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Temporal course of emotional negativity bias: An ERP study

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Abstract

There is considerable evidence that people are especially sensitive to emotionally negative materials. However, the temporal course of the negativity bias is still unclear. To address this issue, we observed the changes of P2, late positive components (LPC) and lateralized readiness potential (LRP) under positive, negative and neutral conditions, with International Affective Picture System (IAPS) pictures as emotional stimuli. We found that the amplitude of P2 in the negative block was significantly larger than that in the positive block, indicating that the attentional negativity bias occured very early in emotion perception. The LPC amplitude evoked by negative pictures was larger than that by positive and neutral pictures, suggesting that the negativity bias also occurred in a later evaluation stage of emotion processing. The response-locked LRP interval was shortest in the block of negative pictures, indicating that the negative contents elicited a reaction priming effect. Above all, this research showed that emotional negativity bias could occur in several temporal stages distinguished by attention, evaluation and reaction readiness periods.
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Considerable research has revealed that people seem to have a special sensitivity to emotionally negative events, which often get preferentially processed compared with positive and neutral events. When subjects were asked to respond to the emotional properties of the stimuli, the negative stimuli often seemed to facilitate the task more than the other stimuli [7,16]. When the task was to respond to some other aspect of the stimuli, it was often obstructed more heavily by negative stimuli than by other stimuli [18]. However, it is difficult for the behavioral approach to identify when this negativity bias occurs in emotional information processing. It may occur in the earlier attention allocation stage, or alternatively, in the later evaluation stage. And there is still another possibility that the stimuli do not differ in the information processing periods, but rather the negativity bias is resulted from a reaction readiness difference among positive, negative and neutral stimuli. Event-related brain potentials with a high temporal resolution have facilitated the studies with the purpose of identifying the temporal stages of the emotional negativity bias.

A growing body of literature documents a bias of attention toward negative over positive information [7,16]. In two studies [21], P1 amplitude was measured while participants evaluated positive and negative pictures. The results showed that P1 amplitude to frequent stimuli and to rare negative stimuli were larger than that to rare positive stimuli. Also, there are data indicating that two components, P200post and P340post, reflect input processing-related attention toward affective pictures [2]. In another experiment with an implicit emotional task, they found that P200, an attention-related component, showed higher amplitudes and shorter latencies in response to negative stimuli than in response to positive stimuli [3].

However, this early attention difference may not provide the sole explanation for the negativity bias. Since cognitive evaluation exerts an important influence on the generation and regulation of emotion, it is also possible that the bias may operate at the evaluative stage. To demonstrate this hypothesis, variations of a late positive component (LPC) were recorded as participants viewed positive, negative and neutral pictures [10]. Results revealed larger amplitude LPCs during the evaluative categorization of (a) positive and negative stimuli as compared with neutral stimuli and (b) negative as compared with positive stimuli.

The researches mentioned above devoted to only one certain mental stage of information processing. There is lacking more

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integral consideration about the whole process of emotional negativity bias. Moreover, some conflicting results between different mental processes can be seen in the previous study [21], although that was not the focus of their research. Recently, it was reported that the emotional effects were observed on P1, P2 and P3b in a non-emotional visual oddball task [6]. It indicated that the valence content of stimulus modulates the cognitive processes at several points in the information processing stream. But in fact, in order to acquire the equal arousal values, they had not matched the valence dimension strictly between the emotional conditions. The positive pictures they selected were more emotional extreme than the negative pictures. Nevertheless, in common points, it is better to select positive and negative stimuli with the equal emotional extremities when the experiments are aiming to shed light on the valence effect in the negativity bias. In addition, they found a puzzling result that unpleasant pictures evoked smaller P3b than pleasant ones, particularly at fronto-central sites, while on parietal sites the maximum of P3b was observed but did not differ significantly between the three valence levels. Similarly, in an experiment with briefly presented affective pictures, the LPC amplitude over centro-parietal sensor sites did not differ between pleasant and unpleasant stimuli, although they both elicited enlarged LPC compared to neutral images [20]. In contrast, in the experiment by Ito et al. [10], it was observed that negative pictures evoked larger LPC amplitude over the same scalp areas relative to positive and neutral images. In conclusion, when discussing the whole temporal course of the negativity bias, we encountered some confusing results in the previous researches. Experiments with strictly controlled conditions and more integral considerations are needed to address this issue.

In addition to attention and evaluation biases, it has long been supposed that there is possibly a reaction priming effect of negative material. Events that are emotionally negative are more likely to prime or activate a fight/flight response, thereby produce more extreme reactions. From stimulation onset to overt response, the reaction time period can be divided into at least two stages—psychological processing and response output—and the negativity bias may be produced at the response-output stage. Nevertheless, evidence for this response bias is scarce. It is difficult for behavioral researches to extract the reaction prime stage from the whole reaction period. In principle, this problem can be addressed by using the lateralized readiness potential (LRP) component of the ERP. The LRP is a negative shift that precedes hand-specific movements in the electroencephalogram (EEG). It is typically recorded from electrode sites C3′ and C4′ located over the left and right hand areas of the primary motor cortex, respectively [4,8,19]. LRPs can be either stimulus- or response-locked. The interval between a stimulus onset and the onset of the stimulus-locked LRP (S-LRP) is related to the duration of pre-motor processes (e.g., stimulus identification and response selection processes). The R-LRP interval is related to the duration of reaction readiness. Thus, the onset of the LRP provides a time marker between stimulus and response, enabling us to discern whether the negativity bias arises from the perception and evaluation of stimuli (associated with the S-LRP) or from the response-output period (associated with the R-LRP).

