International Journal of Psychophysiology 141 (2019) 37–44

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Regulatory effect of implicit acceptance during outcome evaluation: The temporal dynamics in an event-related potential study

Jiajin Yuan[a,b,*], Quanshan Long[a], Xiang Li[a], Zhongyan Deng[a], Bin Ma[a], Shengdong Chen[a], Jiemin Yang[a]

[a] The Laboratory for Affect Cognition and Regulation (ACRLAB), Key Laboratory of Cognition and Personality of Ministry of Education (SWU), Faculty of Psychology, Southwest University, Chongqing 400715, China

[b] Key Laboratory for Neuroinformation of Ministry of Education, University of Electronic Science and Technology of China, Chengdu, 611731, China

ARTICLE INFO

Keywords:
Acceptance
Decision making
Emotion regulation
Event-related potentials (ERP)
Outcome evaluation

ABSTRACT

The acceptance of emotion is important for humans' wellbeing and social functioning. Despite its regulatory advantages, the temporal dynamics of acceptance for regulating decision-related emotion remains unclear. For this purpose, Event-related potentials were recorded for outcome presentation, when participants either in explicit or implicit acceptance condition performed a Gambling Task. Results showed that acceptance effectively regulated emotional experiences, irrespective of how it was realized (explicit/implicit). Compared to viewing condition, explicit acceptance increased overall amplitudes of feedback-related negativity (FRN,180-240 ms) at the early stage and reduced P3 amplitude (240–440 ms) in general at the late stage, regardless of feedback valence or magnitude. By contrast, implicit acceptance did not influence the FRN amplitudes but increased the P3 amplitudes globally, an effect unaffected by feedback valence and magnitude. In addition, the P3 amplitude for explicit acceptance was negatively correlated with the ratio of risky choices, regardless of outcome valence. These results suggest that explicit acceptance is associated with cognitive conflict and resource depletion, while these adverse effects are not engendered during implicit acceptance. These regulatory effects are independent of specific feedback valence and magnitude. These findings highlight the role of implicit acceptance in cognitive demanding context, such as decision-making.

1. Introduction

As two typical decisional outcomes, reward and punishment are usually associated with positive and negative emotional outcomes, respectively (Rolls, 2000). Importantly, the emotional effects caused by the previous outcome evaluation affect the subsequent decision. Moderate emotions lead to learning and adaptive decision-making (Cohen et al., 2011), while excessive emotions can induce unwanted biases, such as risk-taking (Gehring and Willoughby, 2002). Thus, it is practically important to regulate emotions triggered by decisional outcome evaluation, in order to reduce bias and keep rational during decisional making.

Acceptance, different from the traditional strategies (i.e. reappraisal, suppression) and resignation, is central to mindfulness, defined as the aware embracing of emotional events and the active experiencing of emotional experiences without attempting to change anything (Hayes et al., 2004). Previous studies consistently reported that accepting negative experiences can protect individuals from experiencing negative affect, developing depressive and anxiety disorder (Brzozowski et al., 2018; Ding et al., 2015; Malinowski et al., 2017; Shallcross et al., 2013; Shallcross et al., 2015; Webb et al., 2012). While the advantages of acceptance in regulating negative emotion are well established, it is presently not known whether acceptance also effectively regulates the feedback-related emotion in the contexts of decision making that involve sustained high demands for mental resources.

Explicit (also called conscious, controlled, or reflective) processes, as one of dual-process framework, requires cognitive resources, is volitional, and is driven by explicit goals (Braunstein et al., 2017; Gyurak et al., 2011). Individuals need to use top-down cognitive control mechanisms to regulate emotional responses in those situations (Morawetz et al., 2016), suggesting that the practice of explicit acceptance may entail the access to cognitive control resources. This is, on the one hand, manifested by the fact that explicit acceptance instruct people to embrace negative outcomes and emotional experience, which are usually processed with defensive motivation (Lang et al., 1997). The process of

* Corresponding author at: Faculty of Psychology, Southwest University, Chongqing 400715, China.
E-mail address: yuanjiaj@swu.edu.cn (J. Yuan).

https://doi.org/10.1016/j.ijpsycho.2019.05.003
Received 22 November 2018; Received in revised form 4 May 2019; Accepted 5 May 2019
Available online 07 May 2019
0167-8760/

embracing and active experiencing is contrary to the instinctual defensive tendencies, and is thus most likely resource costly (Ding et al., 2015). Notably, the limited capacity model indicates that a temporary state of self-control resource depletion may lead to a greater likelihood for the subsequent attempts at self-control to fail (Muraven and Baumeister, 2000; Vadillo et al., 2016). This may explain why explicit acceptance was sometimes associated with increases rather than decreases in negative feelings (Dunn et al., 2009). On the other hand, as previous study showed that decision making and emotion regulation shared the same prefrontal cognitive control mechanism, which means that explicit emotion regulation may deplete cognitive resources necessary for rational decision making (Mitchell, 2011; Vohs et al., 2008). Thus, though the acceptance may not be as resource-costly as other explicit strategies (i.e. reappraisal), the execution of explicit acceptance most likely requires the involvement of cognitive resources.

In contrast, implicit (also called nonconscious, automatic, or impulsive) process is initiated by simple registration of sensory input, which in turn activates knowledge structures that then shape other psychological functions (Mauss et al., 2007). It is worth noting that goals can be activated and performed well without the intervention of awareness (Bargh et al., 2001). That is, implicit emotion regulation can facilitate goal-driven change without making a conscious decision to do so, without paying attention to the process of emotion regulation, as shown by the reports of reduced emotional experience without enhanced cognitive effort engagement, which can be realized by priming technique (Fitzgerald et al., 2018; Mauss et al., 2007; Yang et al., 2015). For instance, Mauss and colleagues adapted the Sentence Unscrambled Task (SUT) to prime emotion control and emotion expression, in which individuals were required to construct grammatical 4-word sentence from 5-word jumbles (Mauss et al., 2007). And those five words contained a priming word related to emotion regulation. Yang et al. (2015) asked participants to select one of two Chinese four-character to match the meaning of a third one before decision making, suggesting that priming reappraisal reduced subjective emotional experience. In addition, a recent study reported that implicit priming of acceptance strategy protected individuals from depressive mood during frustration, an effect absent when explicit acceptance was used (Ding et al., 2015).

