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A Study of High and Low Behavior Inhibitory Control on Emotional Labeling Effect from ERPs

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Abstract

Emotional labeling effect refers to the reduction of Emotion in labeling or naming emotional features of stimulus. Previous researches have explored whether the ability of behavioral inhibition affects the regulation of explicit emotions, while there are no studies learning about the impact of behavioral inhibition on implicit emotions regulation. This study used ERPs to examine whether individuals with high and low behavioral inhibition control ability differed in their emotional labeling effects. Dual-choice Oddball task was used to screen out groups with high and low behavioral inhibition ability, and they were asked to make judgments on faces with different emotions and genders, and the LPP amplitude after picture presentation was analyzed. The results showed that the LPP amplitude induced by high inhibition ability group was significantly lower than that induced by gender labeling, while the LPP amplitude induced by low inhibition ability group was not significantly different between emotion labeling and gender labeling. The results show that individuals with high inhibition ability can produce emotion labeling effect, and the higher the inhibition ability of individuals, the better the emotional labeling effect.

Keywords

Behavioral Inhibition, Emotion Labeling, Emotional Labeling Effects, ERPs

1. Introduction

A large number of studies have found that behavioral inhibitory control (BIC) can have transfer effects on cognitive tasks such as working memory, cognitive flexibility, and weight reduction utility (Zhao, Chen, & Maes, 2018; Zhao & Jia, 2019; Maraver et al., 2016; Liu et al., 2016), helping to improve alcoholism, gambling and partial eating (Houben, 2011; Houben & Jansen, 2011), but there are also some studies that have not found transfer effects on fluid intelligence, cognitive reappraisal (Enge et al., 2014; Beauchamp et al., 2016). A meta-analysis study shows behavioral inhibitory control can have an effect on self-regulation (Friese et al., 2017). Emotional labeling, as one of self-regulation, is highly likely to be affected by behavioral inhibitory control. However, only one study has explored the influence of behavioral inhibitory control training on explicit emotion regulation (Beauchamp et al., 2016), and the effects on implicit emotion regulation are not yet known.

Emotion labeling is an effective form of implicit emotion regulation, which refers to describing or naming the emotional characteristics of stimulus (Lieberman et al., 2011). Emotional labeling effect refers to the phenomenon that individuals using emotional labeling strategies can effectively regulate negative emotions (Memarian et al., 2017). Currently, factors that have been found to influence emotional labeling effect include word arousal, specificity, word meaning and other characteristics of the individual's use of the word itself (Brooks et al., 2017; Wang et al., 2019; Yue et al., 2020; Yue et al., 2021) as well as the types of emotion, mindfulness traits and so on (Goldin & Gross, 2010; Kassam & Mendes, 2013), however, few studies have explored the effects of behavioral inhibitory control on emotional labeling effects. Studies of the brain mechanism of emotion labeling have confirmed that emotional labeling effects are generated through a neural loop of right ventro-Lateral prefrontal cortex (RVLPFC)—middle prefrontal cortex—amygdala (Lieberman et al., 2007). The right ventral prefrontal cortex is the common neural basis for various self-control (cognitive regulation, emotional regulation and behavioral regulation) and plays a key role in inhibiting activities (Susan & Mortimer, 1970). As a central component of inhibitory control (Verbruggen & Logan, 2008), behavioral inhibitory control and emotional regulation have a complex interaction (Berzenski & Yates, 2021). Specifically, behavioral inhibitory control can enhance individual emotion regulation (Gross, 2015). Since both the process of behavioral inhibition control and emotional regulation contain common self-regulation process that is cognitively and neurologically shared by activation of the lateral prefrontal cortex and middle prefrontal cortex, this means that individuals who regulate behavior could produce emotionally self-regulation process (Heatherton, 2011).

The Strength Model suggests that self-control is a limited resource, and individuals can strengthen their common self-control resources through training. For example, individuals can train their behavioral regulation ability to be transferred to cognitive regulation and emotion regulation, just like training muscles. These regulations also benefit (Muraven, 2010). Based on the strength model, it can be inferred that the higher the behavioral inhibition ability, the better the emotional labeling effect. Secondly, the distant transfer in transfer theory points out that the transfer effect often occurs between different mental functions tasks. If two tasks have similar neural and cognitive mechanisms, the two types of tasks will transfer even if they are different (Alexandra & Jason, 2011). Since behavioral inhibition control and emotion labeling have similar neural and cognitive mechanisms, it is hypothesized that behavioral inhibition control would migrate to the emotion labeling task. In summary, the neural basis of emotion labeling, the strength model and the distant transfer theory all hypothesize that behavioral inhibition control would have a transfer effect on emotional labeling effect.

