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Attentional negativity bias moderated by positive mood arousal

CHEN ChunPing[1,2] & LUO YueJia[3*]

[1] *Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China;*
[2] *Graduate School of Chinese Academy of Sciences, Beijing 100049, China;*
[3] *State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing 100875, China*

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Automatically allocation of more attention to negative stimuli is called emotional negativity bias. An event-related potentials (ERPs) experiment investigated whether or not this bias was altered by positive mood arousal. The results suggested that the attention bias towards negative stimuli was attenuated when positive information was accessible.

negativity bias, positive mood, P2, LPP, ERPs

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That individuals focus on emotionally negative events more than to neutral or positive events, which is designated as emotional negativity bias, has been demonstrated by many behavioral studies. For example, snakes and spiders were detected more rapidly than flowers and mushrooms in a visual search task, suggesting that threat-relevant stimuli in the environment are preferentially perceived [1]. Researchers assumed this privileged access to negative stimulation may be driven by the pre-attentive analysis of stimuli as being threat-related (e.g., snakes, spiders), and that the underlying mechanism may consequently lead to an automatic shift of attention resources to the location of the threatening object [2,3]. Similarly, the attention bias towards negative stimuli is reflected by impaired reaction time (RT) in an emotional Stroop task which requires participants to name the color ink of words varying in emotional value (e.g., neutral versus threat-related words), wherein the RTs between word types are compared [4]. Typically, the longer the RTs, the more psychological resources are put into the processing of negative information. Because participants are presumably distracted by the nature of the words, the RTs of the color-naming task are correspondingly prolonged.

RT studies establish the presence of an attention bias. ERPs provided a better examination than RTs of the time course to information processing during sensory and cognitive stages [5]. Negativity bias in earlier ERP components has also been documented by some literature. One of ERP's components, the P2 which appeared approximately at 200–250 ms poststimulus onset, would be a good index to mirror attention bias. Thomas et al. [6] reported that the amplitude of P2 was specific to stimulus valence and larger P2 amplitudes were required for threat words than for neutral words. Likewise, Huang and Luo [7] found that enlarged P2 amplitudes are solely observed for negative rather than for positive and neutral stimuli. Carretie et al. [8] explored the ERPs for positive, negative and neutral pictorial stimuli in normal participants. They found that the P2 post-target component had the highest amplitudes for negative stimuli. It remains uncertain whether or not enhanced P2 verifies negative stimuli receive more attention than positive stimuli. Chen et al. [9] reported participants who experienced either positive or negative moods elicited smaller P2 amplitudes from negative pictures compared to positive pictures. A smaller P2 elicited by negative but not neutral stimuli was also observed in anxious and female participants [10,11]. Another possible candidate for this effect is the late positive

*Corresponding author (email: luoyj@bnu.edu.cn)

potential (LPP), a sustained P300-like component, which was measured in about a 400–700 ms time window and thought to reflect motivational engagement and commitment of attention resources [12,13]. In the paradigm of evaluation to stimuli valence, Ito et al. [14] found a larger LPP for positive and negative relative to neutral pictures, and for negative relative to positive pictures. Unpleasant words elicited more positive amplitudes than pleasant words across the components of P2 and LPP. According to Huang and Luo [7], the LPP amplitude evoked by negative pictures was larger than that by positive and neutral pictures.

As considerable evidence supported the negativity bias and tied it to evolutionary benefits, researchers regarded the negativity bias as something unchangeable. However, evolution is flexible if adaptive requirements are necessary. Relatively few studies address whether or not positive mood has any influence on attention inhibition or on the switching of this bias. One such researcher, Isaacowitz, reported [15] that compared with pessimists, optimists showed selective inattention to skin cancer images after controlling for attention to matched schematic line drawings. In an experiment, optimism was associated with a greater attention bias for positive stimuli relative to negative stimuli. Optimism was also associated with slower skin conductance response rates during negative stimuli. The optimists' attention bias away from negative stimuli showed that the current mood state actually affected whatever stimulus from the environment they attended to in the first place. From this point of view, it is apparent that optimists wear "rose-colored glasses" in their processing of information from the world [16]. By employing eye tracking methods, Wadlinger et al. [17] found that participants under an induced positive mood made more frequent saccades for slides of neutral and positive valence relative to negative valence. It illustrated that individuals experiencing positive emotions were inclined to seek joy in order to maintain their current mood. Smith et al. [18] posited that attention bias toward negative information was moderated by manipulating the probability of positive and negative stimuli, and thereby manipulating the accessibility of positive and negative information. The attenuation of negativity bias in Smith's study was due to increased accessibility of positive constructs in memory instead of mood alteration.