In the present study, in order to investigate the regulatory effect of acceptance on outcome evaluation, participants were randomly assigned to explicit or implicit group, while ERP and emotional experience to outcomes were recorded during the Gambling Task. Explicit group was instructed to intentionally perform an Acceptance/View strategy when facing the outcome denoting gain or loss. In the implicit group, implicit acceptance was realized by implicitly priming subjects with the acceptance concepts, which were conveyed by the acceptance related words imbedded in SUT before the Gambling Task (Mauss et al., 2007). Given that both explicit and implicit emotion regulation effectively regulated subjective experience in prior studies (Fitzgerald et al., 2018; Mauss et al., 2007; Yang et al., 2013; Yang et al., 2015), we predict that emotional experience in the acceptance strategy would be reduced for both explicit and implicit group.

Feedback-related negativity (FRN) and P3 represent the early and the late stage of outcome evaluation, respectively (Yang et al., 2015). The FRN is a negative deflection in the frontal-central region that peaks approximately 250 ms after feedback, which is larger for negative feedback relative to positive feedback (Gehring and Willoughby, 2002). According to the reinforcement learning theory, the FRN represents the transmission of a negative reinforcement learning signal from the mesencephalic dopamine system to the Anterior Cingulated Cortex (ACC) and this signal is used by the ACC to modify performance on the task (Holroyd and Coles, 2002). This component plays an important role in the monitoring of mismatches or conflicts between goals or intentions and actions, whose amplitude increase represents stronger monitoring of response conflicts (Botvinick et al., 2004; Ullsperger et al., 2014). Importantly, explicit acceptance requires people to deliberately accept emotional experience, refraining from motivationally driven reactions (Baer et al., 2006). Thus, the conceptual framework of deliberate acceptance is contrary to the natural processing tendencies of emotional cues (Lang et al., 1997), which would induce response conflict. By contrast, implicit acceptance is realized by priming technique, free of overt accepting instructions, which would not induce response conflict at the conscious level. Importantly, conflict monitoring occurs on both negative and positive feedback trials (Gehring and Willoughby, 2002; Holroyd, 2004), suggesting that it is necessary to investigate the regulatory effect of acceptance on FRN responses elicited by both negative and positive decisional outcomes. We hypothesize that the FRN amplitude should be increased by explicit acceptance but not implicit acceptance, which is embodied by a significant *strategy* (Acceptance, View) by *group* (Explicit, Implicit) interaction on FRN amplitude.

Moreover, P3 is a positive deflection distributed from frontal to parietal region that peaks approximately 300 ms after feedback onset. This component is associated with attentional resource allocation during task processing (Hajcak et al., 2010; Kok, 2001; Polich, 2007), whose amplitude reduction represents depletion of cognitive resources by a cognitive demanding task. As analyzed above, individuals who use explicit acceptance need to override prepotent, motivated response tendencies to accept the decisional outcome and corresponding emotional experience. This process should involve top-down cognitive control function, entailing the cost of cognitive resources. However, implicit acceptance is evoked automatically without the need of conscious efforts (Ding et al., 2015). Therefore, we hypothesized that the P3 amplitude would be reduced by explicit acceptance but not implicit acceptance, which might be similarly represented by a *strategy* (Acceptance, View) by *group* (Explicit, Implicit) interaction on P3 amplitude. Also, the present study manipulated the magnitude of positive and negative decisional outcome, in order to see whether the effects of interest (*strategy* by *group* interaction) may be modulated by the outcome valence and magnitude.

2. Materials and methods

2.1. Participants

Thirty-three right-handed, healthy college students participated in this study. A post hoc power analysis was performed using G*power 3.1.9.2 software (Faul et al., 2007). With a sample size of 33 participants, a given significance level of 0.05, and an assumed population correlation of at least 0.6 for respective repeated measurements, the two-way interaction of strategy * group can detect a small-to-medium effect ($\eta_p^2 = 0.25$) with a probability of *1-β (statistical power)* > 0.88. Participants signed a written informed consent to the experimental procedure in accordance with the ethical principles of the 1964 Declaration of Helsinki. This study was approved by the local ethical committee of Southwest University (China).

Participants were randomly assigned to Explicit group ($N = 17$, 8 females; $M = 21$) or Implicit group ($N = 16$, 7 females; $M = 20.2$). They were similar in the habitual use of emotion regulation strategy in the Emotion Regulation Questionnaire (ERQ) and Acceptance and Action Questionnaire (reappraisal: $t(31) = 1.04, p = 0.31$; suppression: $t(31) = -0.09$, $p = 0.93$; acceptance: $t(31) = -0.07$, $p = 0.95$) (Gross and John, 2003; Hayes et al., 2004). As shown in Fig. 1, there were no significant group differences in emotion-related states, indicated by similar scores in the Chinese version of the Spielberg State ($t(31) = -1.33$, $p = 0.19$) and Trait ($t(31) = 0.77$, $p = 0.45$) Anxiety Scale, and the Beck Depression Inventory (BDI) ($t(31) = 0.52$, $p = 0.61$) (Li and Qian, 1995; Yang et al., 2012). And these scales had the ideal internal consistency and validity.

2.2. Stimulus and procedure

Each subject completed two sessions (Acceptance and View), and the sequence of session was counterbalanced across the subjects. Each

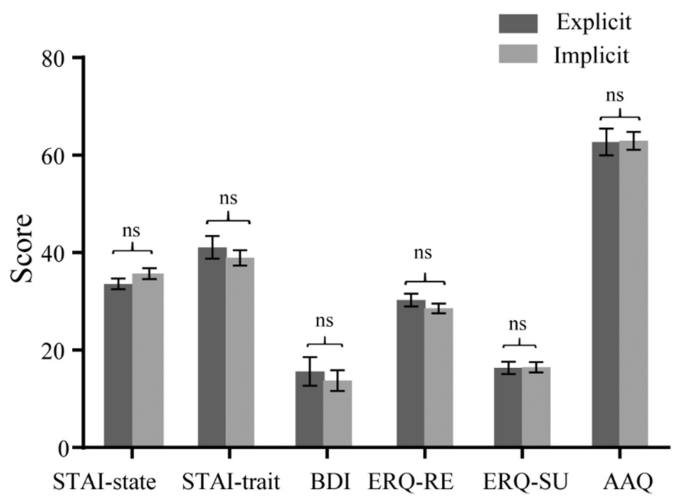

Fig. 1. The scores of two groups on the Spielberg State (STAI-state) and Trait Anxiety Scale (STAI-trait), Beck Depression Inventory (BDI), ERQ-RE (reappraisal), ERQ-SU (suppression) and AAQ (Acceptance and Action Questionnaire). Error bars = ± SEM; ns: non-significant.

session consisted of 4 blocks of 50 trials each. Before each block, participants completed 15 trials of SUT, in which they constructed a grammatical 4-word sentence that had only one correct answer from 5-word jumbles (Ding et al., 2015; Mauss et al., 2007). In Implicit Acceptance condition (IA), those primed with acceptance unscrambled 5 neutral sentences and 10 sentences containing words/phrases related to acceptance (Ding et al., 2015). For example, "1需要 2顺其自然 3最后 4事情 5有些", the correct order of the sentence is 5-4-1-2, which means letting things take its natural course; and the word-2 is related to acceptance. In the conditions of Implicit View (IV), Explicit Acceptance (EA), and Explicit View (EV), participants needed to unscramble 15 neutral sentences, which are irrelevant to emotion regulation.