However, only one study to date had shown that behavioral inhibitory control did not transfer to emotion regulation (Beauchamp et al., 2016). The study did not conduct pre- and post-inhibition control training tests, it is unclear whether three weeks of behabvioral inhibition control training enhanced individuals' behabvioral inhibition control, and behavioral inhibition control becomes a relatively stable trait for individuals in early adulthood (Williams et al., 1999), and three weeks of inhibition control training is not a good measure of high or low behavioral inhibition control for college students. Therefore, the present study did not adopt behavioral inhibition control training, and directly screened the high and low behavioral inhibition ability groups using the response time cost (deviant stimulus-standard stimulus) of double-choice oddball task as an indicator (Yuan et al., 2012; Yuan et al., 2017). In this study, we used an emotion labeling task with the LPP amplitude (late positive potentials) after stimulus picture presentation as the dependent variable indicator, and the LPP amplitude reflected the emotional arousal intensity of the stimulus (Torrisi et al., 2013). When the LPP amplitude of emotion labeling was significantly lower than that of gender labeling, it indicated that emotion labeling strategy suppressed emotion, and emotional labeling effect emerged (Yue et al., 2016). In addition, this study controlled the factors that have been found to influence the emotional labeling effect.

In conclusion, combined with the force model and the distant transfer theory, this study proposed the following hypotheses: Individuals with high behavioral inhibition ability have a good emotional labeling effect; conversely, individuals with low behavioral inhibition ability have a poor emotional labeling effect.

2. Methods

2.1. Subject Selection

A Chinese version of 836 childhood abuse screening questionnaires was distributed at a university in Henan Province (Zhao et al., 2005), and 93 of them were recruited to participate in the experimental task, all of whom were right-handed, free of childhood abuse, without a history of mental illness, with normal or corrected vision, and had not participated in a similar experiment with ERPs. The reaction time cost (RT cost) was calculated based on the subjects' reaction time on the double-choice oddball task, and the high and low behavioral inhibition subgroups, each with 16 subjects, half of each gender, were selected to participate in the subsequent emotion labeling task using a 27% criterion. The final number of valid subjects was 32, 16 in the high behavioral inhibition group (8 males and 8 females) with a mean age of 19.813 (SD = 0.834) years, and 16 in the low behavioral inhibition group (8 males and 8 females) with a mean age of 19.625 (SD = 1.204) years. T-test found no significant difference in age between the two groups (t = 0.512, df = 30, p > 0.05). The mean RT cost was 49.317 (SD = 33.312) ms and 134.583 (SD = 38.317) ms for the high and low behavioral inhibition groups, respectively, and the t-test found a significant difference in RT cost between the two groups (t = −6.717, df = 30, p < 0.001). A post hoc test using G-power software yielded a statistical test of 0.92. All subjects rated their emotions subjectively, understood the experimental procedure and signed an informed consent before the experiment, and received corresponding payment after the experiment. This article was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Xinyang Normal University.

2.2. Experimental Tasks

Refer to the emotional judgment task and gender judgment task used by Luo and Tabibnia (Cui & Luo, 2009; Tabibnia et al., 2008), the task stimulus consisted of 120 emotional face pictures from the Chinese Face Affective Pictures System (CFAPS) (Gong et al., 2011), with 60 positive pleasant and 60 negative angry face pictures, half male and half female. All images are displayed with the consent of the individual. The experimental materials were made using Flash8 software with a white background color and a size of 1024 × 768 pixels. Emotional face pictures were 390 × 450 mm in size, centered in the background against the top (X: 338, Y: 76), with the same faces used for emotion labeling and gender labeling pictures, and the task was presented using the sequential balance of ABBA. The "?" in the page size is 100 pounds, the position in the background is centered slightly above, (X: 320, Y: 250), "?" presents emotion-labeled or gender-labeled words to the left and right (Anger? Happy), both in bold (font size: 59). The annotation words are balanced between the left and right positions.

The computer screen center first presents the instruction, the subjects understand it and then press the key to enter the exercise, the correct rate is greater than 85% to enter the formal experiment. The center screen of the formal experiment first presented the task name, then presented the gaze point "+" for 200 ms, followed by a random face picture for 3000 ms (no response), the picture disappeared and presented the "?" page (1000 ms), the subjects were asked to press the left or right mouse button to judge the emotion or gender of the picture, and move on to the next trial after the reaction of the button. All trials within each block were presented in a completely randomized manner. There were 4 blocks, each with a total of 60 trials, and a guideline prompting subjects to take a break between two blocks. The specific procedure is shown in **Figure 1**. In this study, two indicators were used to represent the performance of the task: 1) the changes in late positive component LPP wave amplitude at five electrodes sites in the whole brain midline: Fz, FCz, Cz, CPz and Pz; 2) Mean and standard deviation of wave amplitude at 300 - 800 ms at Fz, FCz, Cz, CPz and Pz electrodes.