Despite two decades of research emphasizing the negative bias using the emotional Stroop task in clinical and non-clinical populations, the issue of the interaction of positive mood and attention remains inadequately examined. Observing the time course of brain activity associated with emotional information processing in different affective states provides fertile ground for the emotional regulation of mental disorders. The goal of the current study was to clarify 2 questions. First, we were interested in whether or not attention bias toward negative stimuli was moderated by positive mood in the Stroop paradigm of facial expressions. Second, ERPs reveal the temporal course (sensory or cognitive processing stage) of attention bias in positive or neutral moods. We speculated that an emotional Stroop effect would be observed under the neutral arousal condition, whereas attenuated by positive mood arousal. As a result, the P2 and LPP amplitudes elicited by negative and positive pictures would be different in the two arousal conditions. If positive mood arousal resulted in less attention for negative stimuli the difference potentials (negative minus positive picture) in the neutral condition would be larger than the difference potentials in the positive condition.

1 Methods

1.1 Participants

Twenty-four graduate students of Zhejiang Normal University participated in the experiment (13 women; age 20–28 years). All participants were right-handed and had normal or corrected to normal vision. None had any history of neurological or psychiatric disorders, and gave written informed consent to participate.

1.2 Stimuli

Thirty-four positive (pos) and 34 negative (neg) pictures were selected from the Chinese Facial Affective Picture System (CFAPS) [19] for use during this study. The positive and negative pictures were matched according to their valence and arousal values which were collected from a native assessment of CFAPS pictures in a previous survey. Valence means: pos=6.46 (SD=0.55), neg=2.66 (SD=0.41); arousal means: pos=5.79 (SD=0.83), neg=6.63 (SD=0.98). There was no significant difference in arousal strength between positive and negative pictures.

Two short videos were used to induce joy and neutrality. "Comedy" (4 min 54 s), a clip of a stand-up comedian, was used to induce joy. One video was used to induce neutral states. "Neutral" (5 min 2 s), featured footage from an instructional video about Chinese food being made in a kitchen. All people portrayed in the videos were Chinese. Immediately after the practice phase, immediately prior to starting the formal experiment, participants were randomly assigned to view the "Comedy" or "Neutral" video as their first induction. To assess the effectiveness of the mood induction, self-report measures (on a scale from 1 to 9, 1="extremely sad" whereas 9="extremely happy") were used after mood induction. Measure means of video induction: "Comedy"=6.92 (SD=1.38), "Neutral"=4.58 (SD=0.52).

1.3 Procedure

Stimuli were presented in the center of a 19-inch computer monitor on a gray background. Participants sat in a comfortable chair facing a computer monitor at a distance of 60 cm. In the experiment, participants were instructed to judge pictures as either red or blue as quickly and as accurately as possible, while ignoring the facial expression. They were to press “1” on the response box with their right index fingers if the picture was red, and “2” with their right middle fingers if the picture was blue.

All trials began with a fixation cross shown for 500 ms, followed by the presentation of the picture, which remained on the screen until the participant’s response. After the response and a 1000-ms blank, the next trial began (see Figure 1 for an example). There were 4 blocks of 272 trials. The task was preceded by 24 practice trials. Participants had a short break between blocks. In addition, the number of female pictures was equal to the number of male pictures.

1.4 ERP recording and data analysis

Electroencephalographic (EEG) data were recorded using a 128-Ag/AgCl electrode Geodesic Sensor Net (Electrical Geodesics, Oregon, USA) digitizing at 250 Hz. The electrodes’ distribution was set according to the international standard 10–20 sites system. Ocular artifacts were monitored by electrodes placed below and above the eyes and outside of both canthi. Impedance was kept below 50 kΩ.

EEG data were analyzed using the Netstation platform 3.0 (Electrical Geodesics). A 0.1–30 band-pass filter was applied offline. ERP data were computed using a 1000-ms epoch (100 ms prestimulus) and time locked to the onset of stimulus. All epochs exceeding ±60 μV on any of the electrodes were rejected. The baseline correction was related to the averaged interval between −100 and 0 ms. Only behavioral responses and ERPs to stimulus receiving a correct response were analyzed.