Following SUT, participants under EA were provided with the following instruction (Ding et al., 2015): "*Gains or losses will induce two different types of emotions. When the emotion appears, please try to accept and experience your emotion naturally without changing or controlling it in any way. Let your emotion to run naturally, and think of it as a natural phenomenon, just like a cloud passing in the sky. Allow yourself to remain harmonious with your emotions.*" Participants under EV, IA, and IV received the instruction as follows: *"Gains or losses will induce two different types of emotions. Please pay attention to each outcome when it appears. You can attempt any strategies to obtain more rewards. At the same time, just stay still and prevent eyes from blinking."*

Then, the Gambling Task (Fig. 2) started with a fixation cross presented for 500 ms, adjoined on either side by two rectangles. The numbers 5 and 25 were simultaneously and respectively presented in one of the two rectangles. Participants made a choice by pressing the F (for the left) or J (for the right) key on the keyboard with his/her index finger. The stimulus was terminated by key pressing. The choice was highlighted by a thickened red outline of the chosen rectangle for 500 ms followed by a blank screen with duration varying randomly between 1000 and 1500 ms. Participant's choice appeared with the "+" or "−" symbols for 1500 ms, indicating the valence of the outcome: loss or gain. Each outcome was followed by a blank screen whose duration varied randomly between 800 and 1200 ms. After every 12 trials of the task, participants evaluated his/her emotional experience to the previous outcome using the 9-point scale (Bradley and Lang, 1994; Yang et al., 2013). 5 indicated that participant felt calm and bland. From 5 to 9, the positive emotions of pleasure, satisfaction, or excitement strengthened more and more. From 5 to 1, the negative emotions of disappointment, depression, or anger strengthened more and more.

Prior to the experiment, participants had a principal of 50 Yuan RMB and the final reward was 50 plus the cumulative outcomes for the task. Participants did not know that the probability of receiving a gain/loss outcome was random in each trial.

2.3. EEG recordings and analysis

Electroencephalogram (EEG) was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (Brain Products), with the reference electrodes on FCz and the ground electrode on AFz. Vertical electrooculogram (EOG) was recorded below the right eye, and horizontal EOG was recorded on the right side of the right eye. The electrode impedance was maintained below 10 kΩ and all the data were bandpass-filtered (0.01–100 Hz) online. During the off-line analysis, the data were re-referenced to the "infinity" zero reference using the free-software REST (Reference Electrode Standardization Technique; software REST can be found at http://www.neuro.uestc.edu.cn/rest/), which is effective in recovering the potential reference at infinity for sources located at the superficial cortical (Yao, 2001; Yao et al., 2005). Then, we conducted the offline EEG analysis with the computer software Brain Vision Analyzer. All EEG data were bandpass-filtered (0.01–30 Hz) and eye movement artifacts (blinks and eye movements) were rejected offline. An artifact criterion of ± 100 μV was used for all scalp sites to reject trials with excessive electromyographs (EMGs) or other noise transients.

ERP waveforms were time-locked to the onset of stimuli and the average epoch was 1500 ms, including a 200 ms pre-stimulus baseline. The FRN amplitude at the early stage was measured as the average amplitude at the electrode sites of Fz, F3, F4, FCz, FC3, FC4, Cz, C3, and C4 between 180 and 240 ms post feedback. The P3 amplitude at the late stage was measured as the average amplitude at the electrode sites of Fz, F3, F4, FCz, FC3, FC4, Cz, C3, C4, CPz, CP3, and CP4 between 240 and 440 ms post feedback. Based on our priori hypotheses and research purpose, the statistical analysis focused on the two-way interaction between *strategy* (Acceptance, View) and *group* (explicit, implicit), and, additionally, on whether this two-way interaction may be moderated by feedback *valence* or *magnitude*. Post hoc multiple comparisons were conducted using the Bonferroni test. Degrees of freedom were corrected by Greenhouse-Geisser correction whenever appropriate. The effect sizes were reported as partial eta-squared (η_p^2).

3. Results

3.1. Manipulation check

The manipulation check examined whether participants during explicit acceptance (EA) successfully complied with the acceptance instruction. Participants in EA needed to rate the extent to which they accepted their emotion on a 7-point scale (1: not at all; 7: extremely) immediately after the task. Analysis of ratings showed that Acceptance was successfully used in the task ($M = 5.59$, $SE = 0.21$). The scores were significantly higher than the midpoint (4) of the rating scale ($t(16) = 7.53$, $p < 0.001$).

Additionally, to ensure that participants were not skeptical of the experimental purpose in SUT, participants were instructed to complete a questionnaire after study. The result showed that participants did not know the real purpose of SUT. Moreover, participants did not use any emotion regulation strategy in implicit group. Next, given that implicit process is initiated by simple registration of sensory input (acceptance meanings), we used the accuracy of SUT to represent the successfulness of acceptance priming (1: completely correct; 0: completely wrong; 0.5: the chance level). The results showed that the accuracy in implicit acceptance was higher than chance level (0.87 vs. 0.5; $t(15) = 36.66$, $p < 0.001$), suggesting that participants successfully completed the SUT. This means that acceptance strategy, to some extent, was successfully primed by these sensory inputs.