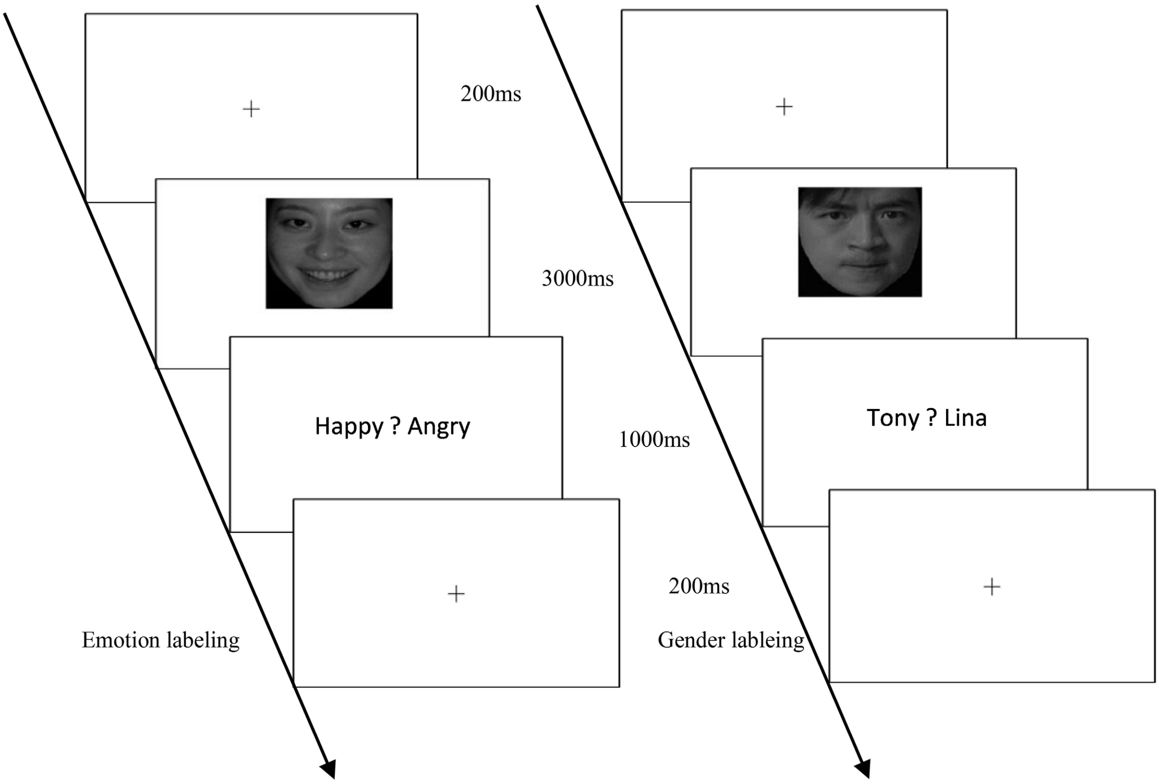

Figure 1. Experimental flow chart.

2.3. Measurement of Additional Variables

Before the start of the formal experiment, the Revised Toronto Alexithymia Scale (TAS) (Yi, Yao, & Zhu, 2003), the Regulatory Emotional self-efficacy scale (RESE) (Wang et al., 2013), Mindful Attention Awareness Scale (MAAS) (Chen et al., 2012), Social Interaction Anxiety Scale (SIAS) and Social Phobia Scale (SPS) (Ye et al., 2007) to measure emotion recognition description ability, emotion regulation self-efficacy, mindfulness traits level, social anxiety traits and social phobia traits that may affect the subjects' emotional labeling effects, thus controlling for additional variables that may affect the emotional labeling effect (Creswell et al., 2007; Burklund et al., 2015; Young et al., 2018; Yue et al., 2019; Wang & Zhao, 2015; Wang et al., 2015).

2.4. Experimental Design

A mixed experimental design of 2 (subjects type: high behavioral inhibition control ability, low behavioral inhibition control ability) × 2 (task type: emotion labeling, gender labeling) × 2 (emotion type: happy, anger), where subjects type was a between-subjects variable and task type, emotion type, electrode points were within-subjects variables. The independent variables of the experiment were behavioral inhibitory control ability, task type, emotion type, and the dependent variable indicator was LPP wave amplitude following emotional face presentation.

2.5. Date Acquisition

The experimental program was presented using E-Prime 2.0 design, and behavioral data were collected from the subjects. The monitor was a 19-inch Samsung 943 NW with a screen resolution of 1440 × 900 and a refresh rate of 60 Hz. EEG data were collected for the EEG experiments using Neuroscan's SynAmp2 amplifier and 64 conductive caps, with impedance values below 5 kΩ at all electrode sites. The left mastoid was used as the reference electrode, and offline analysis was then transferred to the bilateral mastoid; electrodes were placed approximately 1 cm laterally in both eyes to record Horizontal electrooculography (HEOG), and 1 cm in each of the upper and lower orbits of the left eye to record vertical electrooculography (VEOG). The sampling rate of the experimental apparatus was 1000 Hz, and the filter bandwidth was 0.05 - 100 Hz. All experiments were performed individually in a well-lit and quiet laboratory.

2.6. Data Analysis

Independent sample t-tests were performed on the collected subject variables as well as correct rates using SPSS 22.0. The EEG experimental data were analyzed offline using NeuroScan 4.5 software, and the EEG superimposed average waveform amplitude maps were obtained by tran-referencing, EEG preview, removal of oculogram, EEG segmentation (−200 - 1000 ms), baseline correction, artifact removal (>±100 μv), superimposed average, and low-pass 30 hz filtering (24 db/oct), and the waveform superimposed under each type. The number of waveforms superimposed under each type was greater than 36. According to previous studies (Hajcak, Moser, Holroyd, & Simons, 2006; Yue et al., 2020), the analysis focused on the changes in LPP wave amplitude at five electrode sites in the whole brain midline (Fz, FCz, Cz, CPz and Pz). The average wave amplitude of each subject under different tasks and emotion types was superimposed and finally presented as the total average map after intercepting 200 ms before picture appearance to 1000 ms after picture appearance, taking the first 200 ms to 0 ms as the baseline, and analyzing LPP wave amplitude from 300 - 800 ms after stimulus picture appearance, and performing a three-factor repeated measures ANOVA on EEG data, with p-values corrected using the Greenhouse-Geisser method.