The RTs, error rates on the correct result was tested by repeated measure analyses of variance (ANOVA). Factor was the facial expressions (positive/negative) as repeated-measures factors and arousal (positive/neutral) as between-subjects factors. According to previous studies, the Fp1, F7, F3, Fz, F4, F8, Fp2, C3, Cz and C4 (for P2 and LPP) locations were selected for statistical analysis. The peak amplitudes and latencies of P2 (150–200 ms) and LPP (500–800 ms) were analyzed using repeated-measure ANOVA with arousal condition, facial expressions and electrode sites. To decrease the probability of Type I errors, Greenhaus-Geisser method corrected P values were computed for behavioral and ERP data when necessary.

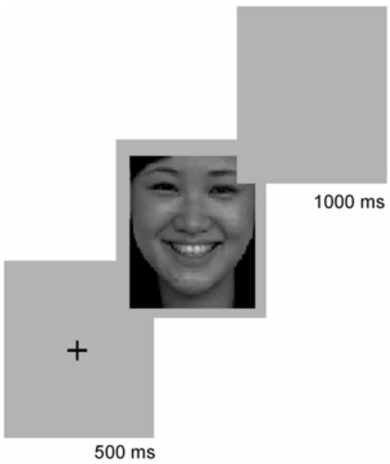

Figure 1 An example of a single trial. The face picture was presented on the screen until the participant’s response.

2 Results

2.1 Behavioral data

Table 1 shows means and standard deviations of RTs as a function of arousal and emotion pictures. RTs were longer in the neutral condition (M=488.15, SD=157.83) than in the positive condition (M=447.41, SD=121.59, $F(1,22)=43.22$, $P<0.001$). The interaction effect of the arousal condition and facial expressions was not significant. In the neutral condition, the proportion of correct responses was 95.8%, 94.9% to positive and negative pictures; in the positive condition, the percentage of correct responses was 98.1% and 98.4% to positive and negative pictures. The accuracy of the neutral condition was significantly lower than for the positive condition, $F(1,22)=6.22$, $P<0.05$.

2.2 Event-related potentials

ERP components were easily identifiable in all participants. Grand average ERPs to arousal condition by facial expressions are presented in Figure 2.

(i) P2 component. There was a significant main effect for facial expressions in the P2 amplitude, $F(1,22)=8.67$, $P<0.05$, the amplitude of the positive picture was larger than for the negative picture. A facial expressions × electrode sites interaction was found in the P2 amplitude, $F(9,198)=5.19$, $P<0.001$. Simple effects analyses were conducted to further investigate this interaction. A main effect of facial expressions on the P2 component was found over Fp1, $F(1,22)=5.32$, $P<0.05$, the amplitude was larger to positive pictures than to negative pictures. There was a significant main effect for facial expressions over Fz, $F(1,22)=23.93$, $P<0.001$, and the P2 amplitude was larger to the positive pictures than to the negative pictures.

The initial ANOVA revealed a significant interaction effect of arousal condition × facial expressions × electrode-

Table 1 Mean response time (ms) and standard deviations by arousal condition and facial expressions

Facial expressions	Neutral condition (n=12)		Positive condition (n=12)	
	Mean	SD	Mean	SD
Positive	485.62	160.94	444.19	119.15
Negative	490.68	154.72	450.63	124.03

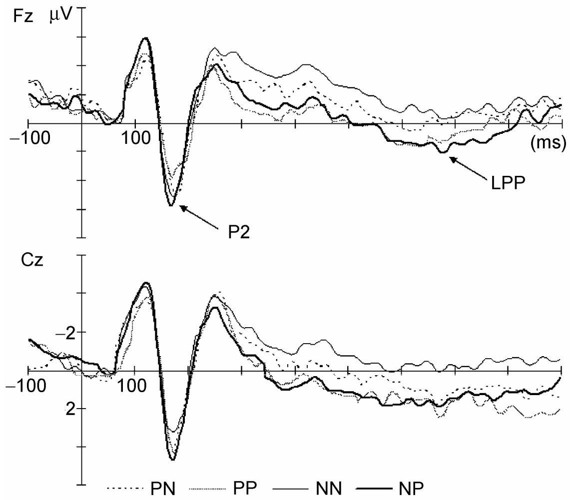

Figure 2 Grand average ERPs to arousal conditions by facial expressions. PN, negative pictures in the positive condition; PP, positive pictures in the positive condition; NN, negative pictures in the neutral condition; NP, positive picture in the neutral condition.