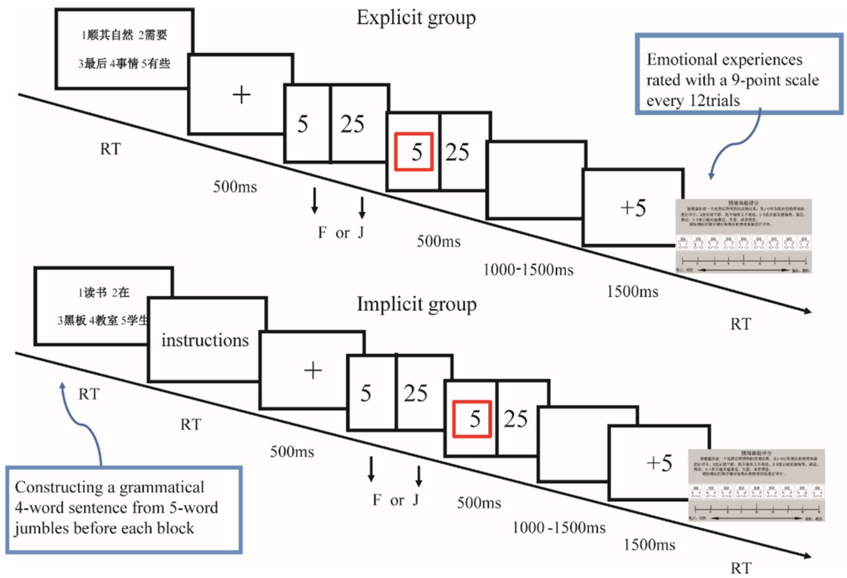

Fig. 2. The sequence of events within a single trial of the Gambling Task. RT: Response time.

3.2. Behavioral results

We defined the option 25 to be the risky choice, and the option 5 to be the risk-avoidant choice in this task (Yang et al., 2015). The ratio of risky choice was represented by the ratio of the number of the option 25 to the total number of feedback in each strategy. A two-way ANOVA showed that the ratio of risky choices was significantly higher in the explicit group than in the implicit group (0.554 vs. 0.454; $F(1, 31) = 5.02$, $p < 0.05$, $\eta_p^2 = 0.139$; Fig. 3a). The main effect of *strategy* and the interaction of *strategy* × *group* were not significant ($p_s > 0.05$).

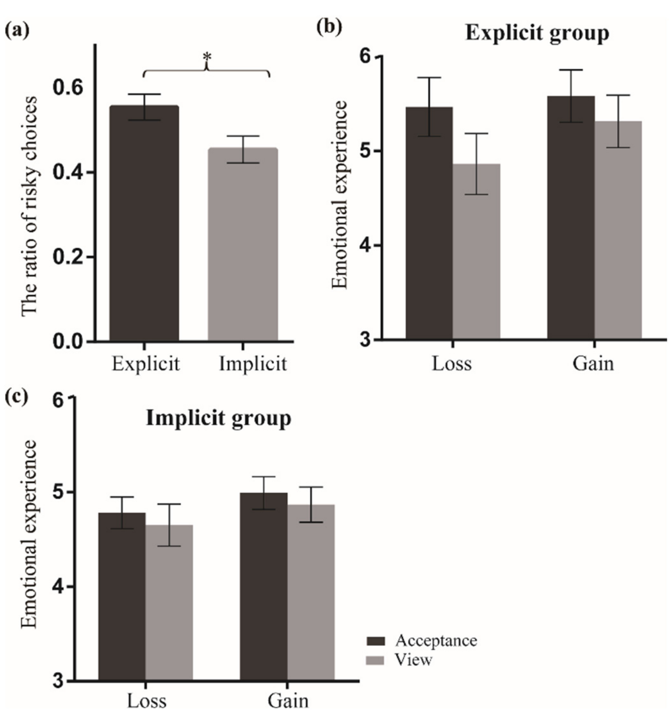

Fig. 3. (a) The ratio of the risky choice for explicit and implicit groups. The emotional experience scores for Acceptance and View in explicit **(b)** and implicit group **(c)**. Error bars denote ± SEM; * represents $p < 0.05$.

3.3. Emotional experience

For every participant, each outcome (+5, +25, −5, −25) was evaluated more than once in each strategy, except that "+5" was not evaluated by three participants in EA and two in EV; and that "+5" was not evaluated by one and "−25" by two in IA, as well as "-25" not evaluated by one and "+25" by three participants during IV. Because these outcomes did not appear in any of the evaluation trials. The score of every outcome was averaged for all participants in each strategy, and 12 missing data were replaced with the corresponding average score of the remaining participants.

The four-way ANOVA of emotional experiences (Fig. 3b, c) showed a significant main effect of *strategy* ($F(1, 31) = 4.26$, $p < 0.05$, $\eta_p^2 = 0.121$), with the higher score in Acceptance relative to View (5.20 vs. 4.92) condition. In addition, gain trials reliably elicited more positive emotion ratings compared to loss trials, shown by the significant main effect of *valence* ($F(1,31) = 8.68$, $p < 0.05$, $\eta_p^2 = 0.219$). Moreover, there was a significant *valence* by *magnitude* interaction ($F(1, 31) = 16.06$, $p < 0.05$, $\eta_p^2 = 0.341$). The simple effect analysis showed a significant difference between −25 and −5 (4.56 vs. 5.33; $F(1, 32) = 27.77$, $p < 0.05$, $\eta_p^2 = 0.465$), whereas the difference between +25 and +5 was not significant (5.17 vs. 5.23; $p = 0.61$). The interaction of *strategy* × *group* was not significant ($p > 0.05$).

3.4. EEG results

3.4.1. FRN amplitude (early stage)

The main effect of *valence* was significant ($F(1, 31) = 9.14$, $p < 0.05$, $\eta_p^2 = 0.228$), with larger amplitudes elicited for the loss versus the gain outcome (2.55 vs. 2.95 μV). The main effect of *magnitude* was significant ($F(1, 31) = 30.08$, $p < 0.05$, $\eta_p^2 = 0.492$), with larger amplitudes elicited for the small versus the large outcome (2.10 vs. 3.39 μV).

More importantly, there was a significant interaction of *strategy* × *group* ($F(1, 31) = 8.32$, $p < 0.05$, $\eta_p^2 = 0.212$; Fig. 4). To break down this interaction, we found that EA elicited larger amplitudes than EV (1.56 vs. 2.61 μV; $F(1, 16) = 7.79$, $p < 0.05$, $\eta_p^2 = 0.327$); while the difference between IA and IV was not significant ($F(1, 15) = 0.94$, $p = 0.35$). This interaction effect was independent of the outcome *valence* or *magnitude*, as the ANOVA detected no any significant three-way ($F_s(1,31) < 0.5$; $p > 0.40$) or four-way interaction ($F(1,31) = 1.60$;$p = 0.22$).