3. Results

3.1. Independent Samples *t*-Test

Independent sample t-test on data for different subjects types at emotion identification description, emotion regulation self-efficacy, mindful awareness, social anxiety and social fear. The results showed that age ($t = 0.512$, $df = 30$, $p > 0.05$), emotion recognition description ($t = 0.744$, $df = 30$, $p > 0.05$), emotion regulation self-efficacy ($t = 0.432$, $df = 30$, $p > 0.05$), mindful attention awareness ($t = 0.796$, $df = 30$, $p > 0.05$), social anxiety ($t = 0.245$, $df = 30$, $p > 0.05$) and social fear ($t = 0.927$, $df = 30$, $p > 0.05$) in the two groups were no significant differences, as shown in Table 1.

Table 1. Independent sample *t*-test.

variable	High behavioral inhibition		Low behavioral inhibition		*t*	*df*	Bootstrap (95% *CI*)
	M	*SD*	*M*	*SD*			
Emotion recognition and description	31.44	7.91	29.38	7.77	0.74	30	[−3.60, 7.72]
Emotion regulation self-efficacy	64.13	8.36	62.81	8.84	0.43	30	[−4.90, 7.52]
Mindful attention awareness	54.79	9.35	51.06	15.13	0.80	30	[−5.86, 13.30]
Social anxiety	43.00	14.63	41.63	16.99	0.25	30	[−10.07, 12.82]
Social phobia	39.63	13.52	33.94	20.50	0.93	30	[−6.85, 18.22]

a. *M* = mean, *SD* = standard deviation; *CI* = confidence interval.

3.2. Behavioral Data Analysis

As subjects were not required to perform keystroke responses when the pictures appeared, only the experiment only analyzed the accuracy index of the behavior data. The results of the descriptive statistics showed that both high behavioral inhibition subgroup and the low behavioral inhibition subgroup achieved a correct rat of over 80% on the emotion labeling task, which means that subjects processed emotional faces adequately and the EEG data for the emotion labeling task was reliable (Deng, & Jiang, 2017), as shown in Table 2.

A three-way repeated measures ANOVA on correctness showed a non-significant main effect of subject type, $F(1, 30) = 1.54$, $p > 0.05$; a significant main effect of mood type, $F(1, 30) = 40.46$, $p < 0.001$, $\eta_p^2 = 0.57$, indicating more correct responses from subjects in pleasant moods; a significant main effect of task type, $F(1, 30) = 83.49$, $p < 0.001$, $\eta_p^2 = 0.74$, indicating that subjects were more accurate on the emotion labeling task; the interaction between subject type and emotion type was not significant, $F(1, 30) = 0.41$, $p > 0.05$; the interaction between subject type and task type was not significant, $F(1, 30) = 0.41$, $p > 0.05$; the interaction between the emotion type and task type was significant, $F(1, 30) = 5.81$, $p < 0.05$, $\eta_p^2 = 0.61$), and simple effects analysis showed that subjects were significantly more correct on the emotion label task than on the gender label task for both angry and pleasant emotions; the interaction between subject type, emotion type, and task type was not significant, $F(1, 30) = 3.66$, $p > 0.05$, as shown in Table 3.

3.3. EEG Data Analysis

Giving to previous studies, the present study used the 200 ms before stimulus presentation as the baseline, and the event-related potentials after stimulus picture presentation were superimposed and averaged to obtain the total average LPP wave amplitude plots for the two groups of subjects under different tasks and emotion types, as shown in Figure 2 and Figure 3.

Combining with previous studies (Herbert et al., 2013; Deng & Jiang, 2017), a time window of 300 - 800 ms after the stimulus picture appeared was selected for descriptive statistics and three-factor repeated measure ANOVA. The results are shown in **Table 4** and **Table 5**.

Table 2. Means and standard deviations of correct rates [M (SD)].

Targets	Emotion labeling		Gender labeling	
	angry	pleasant	angry	pleasant
High group	0.95 (0.04)	0.96 (0.03)	0.85 (0.07)	0.92 (0.05)
Low group	0.90 (0.09)	0.95 (0.05)	0.83 (0.10)	0.90 (0.07)

Table 3. Repeated measures ANOVA for Subject type, Emotion type and Task type.

Indicator		SS	df	F	η_p^2
Correct rate	Subject type	0.02	1	1.54	0.05
	Emotion type	0.09	1	40.46***	0.57
	Task type	0.14	1	83.49***	0.74
	Subject × Emotion	0.00	1	0.41	0.01
	Subject × Task	0.00	1	0.41	0.01
	Emotion × Task	0.01	1	5.81*	0.61
	Subject × Emotion × Task	0.01	1	3.66	0.11

b. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, the same below.