sites, F (9,198)=3.68, P<0.01. There was a significant arousal condition × facial expressions interaction on Fz, F(1,22)=4.62, P<0.05. Single comparisons showed that 2 factors contributed to this interaction. For the neutral condition, the main effect of the facial expression was significant, F(1,11)=29.60, P<0.001, the amplitude of positive facial expressions was larger than for negative. For the positive condition, the difference between facial expressions was not significant. On Cz, arousal condition and facial expressions produced a significantly interactive effect, F (1,22)=5.47, P<0.05, further analysis showed that positive facial expressions had greater positivity than negative for the neutral condition, F (1,11)=5.90, P<0.05. However, a P2 amplitude difference between facial expressions was not significant for the positive condition. There were no significant main and interactive effects on P2 latency.

(ii) LPP component. There was a significant interaction effect of arousal condition × facial expressions × electrode sites, F (9,198)=2.87, P<0.05. A main effect of facial expressions was found over Fz, F (1,22) = 13.31, P<0.01, positive facial expressions evoked significantly greater LPP than negative facial expressions. In addition, a significant interaction of facial expressions and arousal condition was found over Fz, F (1,22) = 8.05, P<0.05. For the neutral condition, the main effect of facial expression was significant, F(1,11)=16.45, P<0.01, the positive facial expressions elicited a larger LPP than did the negative. For the positive condition, there were no significant effects involving facial expressions. For Cz, the interaction of facial expressions and arousal condition was significant, F (1,22)=5.16, P<0.05. Single comparisons suggested that there was a significant main effect of facial expressions for the neutral condition, F(1,11)=7.02, P<0.05, the amplitude of the positive picture was larger than for the negative. In addition, there were no significant main and interactive effects on LPP latency.

(iii) Difference components. Difference potentials are shown in Figure 3. The DN (difference potentials in the neutral condition) and DP (difference potentials in the positive condition) were investigated by analyzing negative minus positive picture difference potentials in arousal conditions. The DN and DP peaked at frontal and central electrode sites. The amplitude in condition DN was significantly larger than for condition DP on Fz of 400–800 ms, F (1,22)=8.05; P<0.05. The amplitude in condition DN was significantly larger than for condition DP on Cz of 400–800 ms, F (1,22)=5.16; P<0.05.

3 Discussion

We conducted a modified emotional Stroop experiment to investigate the influence of positive mood on attentional negativity bias during emotional information processing. Participants were presented with facial expressions which were either congruent or incongruent with the arousal condition at the positive and neutral level.

We found that when participants made a color decision concerning red and blue faces which differed in emotional valences (happy and fear) taken from the CFAPS, they responded more rapidly and accurately in the positive condition than in the neutral condition. It has been demonstrated that mood modifies and influences the quality of cognitive processing and thus performance in cognitive tasks, despite its low level of intensity [20], because a happy mood appears to increase the use of stereotypes and other heuristics as a basis for judgment [21]. Accordingly, participants in a positive mood had enhanced performance in this study.

We did not find significant interaction between arousal

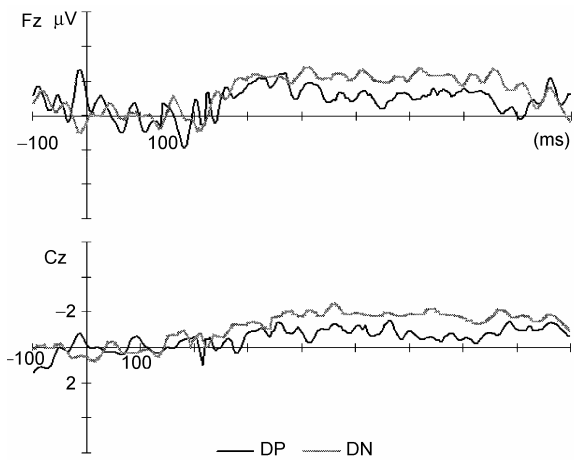

Figure 3 Negative minus positive picture difference potentials in arousal conditions. DP, difference potential in the positive condition; DN, difference potential in the neutral condition.

condition and facial expressions at the behavioral level. In other words, there was neither an emotional Stroop effect in the neutral arousal condition nor the facilitation of positive facial expression processing in positive mood arousal. This behavioral data was inconsistent with the previous general finding that negative stimuli obstruct cognitive judgment. There were other emotional Stroop studies showing that normal participants were able to respond to threat stimuli, including when rated as emotionally disturbing, with equivalent efficiency to neutral stimuli [22–24]. This suggested that under mood arousal circumstances negative pictures were not more difficult to ignore than positive pictures. Another possible reason was that participants either concentrated on the color of the faces presented on the screen rather than on their emotional facial expressions or developed strategies (such as blurring the focus of their eyes) to avoid processing the interfering picture's content [25].

