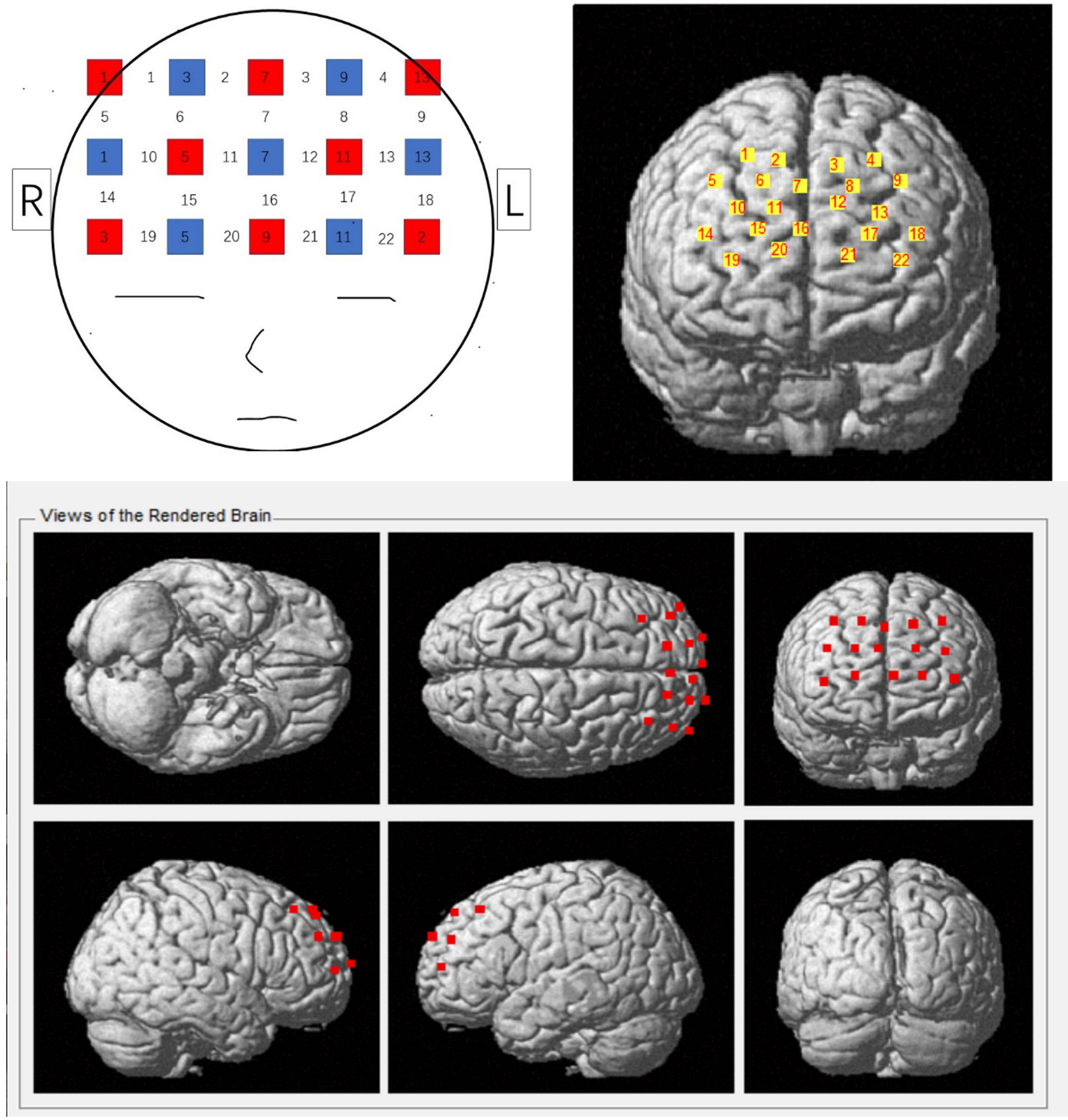


**Figure 3** fNIRS channel and probe layout.
**Note**: The red color represents the emitter of the NIR light and the blue color represents the detector of the NIR light.