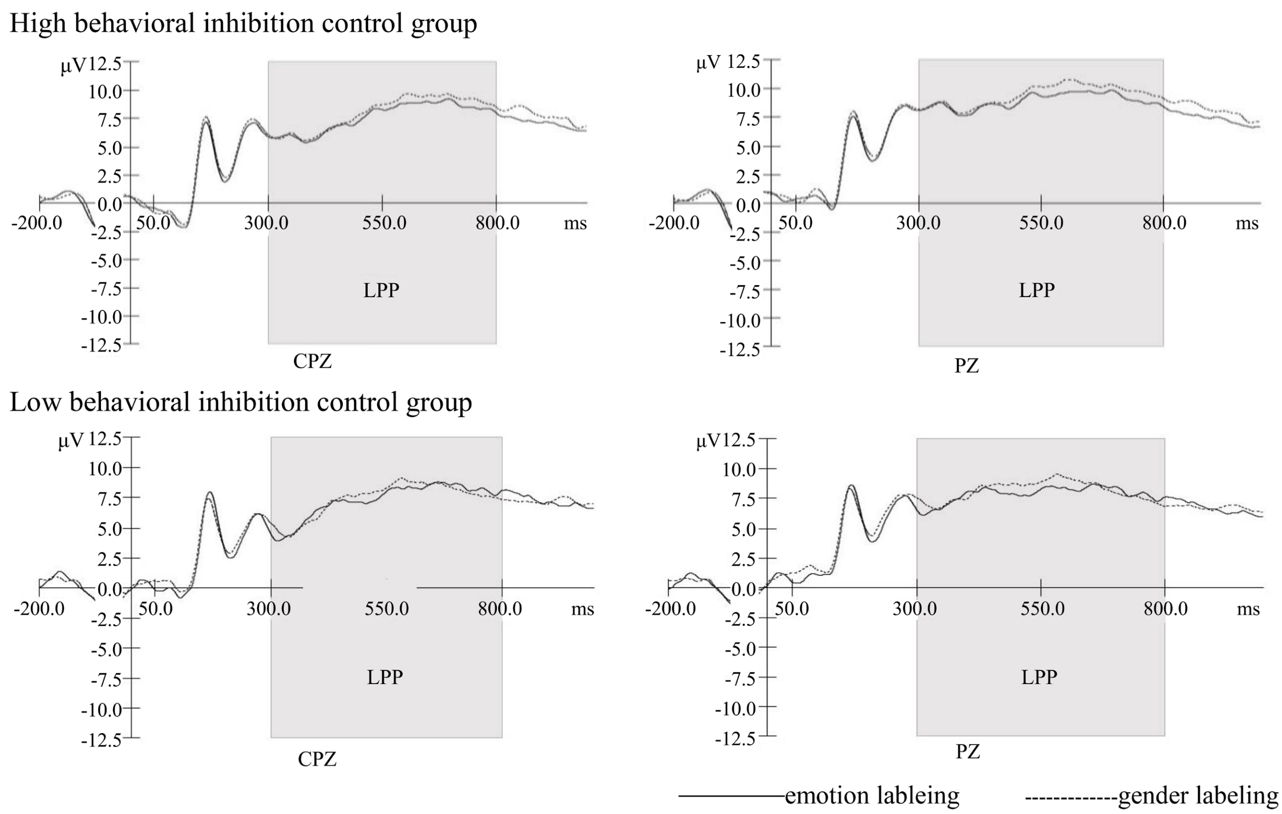

Figure 2. Grand-averaged waveforms of emotion labeling and gender labeling at CPZ and PZ in anger.