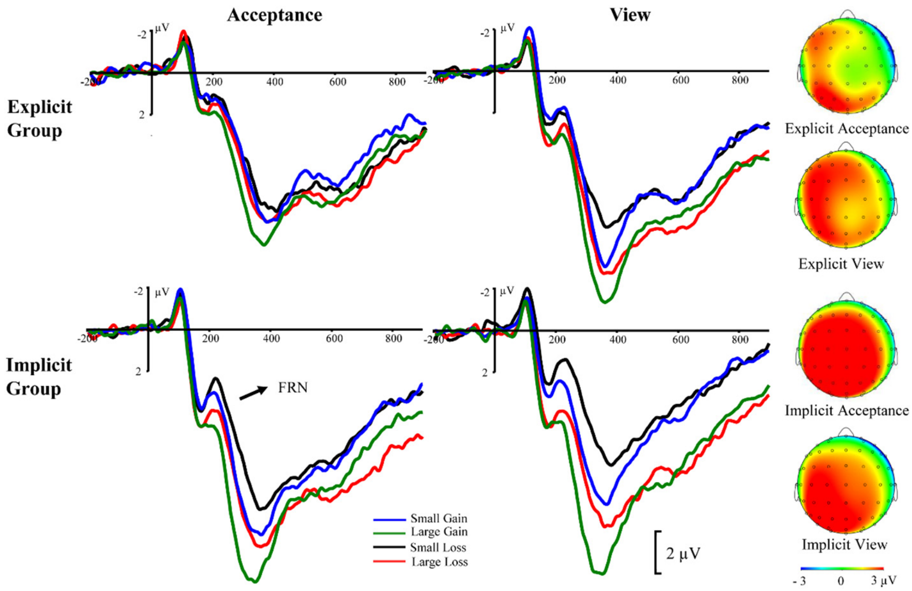

Fig. 4. The waveforms and topographies of the FRN (early stage). Waveforms were calculated by averaging the data at the electrodes of Fz, F3, F4, FCz, FC3, FC4, Cz, C3, and C4 in Explicit and Implicit groups. Topographical plots represent average amplitude during the analysis window (180–240 ms).

3.4.2. P3 amplitude (late stage)

The main effect of *valence* was significant (F (1, 31) = 31.62, $p < 0.05$, $\eta_p^2 = 0.505$), with larger amplitudes elicited for the gain versus the loss outcome (7.89 vs. 6.72 μV). The main effect of *magnitude* was significant (F (1, 31) = 23.72, $p < 0.05$, $\eta_p^2 = 0.433$), with larger amplitudes elicited for the large versus the small outcome (8.20 vs. 6.40 μV).

The interaction of *strategy* × *group* was significant (F (1, 31) = 14.82, $p < 0.05$, $\eta_p^2 = 0.323$; Fig. 5). The simple effect analysis showed smaller amplitudes during EA compared to EV (5.81 vs. 7.29 μV; F (1, 16) = 7.41, $p < 0.05$, $\eta_p^2 = 0.316$); while IA elicited larger amplitudes than IV (8.69 vs. 7.42 μV; F (1, 15) = 7.76, $p < 0.05$, $\eta_p^2 = 0.341$). The above interaction effect was unaffected by the outcome *valence* or *magnitude*, as the ANOVA detected no any significant three or four-way interactions ($F_s(1,31) < 0.20$; $p_s > 0.70$).

3.4.3. Correlation analysis

The P3 amplitude is hypothesized to index attentional resources (Hajcak et al., 2010; Kok, 2001; Polich, 2007). For tasks that require greater amounts of attentional resources, P3 amplitude is smaller as processing resources are used for task performance. Given that the execution of Explicit Acceptance would depletes cognitive resources (indexed by reduced P3 amplitude) and such self-depletion may result in greater risk-taking (Heilman et al., 2010; Vohs et al., 2008), we test the correlation of P3 amplitudes with the ratio of risky choices in EA/IA (Fig. 6). Correlation analysis showed that the P3 amplitudes were negatively correlated with the ratio of risky choices in EA ($r_{Gains} = -0.631$, $p < 0.05$; $r_{Losses} = -0.495$, $p < 0.05$), while this pattern of correlation was absent in IA ($r_{Gains} = 0.019$, $p = 0.945$; $r_{Losses} = 0.039$, $p = 0.885$).

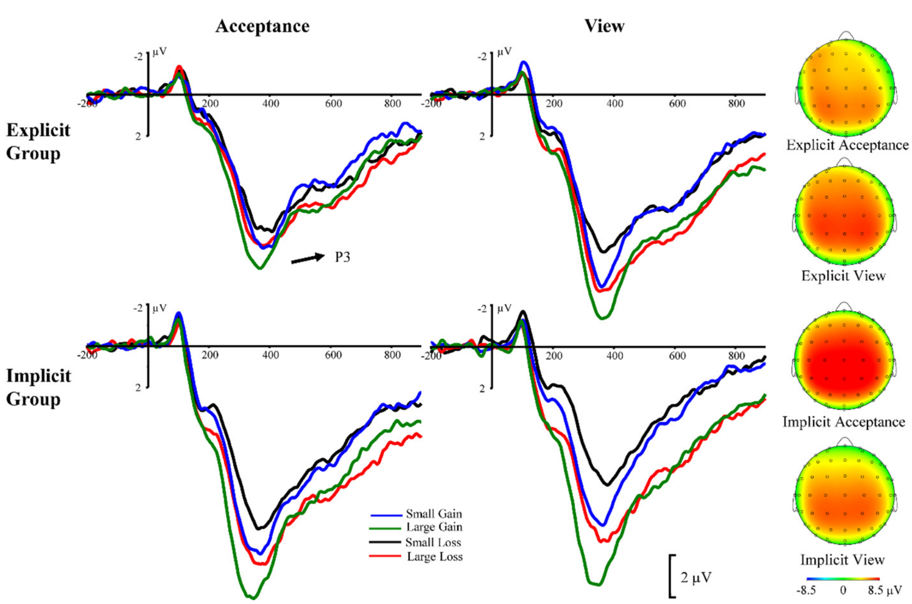

Fig. 5. The waveforms and topographies of the P3 component (late stage). Waveforms were calculated by averaging the data at the electrodes of Fz, F3, F4, FCz, FC3, FC4, Cz, C3, C4, CPz, CP3, and CP4 in Explicit and Implicit groups. Topographical plots represent average amplitude during the analysis window (240–440 ms).