density change signal into the oxy- and deoxy-hemoglobin concentration change signal. Low-pass filtering according to the hemodynamic response function to exclude the effects of machine noise, head movement, heartbeat, breathing, and other noise. High-pass filtering using the Wavelet-MDL method eliminates the effects of global drift due to participants' head movements, physiological changes, or instrument instability, removes global trends, and improves signal-to-noise ratio.[51] Separate first-order analyses of oxy-hemoglobin signals during different emotion-inducing tasks. Then, the actual collected data were fitted to a general linear model (GLM) with theoretically generated reference waves of brain activity patterns to obtain the $\beta$ values of the prefrontal cortex for each participant during different emotion-inducing tasks. The $\beta$ value is the coefficient corresponding to the task-related predictors (which may include task time series and other covariates) generated by the experimental paradigm, estimated through linear regression. The magnitude of the $\beta$ value indicates the contribution of the corresponding condition to signal changes, reflecting the degree of brain region activation.Each channel corresponds to a different brain region, so each channel undergoes independent GLM analysis to obtain its respective $\beta$ value, followed by statistical testing to determine its significance.The GLM formula is: $Y = X\beta + \epsilon$, where Y represents the oxygenated hemoglobin concentration signal (HbO), X represents the predictors, $\beta$ represents the coefficients to be estimated, and $\epsilon$ represents the residuals.

### Statistics

The independent sample *t*-test of SPSS 23.0 was used to analyze the difference between the bonus distribution between the positive emotional awakening group and the neutral emotional awakening group. Later, a single sample *t*-test for the $\beta$ values of the two groups and also conduct an independent sample *t*-test for the $\beta$ values of the two groups. In the same way, analyze the changes in the concentration of prefrontal oxygenated hemoglobin in the positive emotional awakening group and the neutral emotional awakening group during the bonus distribution task.

## Results

### Emotional Arousal Operation Validity Test

We first examined the differences in emotion levels between participants in the positive and neutral emotion groups under ego depletion before watching the video. Independent samples t-tests showed no differences in total positive emotion scores ($t(46)=0.93$, $p>0.05$) and total negative emotion scores ($t(46)=0.86$, $p>0.05$) between the two groups. Next, after watching the video, participants in the positive emotion video group scored significantly higher total positive emotion scores than those in the neutral emotion video group ($t(46)=4.08$, $p<0.001$, $d=1.17$), but there was no difference in total negative emotion scores between the two groups ($t(46)=-0.16$, $p>0.05$). Results are shown in the Supplementary Table 4. The results show that the emotional arousal of positive emotion video was effective.

### The Impact of Positive Emotions on Prosocial Behavior

We first tested for differences in trait self-control levels and prosocial behavioral tendencies between participants in the positive and neutral emotion groups under ego depletion. Independent samples t-tests revealed no differences in self-control scores ($t(46)=0.93$, $p>0.05$) and prosocial behavioral scores ($t(46)=0.86$, $p>0.05$) between the two groups. Therefore, the influence of trait self-control and prosocial behavior tendency on the experimental results can be excluded. Secondly, the emotional arousal conditions (positive and neutral) are taken as the independent variables, and the participants' prosocial behavior (bonus allocation amount) is used as the dependent variable for an independent sample *t*-test. It was shown (Figure 4) that the level of prosocial behavior in the positive emotional group is significantly higher

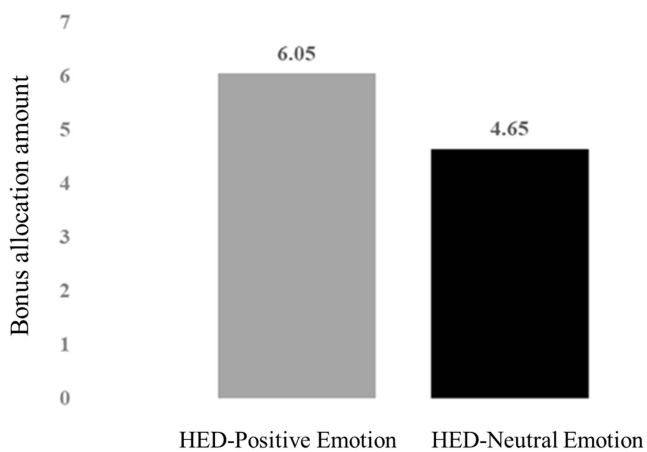


**Figure 4** Bonus allocation amount in the dictator task for different emotion groups under ego depletion.
**Note**: HED means High ego depletion.

**Table 1** Table of Prosocial Behavior Activation Channels After Arousing Positive or Neutral Emotions (M±SD)

| Condition | Passageway | *df* | *M±SD* | *t* | *d* |
|---|---|---|---|---|---|
| Positive emotions VS neutral emotions | ch15 | 46 | 0.004±0.008/-0.002±0.007 | 2.43* | 0.79 |
| | ch20 | 46 | 0.005±0.01/-0.002±0.007 | 2.18* | 0.81 |
| | ch7 | 46 | 0.002±0.006/-0.002±0.008 | 1.89+ | 0.56 |

**Note**: *$p$<0.05; +$p$<0.1. ch indicates a prefrontal activation channel.

than that of the neutral emotion group ($t$ (46) =2.06, $p$ <0.05, $d$=0.59), participants who watched positive video after ego-depletion showed more prosocial behavior.