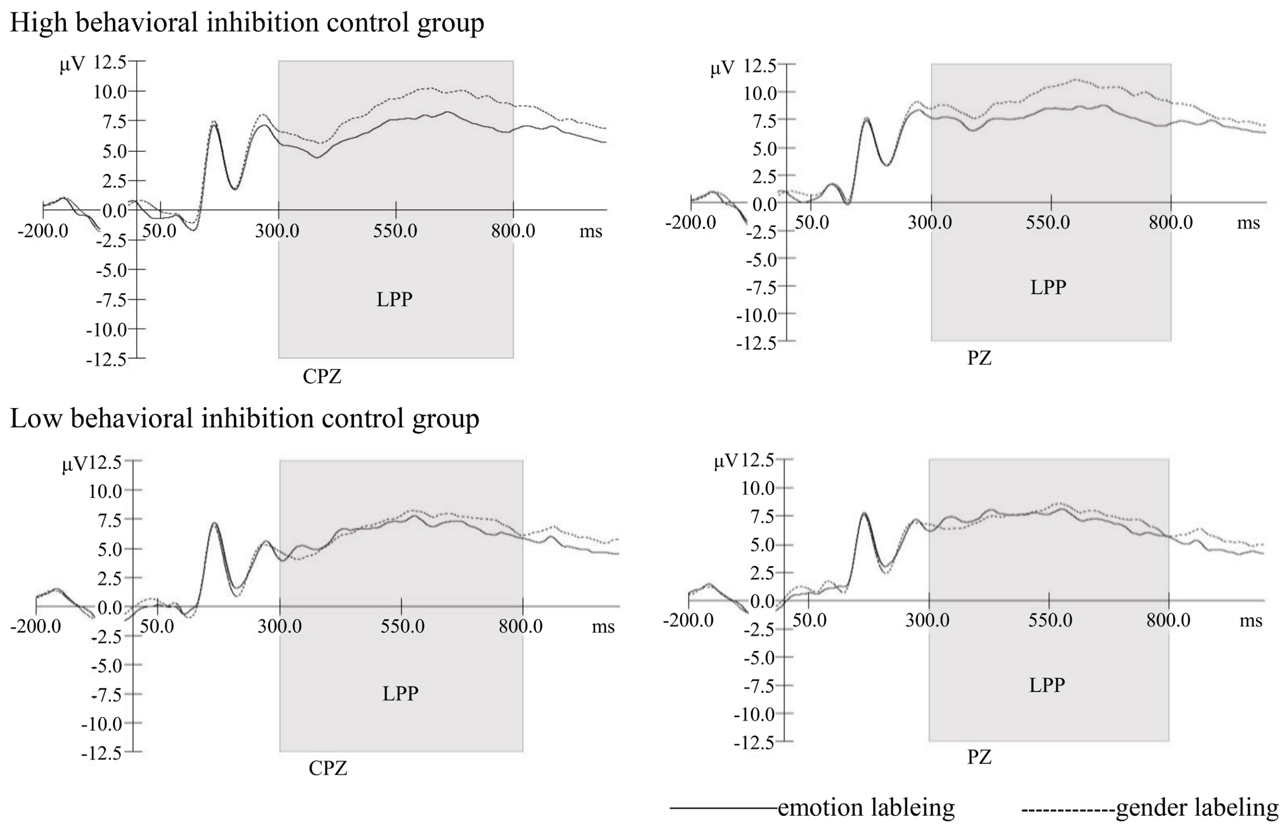

Figure 3. Grand-averaged waveforms of emotion labeling and gender labeling at CPZ and PZ in happiness.

Table 4. Mean and standard deviation of wave amplitudes at 300 - 800 ms time windows for each electrode site.

Emotion	anger				pleasant			
Task	Emotion labeling		Gender labeling		Emotion labeling		Gender labeling	
Subject	high	low	high	low	high	low	high	low
FZ	1.45 (2.64)	2.76 (2.47)	1.95 (2.80)	2.38 (2.02)	1.70 (2.44)	2.46 (2.87)	2.81 (2.55)	2.30 (2.82)
FCZ	3.02 (2.26)	4.01 (2.75)	3.63 (2.56)	3.64 (2.04)	3.18 (2.31)	3.44 (3.33)	4.41 (2.67)	3.39 (2.89)
CZ	5.06 (2.46)	5.63 (2.85)	5.41 (2.65)	5.38 (2.27)	4.79 (2.68)	4.80 (3.49)	6.31 (3.01)	5.13 (3.05)
CPZ	7.27 (3.18)	7.54 (2.49)	7.85 (3.25)	7.20 (1.94)	6.51 (3.44)	6.28 (3.11)	8.46 (3.74)	6.72 (2.29)
PZ	8.61 (3.73)	8.10 (2.48)	9.35 (3.38)	7.91 (1.68)	7.60 (3.69)	7.05 (2.52)	9.47 (3.92)	7.32 (1.70)

Table 5. Repeated measures ANOVA for each electrode site at 300 - 800 ms time window.

	Subject		Emotion		Task		Subject × Emotion		Subject × Task		Emotion × Task		Subject × Emotion × Task	
	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2
FZ	0.35	0.01	0.51	0.02	1.36	0.04	2.13	0.07	5.43*	0.15	1.32	0.04	0.29	0.01
FCZ	0.01	0.00	0.01	0.00	2.16	0.07	2.30	0.07	5.38*	0.15	0.97	0.03	0.11	0.00
CZ	0.03	0.00	0.16	0.01	2.99	0.09	2.35	0.07	2.48	0.08	3.35	0.10	0.38	0.01
CPZ	0.39	0.01	2.71	0.08	4.90*	0.14	1.95	0.06	4.23*	0.12	4.50*	0.13	0.36	0.01
PZ	1.43	0.05	8.55*	0.22	4.98*	0.14	0.77	0.03	4.38*	0.13	2.99	0.09	0.56	0.02

A three-factor repeated-measurement ANOVA was performed for each electrode site at the 300 - 800 time window, with the following results.

1) FZ point. A repeated measures ANOVA revealed a significant interaction between subject type and task type, $F(1, 30) = 5.43$, $p = 0.027$, $\eta_p^2 = 0.15$. Simple effects tests indicated that in the high behavioral inhibition control group, the mean wave amplitude induced on the emotion labeling task ($M = 1.58$, $SD = 0.62$) was significantly lower than the gender labeling ($M = 2.38$, $SD = 0.60$), $F(1, 30) = 6.11$, $p = 0.019$, $\eta_p^2 = 0.17$; while the low behavioral inhibition control group did not differ in the mean amplitude evoked on the emotion labeling and gender labeling tasks, $F(1, 30) = 0.68$, $p > 0.05$.