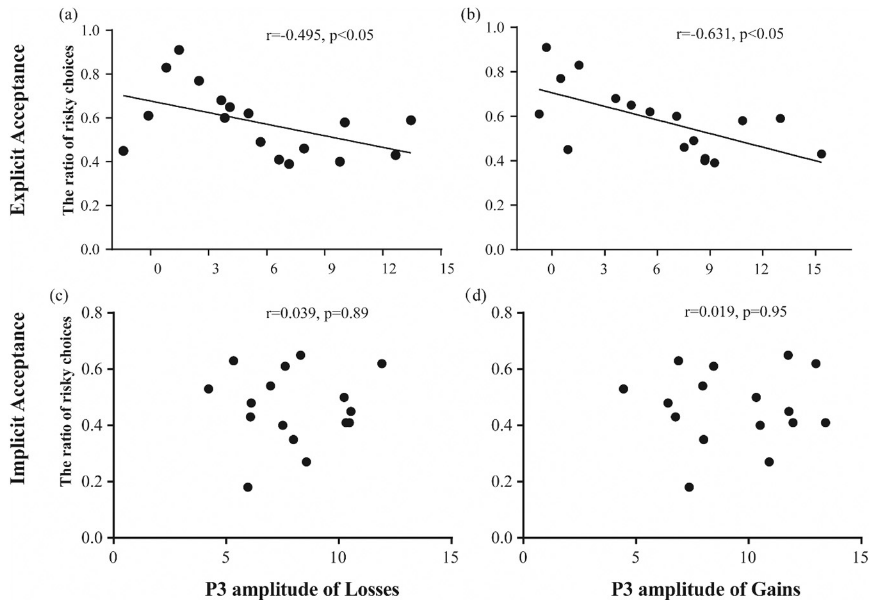

Fig. 6. The relationship between the ratio of risky choices and P3 amplitude of losses **(a)** and gains **(b)** in explicit acceptance. The relationship between the risky choices and P3 amplitude of losses **(c)** and gains **(d)** in implicit acceptance.

4. Discussion

The present study investigated the impact of Explicit and Implicit Acceptance on emotional experiences and ERP responses elicited by decisional outcomes. To be specific, we observed that acceptance strategy could effectively regulate outcome-related emotion. And the FRN amplitude of early stage was increased in Explicit Acceptance, while it was unchanged in Implicit Acceptance. By contrast, the P3 amplitude of late stage was reduced by Explicit Acceptance but increased by Implicit Acceptance. In addition, the ratio of risky choices was higher in Explicit than in Implicit groups. Moreover, the P3 amplitude of late stage was negatively correlated with the ratio of risky choices in Explicit Acceptance, while these correlations were absent in Implicit Acceptance.

The ego depletion model indicates that engaging in an act of self-control impairs self-control in subsequent tasks because those actions draw on limited mental resources (Shenhav et al., 2017; Vadillo et al., 2016). It is possible that the risk-taking is increased when individuals are in a state of ego-depletion (Fischer et al., 2012). Consistent with this argument, Heilman and colleagues find that the reappraisal of fear and disgust promotes risky decisions (Heilman et al., 2010). In the current study, an increased ratio of risky choices was observed in Explicit group relative to Implicit group. Consciously performed acceptance strategy, which cost mental resources, may lead to greater risk-taking. And Explicit Acceptance may produce a background of risk-taking, which likely contributed to risk-taking in the Explicit-View condition. Similarly, the previous study indicates that the N2 amplitude of neutral stimulus is larger in unpleasant versus pleasant sessions, most likely as a result of the background emotion influences (Yuan et al., 2012). Of course, due to the lack of *strategy* × *group* interaction in behavioral results, this inference should be taken with caution.

Interestingly, the correlation analysis showed that the P3 amplitude of late stage was negatively correlated with the ratio of risky choices in Explicit Acceptance but not in Implicit Acceptance. The P3 amplitude reflects attentional resource allocation (Hajcak et al., 2010; Polich, 2007), which is smaller as processing resources are used for task performance (Kok, 2001). Thus, the negative correlation between P3 amplitude and the ratio of risky choices might reflect the association between individual differences in emotion regulation efforts and risk-taking behavior during volitional acceptance. That is, the more cognitive resources depleted by intentional acceptance, the more commission of risk-taking behaviors.

The self-rating scores revealed that gains and losses led to positive and negative emotional experiences, respectively, which is consistent with the classic viewpoint that rewards and punishments are associated with positive and negative emotional outcomes, respectively (Rolls, 2000). Moreover, acceptance effectively regulated emotional experiences compared with the view condition. Consistent with previous studies, explicit and implicit acceptance effectively increased positive emotional experience compared to the observation or view condition (Mauss et al., 2007; Yang et al., 2013; Yang et al., 2015). This result suggests that acceptance is effective in modulating emotional experience during decision-making.

In the early stage (180–240 ms), an increased FRN amplitude was observed in Explicit Acceptance but not in Implicit Acceptance. The human is equipped with a biased processing of emotional events. However, Explicit Acceptance requires people to consciously accept any emotional experiences without attempts to change anything, refraining from impulsive, motivationally driven reactions (Baer et al., 2006). Thus, the conceptual framework of acceptance is contrary to the natural processing tendencies of emotional cues (Lang et al., 1997), consequently leading to cognitive conflict. The Anterior Cingulated Cortex (ACC) is involved in conflict monitoring which refers to a process that detects incongruities between the mental representation of intended goal and actual response (Botvinick et al., 2004; Holroyd and Coles, 2002; Ullsperger et al., 2014). Seeing that the FRN amplitude is generated in the ACC that peaks approximately 250 ms after feedback as a label of conflict monitoring (Botvinick et al., 2004), the increased FRN amplitude of early stage should be interpreted as representing the stronger monitoring of response conflicts in this study. By contrast, Implicit Acceptance is evoked automatically by implicit priming of acceptance and run to completion without monitoring (Ding et al., 2015). Thus, Implicit Acceptance would not induce response conflicts, thus leading to unchanged FRN amplitudes in the early stage. Consistent with our findings, a recent study shows that individuals who report high levels of habitual mindful acceptance, which represents one's degree of automatic acceptance, display significantly less emotion-related FRN differentiation than individuals who report low levels (Teper and Inzlicht, 2014).

In addition, the P3 amplitude of late stage (240–440 ms) was reduced by Explicit Acceptance, while it was increased by Implicit Acceptance. Emotional information, such as reward or punishment, has prioritized access to cognitive resources (Mitchell, 2011). Prior studies have shown that decision-making and emotion regulation share the same prefrontal cognitive control mechanism, and that decision making depletes cognitive resources necessary for effective emotion regulation (Fitzgerald et al., 2018; Mitchell, 2011; Vohs et al., 2008). Explicit Acceptance intentionally instructs people to embrace/accept emotions without attempts to change anything (Hayes et al., 2004). That is, if one's desired outcome is non-judgmental, mindful awareness in the face of current ruminative behaviors, they need to modify the current behavior in order to achieve the desired goal in Explicit Acceptance (Kerns et al., 2004). This process should have involved cognitive control function, entailing the cost of cognitive resources. Importantly, the P3 amplitude that peaks approximately 300 ms after feedback reflects attentional resource allocation (Hajcak et al., 2010; Polich, 2007), which should be decreased with the cognitive load (Kok, 2001). As an alternative interpretation, since Explicit Acceptance was likely more cognitively demanding than Implicit Acceptance, the reduction of P3 amplitude in the late stage (240–440 ms) might be caused by the cognitive load of Explicit Acceptance during decision-making. Consistent with our study, Yang and colleagues observed that explicit emotion regulation reduced the P3 amplitude compared to watching condition during outcome evaluation (Yang et al., 2013).