### fNIRS Results of Prosocial Behavior Occurs Under Positive and Neutral Emotions Groups

We used the independent samples $t$-test on the β-values of the prosocial behavioral decision-making phases after positive and neutral emotion arousal. We obtained the results that the $\beta$ values of channel ch15 (in the right dorsolateral superior frontal gyrus, SFGdor) and channel ch20 (in the right medial superior frontal gyrus, SFGmed) were larger and statistically significant in the positive emotion group than in the neutral emotion group ($p$ < 0.05). The $\beta$ value of channel ch7 (in the left SFGmed) was higher in the positive emotion group than in the neutral emotion group and approached statistical significance ($p$ = 0.068). The results are shown in Table 1, and the activation hotspot diagram is shown in Figure 5. The relationship diagram among ego depletion, positive emotions, brain activity, and prosocial behavior is shown in Figure 6.

## Discussion

Firstly, Behavioral results of experiment 2 found a significant difference in the results of bonus allocation between the positive and neutral mood groups after the ego depletion task. Specifically, participants in the positive emotion group allocated significantly higher bonuses to each other than the neutral emotion group. This suggests that positive emotions can mitigate the ego depletion aftereffect such that under the condition of ego-depletion, participants with positive emotions displayed more prosocial behavior than those with neutral emotions. The experimental results are consistent with Hypothesis 2.

Secondly, during the bonus allocation task phase (prosocial decision-making phase), independent samples t-tests were conducted on the channel $\beta$-values of bonus allocation in positive and neutral emotions. The results indicated that there

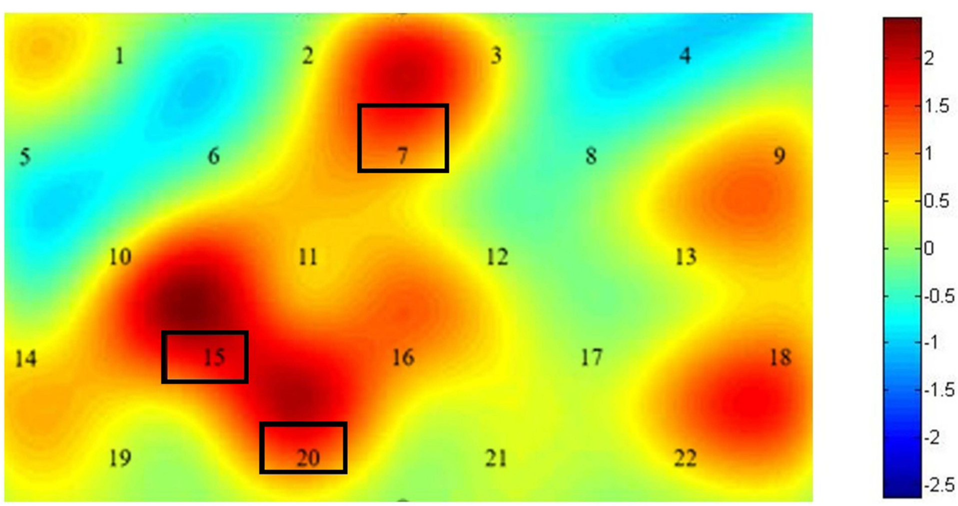


**Figure 5** Activation difference diagram of the comparison of prosocial behaviour under positive and neutral emotions group.
**Note**: The black rectangular boxes represent the approximate brain regions of the channels where differences exist.