2) FCZ point. A repeated measures ANOVA revealed a significant interaction between subject type and task type, $F(1, 30) = 5.38$, $p = 0.027$, $\eta_p^2 = 0.15$. Simple effects wave amplitude evoked on the emotion labeling task ($M = 3.10$, $SD = 0.62$) was significantly lower than on the gender labeling ($M = 4.02$, $SD = 0.58$), $F(1, 30) = 7.18$, $p = 0.012$, $\eta_p^2 = 0.19$; while the low behavioral inhibition control group did not differ in the mean amplitude evoked on the emotion labeling and gender labeling tasks, $F(1, 30) = 0.36$, $p > 0.05$.

3) CZ point. A repeated measures ANOVA revealed a borderline significant interaction between mood type and task type, $F(1, 30) = 3.35$, $p = 0.077$. Simple effects tests indicated that the mean wave amplitude evoked on the mood labeling task was significantly lower under pleasant mood ($M = 4.80$, $SD = 0.55$) than gender labeling ($M = 5.72$, $SD = 0.54$), $F(1, 30) = 4.74$, $p = 0.037$, $\eta_p^2 = 0.14$; while there was no difference in the mean amplitude evoked by the emotion labeling and gender labeling tasks under anger, $F(1, 30) = 0.03$, $p > 0.05$.

4) CPZ point. A repeated measures ANOVA revealed a significant task type main effect, $F(1, 30) = 4.90$, $p = 0.035$, $\eta_p^2 = 0.14$, and a significant subject type and task type interaction, $F(1, 30) = 4.23$, $p = 0.048$, $\eta_p^2 = 0.12$, with a simple effects test indicating that in the high behavioral inhibition control ability group, the emotion labeling task evoked on the mean wave amplitude ($M = 6.89$, $SD = 0.72$) was significantly lower than gender labeling ($M = 8.16$, $SD = 0.67$), $F(1, 30) = 9.12$, $p = 0.005$, $\eta_p^2 = 0.23$; while the low behavioral inhibition control group did not differ in the mean amplitude evoked on the emotion labeling and gender labeling tasks, $F(1, 30) = 0.01$, $p > 0.05$. In addition, the mood type and task type interaction was significant, $F(1, 30) = 4.50$, $p = 0.048$, $\eta_p^2 = 0.12$, and simple effects tests indicated that the mean wave amplitude evoked on the mood labeling task was significantly lower under pleasant mood ($M = 6.40$, $SD = 0.58$) than on the gender labeling ($M = 7.59$, $SD = 0.55$), $F(1, 30) = 7.93$, $p = 0.011$, $\eta_p^2 = 0.20$; while there was no difference in the mean amplitude evoked by the emotion labeling and gender labeling tasks under anger, $F(1, 30) = 0.13$, $p > 0.05$; while on the emotion labeling task, the mean wave amplitude evoked by pleasant emotion ($M = 6.40$, $SD = 0.58$) was significantly lower than that evoked by anger ($M = 7.41$, $SD = 0.51$), $F(1, 30) = 7.62$, $p = 0.01$, $\eta_p^2 = 0.20$; while there was no difference in the mean amplitude of anger emotion and pleasant emotion evoked on the gender labeling task, $F(1, 30) = 0.03$, $p > 0.05$.

5) PZ point. A repeated measures ANOVA revealed a significant main effect of emotion type, $F(1, 30) = 8.55$, $p = 0.01$, $\eta_p^2 = 0.22$, a significant main effect of task type, $F(1, 30) = 4.98$, $p = 0.033$, $\eta_p^2 = 0.14$, and a significant interaction of subject type and task type, $F(1, 30) = 4.38$, $p = 0.045$, and $\eta_p^2 = 0.13$, and simple effects tests indicated that in the high behavioral inhibition control group, the mean wave amplitude evoked on the emotion labeling task ($M = 8.11$ $SD = 0.76$) was significantly lower than the gender labeling ($M = 9.41$, $SD = 0.68$), $F(1, 30) = 9.35$, $p = 0.005$, $\eta_p^2 = 0.24$; whereas the low behavioral inhibition control group had significantly lower mean wave amplitude evoked on the emotion labeling and gender labeling task induced no difference in mean amplitude, $F(1, 30) = 0.01$, $p > 0.05$.

It was found that the LPP amplitudes evoked by the emotion labeling task were significantly lower at FC, FCZ, CPZ, and PZ points compared to the low behavioral inhibition ability group, and there was an emotional labeling effect; whereas in the low inhibition ability group, the difference in EEG wave amplitudes evoked by the emotion labeling and gender labeling tasks was not significant, and there was no emotional labeling effect. Also at the CZ and CPZ points both showed lower LPP wave amplitudes in the emotion labeling task than in the gender labeling task only in the pleasant emotion, and also found lower wave amplitudes in the pleasant emotion than in the angry emotion only in the emotion labeling task at the CPZ point, indicating significant differences between the emotion labeling task and the gender labeling task.