Conversely, Implicit Acceptance is evoked automatically without the cost of cognitive efforts (Ding et al., 2015). In Implicit Acceptance condition, the increased P3 should reflect increased availability of cognitive resources after acceptance priming during decision-making. Previous studies have reported that compared with neutral priming, priming emotion regulation reduces emotional experience without the cost of increasing cognitive loads (Yang et al., 2015). Also, implicit acceptance priming not only reduces emotion-related physiological activity but also protects mood stability compared with explicit acceptance (Ding et al., 2015). These evidence consistently suggests that the emotion regulation by implicit priming is an effortless, resource-saving process. The outcome observation in the Implicit view condition should have elicited a natural, motivationally-engaged processing of outcomes, which also consumes cognitive resources (Long et al., 2015). This weighted processing, however, should have diminished due to the use of implicit acceptance. This may have contributed to P3 amplitude enhancement in the late stage during implicit acceptance relative to implicit view.

4.1. Limitations

Firstly, the regulatory effect of explicit and implicit acceptance is a general effect, independent of outcome valence and magnitude as indicated by the lack of strategy, group and valence/magnitude interaction. One potential explanation for this result is that we did not design a neutral outcome denoting neither reward nor punishment. That is, all the outcomes in the current study were emotionally relevant, either gain or loss of varying magnitudes. As a result, two forms of acceptance modulated the cognitive components indexed by FRN or P3 in a global manner, and these regulatory effects did not vary across feedback valence or magnitude. Thus, future studies need to design a neural, non-emotional outcome condition, in order to isolate an index of emotion effect and to examine how this index varies with regulatory conditions. Secondly, it is worth noting that the entire amplitude is less positive for explicit acceptance relative to explicit view. That is, explicit acceptance modulates the early feedback-related negativity and the late P3 amplitudes in a global manner, regardless of the specific stage of outcome evaluation, or feedback valence and magnitude. But it is presently not clear why this pattern appears in the explicit acceptance. Due to the spatial resolution issue of ERP technique, we are unable to isolate the neural circuits that mediate conflict monitoring (early stage) and resource depletion (late stage) components of outcome evaluation, which is engendered by explicit relative to implicit acceptance. To compare the two distinct acceptance strategies, future studies need to isolate neural substrates underpinning these two strategies using high spatial resolution technique, in addition to the current knowledge of temporal dynamic differences.

4.2. Conclusions

In this work, we evaluated the effect of explicit and implicit acceptance strategies on outcome-evoked emotion, which is represented by different effects in the early and late ERP amplitudes. Specifically, the current study suggests that Explicit Acceptance regulates emotional experiences at the cost of cognitive conflict and resource depletion, irrespective of outcome valence and magnitude. However, these adverse effects were not engendered during Implicit Acceptance. It is noteworthy that the regulatory effect of acceptance is a general effect, independent of outcome valence and magnitude. This highlights the potential importance of implicit acceptance in emotion regulation during cognitive demanding context, like decision making.

Declarations of interest

None.

Acknowledgments

This research was funded by the National Natural Science Foundation of China [31671164; 31871103] and the Fundamental Research Funds for the Central Universities of PR China (grant number SWU1809361).

References

Baer, R.A., Smith, G.T., Hopkins, J., Krietemeyer, J., Toney, L., 2006. Using self-report assessment methods to explore facets of mindfulness. Assessment 13, 27–45.
Bargh, J.A., Gollwitzer, P.M., Lee-Chai, A., Barndollar, K., Trotschel, R., 2001. The automated will: nonconscious activation and pursuit of behavioral goals. J. Pers. Soc. Psychol. 81, 1014–1027.
Botvinick, M.M., Cohen, J.D., Carter, C.S., 2004. Conflict monitoring and anterior cingulate cortex: an update. Trends Cogn. Sci. 8, 539–546.
Bradley, M.M., Lang, P.J., 1994. Measuring emotion: the self-assessment manikin and the semantic differential. J. Behav. Ther. Exp. Psychiatry 25, 49–59.
Braunstein, L.M., Gross, J.J., Ochsner, K.N., 2017. Explicit and implicit emotion regulation: a multi-level framework. Soc. Cogn. Affect. Neurosci. 12, 1545–1557.
Brzozowski, A., Gillespie, S.M., Dixon, L., Mitchell, I.J., 2018. Mindfulness dampens cardiac responses to motion scenes of violence. Mindfulness 9, 575–584.
Cohen, M.X., Wilmes, K.A., Vijver, I.V.D., 2011. Cortical electrophysiological network dynamics of feedback learning. Trends Cogn. Sci. 15, 558–566.
Ding, N., Yang, J., Liu, Y., Yuan, J., 2015. Paying less but harvesting more: the effect of unconscious acceptance in regulating frustrating emotion. Sci. China Life Sci. 58, 799–809.
Dunn, B.D., Billotti, D., Murphy, V., Dalgleish, T., 2009. The consequences of effortful emotion regulation when processing distressing material: a comparison of suppression and acceptance. Behav. Res. Ther. 47, 761–773.
Faul, F., Erdfelder, E., Lang, A.G., Buchner, A., 2007. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods 39, 175–191.
Fischer, P., Kastenmüller, A., Asal, K., 2012. Ego depletion increases risk-taking. J. Soc. Psychol. 152, 623–638.
Fitzgerald, J.M., Kinney, K.L., Phan, K.L., Klumpp, H., 2018. Distinct neural engagement during implicit and explicit regulation of negative stimuli. Neuropsychologia. https://doi.org/10.1016/j.neuropsychologia.2018.02.002. (pii: S0028-3932(18) 30059-9).
Gehring, W.J., Willoughby, A.R., 2002. The medial frontal cortex and the rapid processing of monetary gains and losses. Science 295, 2279–2282.
Gross, J.J., John, O.P., 2003. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. J. Pers. Soc. Psychol. 85, 348–362.
Gyurak, A., Gross, J.J., Etkin, A., 2011. Explicit and implicit emotion regulation: a dual-process framework. Cognit. Emot. 25, 400–412.
Hajcak, G., MacNamara, A., Olvet, D.M., 2010. Event-related potentials, emotion, and emotion regulation: an integrative review. Dev. Neuropsychol. 35, 129–155.
Hayes, S.C., Masuda, A., Bissett, R., Luoma, J., Guerrero, L.F., 2004. DBT, FAP, and ACT: how empirically oriented are the new behavior therapy technologies? Behav. Ther. 35, 35–54.