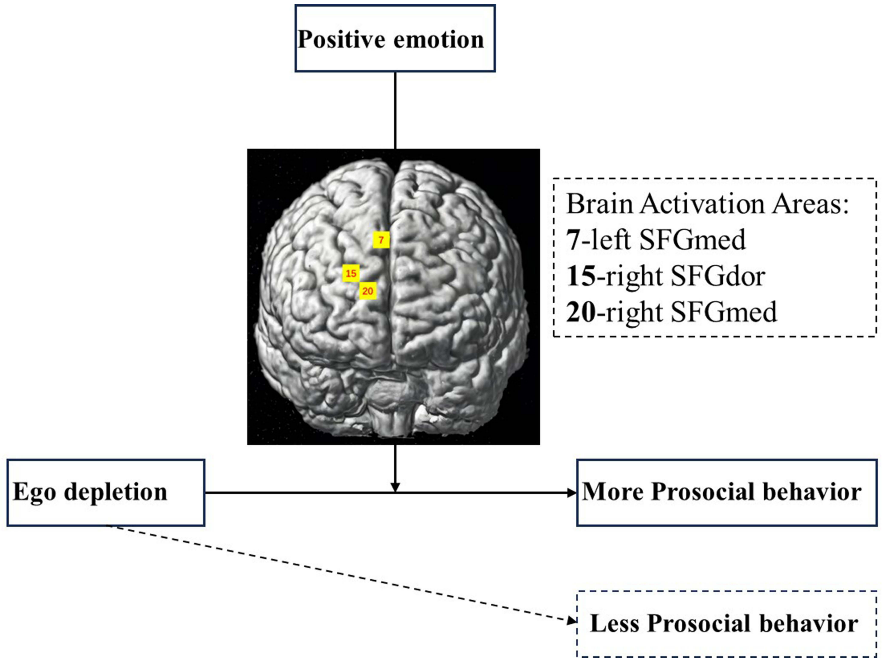


**Figure 6** The relationship diagram among ego depletion, positive emotions, brain activity, and prosocial behavior.
**Abbreviations**: SFGdor, dorsolateral superior frontal gyrus; SFGmed, medial superior frontal gyrus.

was a significant difference in SFGdor and SFGmed activation. The SFGmed and right SFGdor during bonus allocation in positive emotion had higher positive activation than in neutral emotion. This result suggests that the activation of bilaterally SFGmed and right SFGdor may represent a neural basis for the active effect of positive emotions on decision-making in prosocial behavior.

## General Discussion

Previous research has shown that the Stroop task leads to cognitive ego-depletion in individuals, which in turn reduces their prosocial behavior.[9,10] Through Experiment 1 in the present research, it was found that participants in the high ego-depletion group assigned significantly lower bonuses to recipients compared to the low ego-depletion group. This suggests that individuals may enact less prosocial behavior when they are in a state of depleted self-control resources. This result further validates the limited resource model of self-control, which emphasizes that executive self-control needs to rely on limited self-control resources.[5] Individuals performing high cognitive attrition tasks need to expend psychological resources, thus a potential consequence is the insufficient resources left for practicing self-control in subsequent direct dictator tasks.[6] This suggests that the low availability of self-control resources as a result of ego depletion may prompt individuals to engage in behaviors more for the interest of themselves[10] than for the interest of others.[9] Thus, ego depletion is followed by a reduction in the prosocial behavior of individuals. These explanations reflect the important role of self-control in prosocial behavior.

The findings of experiment 2 found that positive emotions can significantly increase individuals' prosocial behaviors following a state of ego depletion, lending support to Hypothesis 2. The result was also consistent with previous findings, such as the fact that individuals with higher levels of positive emotions induced through movie clips are more willing to spend time helping others.[21] Additionally, Snippe et al[3] found that more positive emotions were associated with more prosocial behaviors, and reversely, more prosocial behaviors were accompanied by more positive emotions. The Broaden and Build theory of positive emotions also states that positive emotions can reduce selfish behavior and promote more decisions that benefit others and society.[19] Therefore, individuals in positive emotional states are more likely to think positively and focus more on kindness and mutual aid than neutral emotions, which in turn promotes prosocial behaviors in individuals.[21] Thus, even when individuals are in a state of high depletion, they are able to replenish depleted

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resources and thus engage in more prosocial behaviors due to an increase in positive emotions. However, our findings are inconsistent with those of Bray et al,[22] who found that induced positive emotions did not alleviate the aftereffects of ego depletion in participants. The inconsistent results may be related to differences in the types of positive emotions induced. The motivational model of emotion categorizes positive emotions into high-approach-motivation positive emotions (eg, enthusiasm and excitement) and low-approach-motivation positive emotions (eg, joy and contentment).[52] In this study, low-approach-motivation positive emotions were induced in participants through humorous videos, whereas Bray et al[22] induced high-approach-motivation positive emotions through exciting music. Further distinguishing between positive emotions with different approach motivations will help clarify the reasons for the inconsistent results.

Importantly, the present study used the fNIRS technique to detect prefrontal oxygen signals during bonus allocation in participants from different emotion groups. The results revealed that the bilaterally SFGmed and right SFGdor had a higher level of activation in the positive emotion group during bonus distribution. The resulting hemodynamic results are consistent with the behavioral results. Thus, the reason why participants in the positive emotion group assigned higher bonuses to each other could be the result of an enhanced function of the SFGmed and right SFGdor. The conclusions of much previous research can provide an adequate explanation for the current findings.