In conclusion, there was a significant difference between the high behavioral inhibition ability group on the emotion labeling task and the gender labeling task, with lower LPP wave amplitudes on the emotion labeling task, which means the presentation of emotional labeling effect, whereas there was no significant difference between on the emotion labeling task and the gender labeling task in the low behavioral inhibition ability group, which means the abence of emotional labeling effect.

4. Discussion

The present study was the first to examine the effect of behavioral inhibition control on the emotion labeling effect by controlling for behavioral inhibition control ability, and found that the high behavioral inhibitory control group evoked significantly lower LPP amplitudes on the emotion labeling task than gender labeling, whereas the low behavioral inhibition control group evoked nonsignificant difference in EEG wave amplitudes on the emotion labeling and gender labeling. This suggests that high behavioral inhibition control have a significant positive effect on the emotion labeling effect, with higher behavioral inhibition being associated with better emotion labeling effects. This is inconsistent with previous research by Beauchamp, who found that "behavioral inhibition control training did not have a transfer effect on cognitive reappraisal as an explicit emotion regulation", most likely because the 3-week behavioral inhibition control training did not improve behavioral inhibition control in the college students, resulting in no significant results (Beauchamp et al., 2016). It is also possible that because the mental processing of cognitive reappraisal is relatively more complex and involves a wider range of brain regions. Although the inferior frontal gyrus also plays an important role in cognitive reappraisal, cognitive reappraisal also requires the synergy of brain regions such as the anterior cingulate gyrus, parietal lobe, parahippocampal gyrus and occipital lobe (Sun et al., 2020), so enhancement of inferior frontal gyrus alone may not enhance the effect of cognitive reappraisal. In contrast, the main psychological process involved in emotional labeling is the naming of stimuli that activates the language center Broca area 44, which overlaps highly with the inhibitory center right inferior frontal gyrus and the right ventral prefrontal cortex, making changes in the prefrontal cortex more likely to affect emotion labeling (Ferdinand & Giovanni, 2004; Massimo & Giuseppe, 1996). Furthermore, studies have shown that higher levels of mindful traits have better emotion labeling effects, possibly due to higher activation in the right ventral prefrontal or right inferior frontal gyrus (Creswell et al., 2007; Goldin & Gross, 2010), whereas the inferior frontal gyrus is impaired in those with impaired emotional labeling abilities such as social anxiety and social fear (Taylor et al., 2006; Burklund et al., 2015), so the most important factor influencing emotional labeling effect is activation of the right ventral prefrontal or right inferior frontal gyrus, and behavioral inhibition control may only be the most general factor influencing emotional labeling effect.

The results of the present study support the strength model. The reason may be due to that high inhibitors use the right ventral prefrontal cortex more often than low inhibitors, constantly reinforcing the “muscle memory” of this region, automating full activation of this region in another task that also uses this muscle, and thus dampening emotion through the inhibitory loop. In contrast, those with low behavioral inhibition use the right ventral prefrontal cortex more sparingly and do not fully activate it in the same task that requires its activation (Berkman, Burklund, & Lieberman, 2009). It is hypothesized that individuals with high behavioral inhibitory control can produce emotion labeling effects by means of emotion labeling. Previous studies have also found individuals with low behavioral inhibition also have mood disorders, such as drug dependence, pedophilia, and pathological internet use (Weafer et al., 2017; Christian et al., 2017). This somewhat supports the idea that poor behavioral inhibition control affects emotion regulation.

Second, the results of the present study also support the distant migration theory, possibly because behavioral inhibition control tasks and emotional labeling tasks have similar shared neural and cognitive mechanisms. Elisabeth et al.’s (2020) study suggests that effective behavioral inhibition control requires bottom-up perceptual processing and top-down inhibition control (Elisabeth et al., 2020), and dual-processing theory also suggests that emotion labeling tasks require early automatic processing that is not dependent on attentional resources as well as controlled processing of emotions (Lieberman et al., 2002), suggesting that behavioral inhibition control and emotion labeling share the same cognitive mechanisms. Previous research has also shown that individuals completing behavioral inhibition or emotion labeling tasks in neural mechanisms both manifest as activation of the prefrontal cortex (Agatha et al., 2011; Herbert et al., 2013) and at the behavioral level both manifest as the need to inhibit irrelevant information (Yuan et al., 2017; Lieberman et al., 2011). The results of the present study support the inference that there are neural and cognitive mechanisms that correlate between behavioral inhibitory control and emotion labeling.

In conclusion, both the strength model and the distant transfer theory support the conclusion that the higher the behavioral inhibition capacity the better the emotion labeling effect in this study. Given that emotion disorders lead to individuals' inability to engage in emotion regulation and are responsible for a variety of psychological problems such as PTSD, depression, anxiety, eating disorders and psychosis (Brewin et al., 2010; Liu et al., 2020), behavioral inhibition control training could be manipulated more rigorously in the future to explore whether pre- and post-training have an effect on the emotion labeling effect. In addition, some studies have found that cognitive training is more plastic in children and adolescents than in adults, and following research could also explore whether inhibitory control training for children or adolescents could transfer to emotion labeling tasks (Wang et al., 2020; Zhao & Jia, 2019).

5. Conclusion

The conclusion that can be drawn in the present experimental condition is that the higher the behavioral inhibition control, the better the emotional labeling effect.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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