The ERP findings did not follow the pattern of results noted in the behavioral data and provided strong evidence that positive mood affected the processing of facial emotional information. In particular, the sensory ERP component (i.e., P2), showed differences in response to negative and positive images across arousal conditions. The P2 component showed smaller amplitude to negative facial expressions versus positive faces across arousal conditions. It was similar to Chen et al.'s study [9] wherein predominantly negative pictures elicited smaller P2 than positive pictures regardless of which kind of mood induction. The author argued that frontal P2 activation within 200 ms is indicative of rapid detection of typical stimulus features so that a subconscious process that attends to the emotional salience of pictures was observed [9]. In our study, negative faces also served as a salient threatening signal, which was thought to rapidly and automatically capture human attention resources, thus the detection of predominantly threatening features was facilitated. In the above-mentioned experiment a music-primed valence categorization task was utilized, which had a closer tie with memory processing. In our opinion, the Stroop task better reflected automatic processing of emotional information. In line with other ERP studies showing the emotional Stroop effect begins at early stages of information processing, our ERP results indicated that negative attention bias in a modified Stroop paradigm may occur in relatively early attention stages of stimuli processing.

For LPP, negative pictures evoked smaller amplitude than positive pictures over the frontal area in both arousal conditions. This is a contrast to previous research done in emotional negativity bias, which found that the negative pictures evoked a larger LPP as compared with positive and neutral images. They speculated that LPP differences among facial expressions indicated that higher cognitive evaluation exerted an influence on emotional negativity bias [26]. Posterior P3 (or LPP), as an index of an inhibition of task-irrelevant information, has demonstrated that it also represents later conscious categorization, decision-making and premotor response-related activities [27,28]. For example, in an oddball task, a smaller P3b was observed to unpleasant pictures contrasted to neutral and pleasant pictures over a wide range of recording sites, because the processing engaged in this implicit emotional task was not based on the emotional content of each stimulus but on the rare/frequent distinction [29]. In Yuan et al.'s experiment [30], a smaller LPP was elicited by negative stimuli rather than by positive and neutral stimuli which reflected the degree to which individuals inhibit the task-irrelevant information. Consequently, in order to attain considerable rapidity, participants had to inhibit the emotional content of each picture. The strongest inhibition to negative faces may account for the small LPP across arousal conditions in the present study. Beyond that, LPP was also associated with emotional regulation. Li et al. [31] reported extremely negative pictures elicited smaller LPPs than less negative pictures in the evaluation stage of emotion processing, which did not follow the negativity bias. Similarly, with the repetition of negative stimuli, participants in the current experiment may have utilized an emotion regulating strategy, thereby causing the reduction of attention allocation to negative stimuli.

We found in the 400–800 ms interval, the amplitude differences between negative and positive images were larger under the neutral condition than under the positive condition. Previous studies [18] showed that attentional bias toward negative information was altered by affective context. According to this view, it was most likely that negativity bias was attenuated by positive mood arousal in our experiment. Under the positive arousal condition, for the purpose of maintaining the current emotion status, participants avoided the negative stimuli by attention reduction. The difference amplitudes were less pronounced for positive arousal, indicating less involvement of processing resources, although there were no discernable differences between faces at the RT level. It seemed that positive mood inhibited the processing and decreased the attention intensity to negative information.

The present study demonstrated the weakened attention bias toward negative stimuli, which has been regarded as being obligatory. The results convinced us that the interaction between emotion and cognition may occur in the preconscious stage. It is necessary to take the mental state into account when conducting an attention experiment. The attenuation strength of negative bias caused by the increased accessibility of positive information paves the way for emotional management. Individuals with social phobia and social anxiety found that their attention was always directed by threat-related stimuli, which intensified these disorders. It may therefore be possible to break down this pathological circle of mental disorders by manipulating the types of stimuli which are available.

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