Previous studies have found that the right DPFC is a key brain region in controlling the conflict between selfish and prosocial behavior.[33,53] For example, Ruff et al[34] found that increasing activity in the right DPFC led to the decreasing of the amount of money individuals allocated to others. In addition, the frontal lobe may be a brain mechanism for the effects of positive emotions on cognitive processes such as executive functioning and cognitive flexibility, because inducing positive emotions can alter the asymmetry of EEG activation in the PFC.[37,52] Gray et al[39] found that emotions selectively affect neural activity in the lateral prefrontal lobes associated with cognition. Following the depletion of self-control resources, individuals showed reduced activation in the right MFG of the right DPFC when doing a choice task.; this implies that the right MFG of the DPFC is a core brain region for performing top-down self-control procedures.[54]

The generation of prosocial behavior also involves a process of integrating different information, which may be related to the enhanced activation of the MPFC.[55,56] Using dynamic causal modeling (DCM), Bault et al[55] found that MPFC is able to regulate subsequent prosocial behaviors in a public goods game by integrating information about social relationships (eg, closeness to each other) in the temporoparietal junction and posterior superior temporal sulcus regions, as well as emotional signals in the anterior insula region. Moreover, McLellan et al's study[57] found increased activity in the left SFGmed when individuals were confronted with positive information. Integrating the findings of the previous and current research, we conclude that positive emotions promote executive control functions through the activation of the SFGmed and right SFGdor, enabling individuals to engage in less selfish allocative behaviors and more in altruistic allocative behaviors.

This study verified the negative impact of ego depletion on prosocial behavior and explored the psychological and brain mechanisms that relieve the relationship between ego depletion and prosocial behavior. Our findings extend the traditional self-control resource model by demonstrating that positive emotions can modulate resource availability. While the original framework focuses on passive recovery of resources over time, our results suggest that active emotion-based interventions (eg, positive emotion induction) may accelerate resource replenishment. This aligns with emerging critiques of the "passive recovery" assumption and supports revised models emphasizing dynamic interactions between affect and cognition.[58] Our findings bridge the Broaden-and-Build Theory and self-control resource model by demonstrating that positive emotions not only broaden cognition but also partially replenish depleted resources. Future research should explore whether other affective interventions (eg, mindfulness, awe induction) similarly buffer ego depletion effects. Our study has several practical implications, particularly for designing interventions to promote prosocial behavior in high-stress or resource-depleted environments. Students frequently face ego depletion from academic demands, which may reduce their willingness to engage in prosocial behaviors like helping peers or participating in group projects. Schools could implement positive emotion interventions (eg, encouraging positive social interactions or incorporating enjoyable activities) to mitigate these effects and foster a more cooperative learning environment.

However, there are still some limitations in this study: first, the gender imbalance exists in the sample due to the preponderance of female participants. When interpreting the gender differences in how ego-depletion relates to prosocial behavior, caution must to be practiced and more research with balanced gender ratio is needed. Second, the context of the dictator task in this study is relatively simple and does not fully equate to real-life prosocial behavior. Future research should try to measure pro-social behaviors in individuals of higher ages by using emergency situation designs, such as seizure experiments, smoke experiments, fainting experiments, etc., which are closer to real-life prosocial behaviors and have better ecological validity.

## Conclusions

Ego depletion negatively affects prosocial behavior, and there was a significant decrease in prosocial behavior after ego-depletion. Positive emotions relieved the negative effects of ego-depletion on prosocial behavior, and positive emotions significantly enhanced individuals' prosocial behavior in the high ego depletion state. The medial superior frontal gyrus (SFGmed) and right dorsolateral superior frontal gyrus (SFGdor) may be the primary brain region in which positive emotions enhance individuals' prosocial behaviors in an ego-depleted state.

## Data Sharing Statement

The raw data that support the findings of this study are publicly available from the corresponding author.

## Ethical Statement

This study was conducted under the ethical standards set forth in the 2013 helsinki Declaration and complied with the ethical regulations of the ethics committee of School of Education, Guangzhou University.