Heilman, R.M., Crisan, L.G., Houser, D., Miclea, M., Miu, A.C., 2010. Emotion regulation and decision making under risk and uncertainty. Emotion 10, 257–265.
Holroyd, C.B., 2004. A note on the oddball N200 and the feedback ERN. Neurophysiology 78, 447–455.
Holroyd, C.B., Coles, M.G., 2002. The neural basis of human error processing: reinforcement learning, dopamine, and the error-related negativity. Psychol. Rev. 109, 679.
Kerns, J.G., Cohen, J.D., MacDonald, A.W., Cho, R.Y., Stenger, V.A., Carter, C.S., 2004. Anterior cingulate conflict monitoring and adjustments in control. Science 303, 1023–1026.
Kok, A., 2001. On the utility of P3 amplitude as a measure of processing capacity. Psychophysiology 38, 557–577.
Lang, P.J., Bradley, M.M., Cuthbert, B.N., 1997. Motivated attention: Affect, activation, and action. In: Attention and Orienting: Sensory and Motivational Processes, pp. 97–135.
Li, W.L., Qian, M.Y., 1995. Revision of the state-trait anxiety inventory with sample of Chinese college students (in Chinese). Acta Sci. Nat. Univ. Pekin. 31, 108–114.
Long, Q.S., Yang, J.M., Lou, Y.X., Cai, A.y., Yuan, J.J., 2015. Humans' emotional habituation to pleasant stimuli: behavioral and electrophysiological evidence(in Chinese). Chin. Sci. Bull. 60, 3594–3605.
Malinowski, P., Moore, A.W., Mead, B.R., Gruber, T., 2017. Mindful aging: the effects of regular brief mindfulness practice on electrophysiological markers of cognitive and affective processing in older adults. Mindfulness 8, 78–94.
Mauss, I.B., Cook, C.L., Gross, J.J., 2007. Automatic emotion regulation during anger provocation. J. Exp. Soc. Psychol. 43, 698–711.
Mitchell, D.G.V., 2011. The nexus between decision making and emotion regulation: a review of convergent neurocognitive substrates. Behav. Brain Res. 217, 215–231.
Morawetz, C., Bode, S., Baudewig, J., Jacobs, A.M., Heekeren, H.R., 2016. Neural representation of emotion regulation goals. Hum. Brain Mapp. 37, 600–620.
Muraven, M., Baumeister, R.F., 2000. Self-regulation and depletion of limited resources: does self-control resemble a muscle? Psychol. Bull. 126, 247.
Polich, J., 2007. Updating P300: an integrative theory of P3a and P3b. Clin. Neurophysiol. 118, 2128–2148.
Rolls, E.T., 2000. Precis of the brain and emotion. Behav. Brain Sci. 23, 177–191.
Shallcross, A.J., Ford, B.Q., Floerke, V.A., Mauss, I.B., 2013. Getting better with age: the relationship between age, acceptance, and negative affect. J. Pers. Soc. Psychol. 104, 734–749.
Shallcross, A.J., Gross, J.J., Visvanathan, P.D., Kumar, N., Palfrey, A., Ford, B.Q., Dimidjian, S., Shirk, S., Holmdenoma, J., Goode, K.M., 2015. Relapse prevention in major depressive disorder: mindfulness-based cognitive therapy versus an active control condition. J. Consult. Clin. Psychol. 83, 964–975.
Shenhav, A., Musslick, S., Lieder, F., Kool, W., Griffiths, T.L., Cohen, J.D., Botvinick, M.M., 2017. Toward a rational and mechanistic account of mental effort. Annu. Rev. Neurosci. 40, 99–124.
Teper, R., Inzlicht, M., 2014. Mindful acceptance dampens neuroaffective reactions to external and rewarding performance feedback. Emotion 14, 105–114.
Ullsperger, M., Fischer, A.G., Nigbur, R., Endrass, T., 2014. Neural mechanisms and temporal dynamics of performance monitoring. Trends Cogn. Sci. 18, 259–267.
Vadillo, M.A., Gold, N., Osman, M., 2016. The bitter truth about sugar and willpower: the limited evidential value of the glucose model of ego depletion. Psychol. Sci. 27, 1207–1214.
Vohs, K.D., Baumeister, R.F., Schmeichel, B.J., Twenge, J.M., Nelson, N.M., Tice, D.M., 2008. Making choices impairs subsequent self-control: a limited-resource account of decision making, self-regulation, and active initiative. J. Pers. Soc. Psychol. 94, 883–898.
Webb, T.L., Miles, E., Sheeran, P., 2012. Dealing with feeling: a meta-analysis of the effectiveness of strategies derived from the process model of emotion regulation. Psychol. Bull. 138, 775.
Yang, W.H., Wu, D.J., Peng, F., 2012. Application of Chinese version of Beck depression inventory-II to Chinese first-year college students (in Chinese). Chin. J. Clin. Psych. 20, 762–764.
Yang, Q., Gu, R., Tang, P., Luo, Y., 2013. How does cognitive reappraisal affect the response to gains and losses? Psychophysiology 50, 1094–1103.
Yang, Q., Tang, P., Gu, R., Luo, W., Luo, Y., 2015. Implicit emotion regulation affects outcome evaluation. Soc. Cogn. Affect. Neurosci. 10, 518–526.
Yao, D., 2001. A method to standardize a reference of scalp EEG recordings to a point at infinity. Physiol. Meas. 22, 693–711.
Yao, D., Wang, L., Oostenveld, R., Nielsen, K.D., Arendtnielsen, L., Chen, A.C., 2005. A comparative study of different references for EEG spectral mapping: the issue of the neutral reference and the use of the infinity reference. Physiol. Meas. 26, 173–184.
Yuan, J., Zhang, J., Zhou, X., Yang, J., Meng, X., Zhang, Q., Li, H., 2012. Neural mechanisms underlying the higher levels of subjective well-being in extraverts: pleasant bias and unpleasant resistance. Cogn. Affect. Behav. Neurosci. 12, 175–192.