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## Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

1. Handbook of child psychology: vol. 3. In: Eisenberg N, Damon W, Lerner RM, editors. *Social, Emotional, and Personality Development*. 6th ed. Hoboken, NJ:John Wiley & Sons Inc; 2006.
2. Osgood JM, Muraven M. Self-control depletion does not diminish attitudes about being prosocial but does diminish prosocial behaviors. *Basic Appl Soc Psychol*. 2015;37(1):68–80. doi:10.1080/01973533.2014.996225
3. Snippe E, Jeronimus BF, Rot M, Bos EH, de Jonge P, Wichers M. The reciprocity of prosocial behavior and positive affect in daily life. *J Pers*. 2017;86(2):139–146. doi:10.1111/jopy.12299
4. Martinsson P, Myrseth KOV, Wollbrant C. Reconciling prosocial vs selfish behavior: on the role of self-control. *Judgm Decis Mak*. 2012;7 (3):304–315. doi:10.1017/S1930297500002278
5. Baumeister RF, Vohs KD, Tice DM. The strength model of self-control. *Curr Dir Psychol Sci*. 2007;16(6):351–355. doi:10.1111/j.1467-8721.2007.00534.x
6. Dang J, Barker P, Baumert A, et al. A multilab replication of the ego depletion effect. *Soc Psychol Personal Sci*. 2021;12(1):14–24. doi:10.1177/1948550619887702
7. Finley AJ, Crowell AL, Harmon-Jones E, Schmeichel BJ. The influence of agreeableness and ego depletion on emotional responding. *J Pers*. 2017;85(5):643–657. doi:10.1111/jopy.12267
8. Garrison KE, Finley AJ, Schmeichel BJ. Ego depletion reduces attention control: evidence from two high-powered preregistered experiments. *Pers Soc Psychol Bull*. 2019;45(5):728–739. doi:10.1177/0146167218796473
9. Achtziger A, Alósferrer, Carlos, Wagner AK, Wagner AK. Money, depletion, and prosociality in the dictator game. *J Neurosci Psychol Econ*. 2015;8(1):1–14. doi:10.1037/npe0000031
10. Jin HS, Kim HJ, Suh J, Sheehan B, Meeds R. Ego depletion and charitable support: the moderating role of self-benefit and other-benefit charitable appeals. *J.Advert*. 2021;50(4):1–15. doi:10.1080/00913367.2021.1887012
11. Wang GH, Lu JC, Li H, Lei Y. Inducing high self-efficacy improves cognitive control after self depletion. *J Psychol Sci*. 2023;46(6):1282–1289. doi:10.16719/j.cnki.1671-6981.20230601
12. Storr SM, Sparks P. Does self-affirmation following ego depletion moderate restrained eaters' explicit preferences for, and implicit associations with, high-calorie foods? *Psychol Health*. 2016;31(7):840–856. doi:10.1080/08870446.2016.1149585
13. Nie YG, Li ZH, Dou K, Mao LP. Will fatigue lead to lie? Ego depletion weaken honest behavior and its mitigation mechanism. *Studies Psychol Behav*. 2018;16(4):525–533.
14. Wenzel M, Kubiak T, Conner TS. Positive affect and self-control: attention to self-control demands mediates the influence of positive affect on consecutive self-control. *Cogn Emot*. 2014;28(4):747–755. doi:10.1080/02699931.2013.851069

15. Shmueli D, Prochaska JJ. A test of positive affect induction for countering self-control depletion in cigarette smokers. *Psychol Addict Behav*. 2012;26(1):157–161. doi:10.1037/a0023706
16. Ren J, Hu LY, Zhang HY, Huang ZH. Implicit positive emotion counteracts ego depletion. *Soc Behav Pers*. 2010;38(7):919–928. doi:10.2224/sbp.2010.38.7.919
17. Ma LY, Mo W. The influence of positive emotion on prosocial behavior under ego-depletion. *Studies Psychol Behav*. 2022;20(5):684–691. doi:10.12139/j.1672-0628.2022.05.016
18. Forest D, Clark MS, Mills J, et al. Helping as a function of feeling state and nature of the helping behavior. *Motiv Emot*. 1979;3(2):161–169. doi:10.1007/BF01650601
19. Fredrickson BL. The role of positive emotions in positive psychology: the broaden-and-build theory of positive emotions. *Am Psychol*. 2001;56(3):218–226. doi:10.1037/0003-066X.56.3.218
20. Fredrickson BL, Branigan C. Positive emotions broaden the scope of attention and thought-action repertoires. *Cogn Emot*. 2005;19(3):313–332. doi:10.1080/02699930441000238
21. Feng LL, Zong H, Zhang LL. Influence of emotional response on state empathy and helping behavior during emotion induction. *Chin J Health Psychol*. 2021;29(7):1085–1091. doi:10.13342/j.cnki.cjhp.2021.07.027
22. Bray SR, Oliver JP, Graham JD, Martin Ginis KA. Music, emotion, and self-control: does listening to uplifting music replenish self-control strength for exercise. *J Appl Biobehav Res*. 2013;18(3):156–173. doi:10.1111/jabr.12008
23. Wyland CL, Forgas JP. On bad mood and white bears: the effects of mood state on ability to suppress unwanted thoughts. *Cogn Emot*. 2007;21(7):1513–1524. doi:10.1080/02699930601063506
24. Dosenbach NUF, Fair DA, Cohen AL, Schlaggar BL, Petersen SE. A dual-networks architecture of top-down control. *Trends Cognit Sci*. 2008;12(3):99–105. doi:10.1016/j.tics.2008.01.001
25. Gbadeyan O, Mcmahon K, Steinhauser M, Meinzer M. Stimulation of dorsolateral prefrontal cortex enhances adaptive cognitive control: a high definition transcranial direct current stimulation study. *J Neurosci*. 2016;36(50):12530–12536. doi:10.1523/JNEUROSCI.2450-16.2016
26. Power JD, Petersen SE. Control-related systems in the human brain. *Curr Opin Neurobiol*. 2013;23(2):223–228. doi:10.1016/j.conb.2012.12.009
27. Figner B, Knoch D, Johnson EJ, et al. Lateral prefrontal cortex and self-control in inter-temporal choice. *Nat Neurosci*. 2010;13(5):538–539. doi:10.1038/nn.2516
28. Wilson SJ, Sayette MA, Fiez JA. Self-control, negative affect and neural activity during effortful cognition in deprived smokers. *Soc Cogn Affect Neurosci*. 2014;9(6):887–894. doi:10.1093/scan/nst065
29. Dosenbach NUF, Fair DA, Miezin FM, et al. Distinct brain networks for adaptive and stable task control in humans. *Proc Natl Acad Sci U S A*. 2007;104(26):11073–11078. doi:10.1073/pnas.0704320104
30. Abe N. The neurobiology of deception: evidence from neuro-imaging and loss-of-function studies. *Curr Opin Neurol*. 2009;22(6):594–600. doi:10.1097/wco.0b013e328332c3cf
31. Christ SE, Essen DC, Watson JM, Brubaker LE, McDermott KB. The contributions of prefrontal cortex and executive control to deception: evidence from activation likelihood estimate meta-analyses. *Cereb. Cortex*. 2009;19(7):1557–1566. doi:10.1093/cercor/bhn189
32. Hu X, Wu H, Fu G. Temporal course of executive control when lying about self- and other referential information: an ERP study. *Brain Res*. 2011;1369:149–157. doi:10.1016/j.brainres.2010.10.106
33. Liu X, Li J, Wang G, Yin X, Li S, Fu X. Transcranial direct current stimulation of the rLPFC shifts normative judgments in voluntary cooperation. *Neurosci Lett*. 2017;719:133164. doi:10.1016/j.neulet.2017.10.020
34. Ruff CC, Ugazio G, Fehr E. Changing social norm compliance with noninvasive brain stimulation. *Science*. 2013;342(6157):6157):482–484. doi:10.1126/science.124139
35. Krajbich I, Adolphs R, Tranel D, Denburg NL, Camerer CF. Economic games quantify diminished sense of guilt in patients with damage to the prefrontal cortex. *J Neurosci*. 2009;29(7):2188–2192. doi:10.1523/JNEUROSCI.5086-08.2009
36. Tusche A, Böckler A, Kanske P, Trautwein FM, Singer T. Decoding the charitable brain: empathy, perspective taking, and attention shifts differentially predict altruistic giving. *J Neurosci*. 2016;36(17):4719–4732. doi:10.1523/JNEUROSCI.3392-15.2016
37. Herrington JD, Mohanty A, Koven NS, et al. Emotion-modulated performance and activity in left dorsolateral prefrontal cortex. *Emotion*. 2005;5(2)::200–207. doi:10.1037/1528-3542.5.2.200
38. Wang YM, Guo DJ, Fang P, P YP. The Neural Basis of Moderate Emotional Pictures:An fMRI Study. *Studies Psychol Behav*. 2012;10(01):1–6.
39. Gray JR, Braver TS, Raichle ME. Integration of emotion and cognition in the lateral prefrontal cortex. *Proc Natl Acad Sci U S A*. 2002;99(6):4115–4120. doi:10.1073/pnas.062381899
40. Rodrigo AH, Di Domenico SI, Ayaz H, Gulrajani S, Lam J, Ruocco AC. Differentiating functions of the lateral and medial prefrontal cortex in motor response inhibition. *Neuroimage*. 2014;85:423–431. doi:10.1016/j.neuroimage.2013.01.059
41. Hirsch J, Tiede M, Zhang X, Noah JA, Salama-Manteau A, Biriotti M. Interpersonal agreement and disagreement during face-to-face dialogue: an fNIRS investigation. *Front Human Neurosci*. 2021;14:606397. doi:10.3389/fnhum.2020.606397
42. Kovelman I, Shalinsky MH, Berens MS, Petitto LA. Shining new light on the brain's "bilingual signature": a functional near infrared spectroscopy investigation of semantic processing. *Neuroimage*. 2008;39(3):1457–1471. doi:10.1016/j.neuroimage.2007.10.017
43. Tangney JP, Baumeister RF, Boone AL. High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *J Pers*. 2004;72(2):271–324. doi:10.1111/j.0022-3506.2004.00263.x
44. Padilla-Walker LM, Carlo G, Memmott-Elison MK. Longitudinal change in adolescents' prosocial behavior toward strangers, friends, and family. *J Res Adolesc*. 2018;28(3):698–710. doi:10.1111/jora.12362
45. Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: the PANAS scales. *J Pers Soc Psychol*. 1988;54(6):1063–1070. doi:10.1037/0022-3514.54.6.1063
46. Botvinick MM, Braver TS, Barch DM, Carter CS, Cohen JD. Conflict monitoring and cognitive control. *Psychol Rev*. 2001;108(3):624–652. doi:10.1037/0033-295X.108.3.624
47. Xu H, Bègue L, Bushman BJ. Too fatigued to care: ego depletion, guilt, and prosocial behavior. *Journal of Experimental Social Psychology*. 2012;48(5):1183–1186. doi:10.1016/j.jesp.2012.03.007
48. Wan EW, Agrawal N. Carryover effects of self-control on decision making: a construal-level perspective. *J Consum Res*. 2011;38(1):199–214. doi:10.1086/658471

49. Ben-Ner A, Halldorsson F. Trusting and trustworthiness: what are they, how to measure them, and what affects them. *J Economic Psychol*. 2010;31 (1):64–79. doi:10.1016/j.joep.2009.10.001
50. Strangman G, Culver JP, Thompson JH, Boas DA. A quantitative comparison of simultaneous BOLD fMRI and NIRS recordings during functional brain activation. *Neuroimage*. 2002;17(2):719–731. doi:10.1006/nimg.2002.1227
51. Yang HB, Liu HJ, Zhang P, Li L. The effect of masking stimuli on target recognition processing: evidence from fNIRS. *Acta Psychol Sin*. 2019;51 (11):1187–1197. doi:10.3724/SP.J.1041.2019.01187
52. Gable P, Harmon-Jones E. The mo tivational dimensional model of affect: implications for breadth of attention, memory, and cognitive categorisation. *Cognition & Emotion*. 2010;24(2):322–337. doi:10.1080/02699930903378305
53. Strang S, Gross J, Schuhmann T, Riedl A, Weber B, Sack AT. Be nice if you have to—the neurobiological roots of strategic fairness. *Soc Cogn Affect Neurosci*. 2015;10(6):790–796. doi:10.1093/scan/nsu114
54. Hedgcock WM, Vohs KD, Rao AR. Reducing self-control depletion effects through enhanced sensitivity to implementation: evidence from fMRI and behavioral studies. *J Consum Psychol*. 2012;22(4):486–495. doi:10.1016/j.jcps.2012.05.008
55. Bault N, Pelloux B, Fahrenfort JJ, Ridderinkhof KR, Van Winden F. Neural dynamics of social tie formation in economic decision-making. *Soc Cogn Affect Neurosci*. 2015;10(6)::877–884. doi:10.1093/scan/nsu138
56. Era V, Fusaro M, Gallo S. Commentary: decoding the charitable brain: empathy, perspective taking, and attention shifts differentially predict altruistic giving. *Front Behav Neurosci*. 2017;11:110. doi:10.3389/fnbeh.2017.00110
57. McLellan TL, Wilcke JC, Johnston L, Watts R, Miles LK. Sensitivity to posed and genuine displays of happiness and sadness: a fMRI study. *Neurosci Lett*. 2012;531(2):149–154. doi:10.1016/j.neulet.2012.10.039
58. Inzlicht M, Schmeichel BJ, Macrae CN. Why self-control seems (but may not be) limited. *Trends Cognitive Sci*. 2014;18(3):127–133. doi:10.1016/ j.tics.2013.12.009