Therefore, the aim of the current study was to discern the temporal stages of the negativity bias. We further sought to determine whether negative material really elicits a greater allocation of early attention, or if it is preferentially processed later—in the evaluation stage; or alternatively if response readiness plays a critical role in the negativity bias. It is possible that all of these stages contribute to what we call the negativity bias.

Sixteen right-handed healthy undergraduates aged between 19 and 22 years (mean = 20.7) were included in this study. Eight of whom were male.

Fifty neutral (neu), 25 positive (pos) and 25 negative (neg) pictures were selected from the International Affective Picture System (IAPS) [12] for use during this study[1]. The positive and negative pictures were matched according to their normative valence extremity (indicated by the distance-score, i.e., the distance between the valence values and the neutral midpoint of the valence scale) and arousal values which were collected from a native assessment of IAPS pictures in a previous survey [9] (valence means: pos = 7.03, neg = 2.90, t-test of valence distance-score: $t_{48} = -0.842$, $p > 0.05$; arousal means: pos = 6.14, neg = 6.21, $t_{48} = -0.574$, $p > 0.05$). For the experimental paradigm, the neutral stimuli were separated into two equal-sized groups with comparable normative ratings: (a) valence $M = 4.89$, 4.93, $t_{48} = 0.409$, $p > 0.05$; (b) arousal $M = 3.71$, 3.82, $t_{48} = -0.529$, $p > 0.05$.

The participants were told that they would be watching pictures, each sized 10 cm × 7 cm, on a color computer monitor located approximately 70 cm in front of their eyes. After each picture onset, they were instructed to indicate, once they had a valence judgment, whether the picture was positive (or negative, by block, see below) or neutral by pushing the appropriate button on a response pad.

The pictures were presented in four counterbalanced blocks, each composed of 150 trials. Every two blocks consisted of the same copy of pictures differentiated in response hands (right thumb indicated emotional or right thumb indicated neutral) for the LRP extraction. In each block, pictures were presented for 1200 ms, each with a random inter-stimulus interval that varied from 900 to 1100 ms.

Electroencephalogram (EEG) data was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (NeuroScan Inc.), with the linked reference on the left and right mastoids. The vertical electro-oculogram (EOG) was recorded supra- and infra-orbitally at the left eye. The horizontal EOG was recorded from the left versus right orbital rim. Electrode impedances were below 5 kΩ. A bandpass of 0.05–70 Hz was

[1] Positive pictures were IAPS slides 2070, 8500, 2391, 8370, 8021, 8161, 5300, 7475, 5629, 8032, 5623, 5480, 1999, 1440, 8531, 5200, 5660, 8510, 1463, 7230, 1710, 5600, 1920, 2091 and 5831. Negative pictures were slides 9400, 2800, 9008, 1070, 1050, 9490, 3160, 6831, 6370, 9181, 1300, 9921, 1090, 7380, 3230, 9180, 9050, 3220, 2120, 2661, 1201, 6200, 6212, 6300 and 1030. Neutral group one consisted of IAPS slides 7030, 6150, 7234, 2200, 7140, 7710, 2221, 7035, 7180, 7235, 7185, 7560, 7050, 2440, 7100, 2570, 2590, 7550, 2880, 2410, 2381, 7217, 2210, 7620 and 5510. Neutral group two consisted of IAPS slides 7700, 7006, 7150, 9070, 2230, 5534, 2600, 7187, 2270, 5740, 7207, 7640, 7025, 7000, 6000, 7080, 7205, 7237, 7224, 7182, 7090, 2480, 7010, 7130 and 7002.

used for the recording amplifiers. The EEG and EOG data were digitized continuously at a sampling rate of 500 Hz/channel. A regression procedure was used in which variance correlated with vertical EOG activity was removed from the EEG signal. Trials with peak-to-peak deflection exceeding ±80 μV were excluded from averaging.

Each participant's individual trials were aggregated based on trial type. That is, one average ERP waveform was constructed for each cell of the 2 (block: positive or negative) by 2 (valence: emotional or neutral) design.

P2 and LPC were time locked to the stimuli onset. The averaging epoch was 1200 ms including a 200 ms pre-onset baseline. The following 27 electrode sites were chosen for statistical analysis: Fz, FCz, Cz, AF3, AF4, F1, F2, F3, F4, FC1, FC2, FC3, FC4, C1, C2, C3, C4 (for P2); CPz, Pz, CP1, CP2, CP3, CP4, P1, P2, P3, P4 (for LPC). P2 was measured in the 160–200 ms time window and LPC was in the 400–700 ms window. The latencies and amplitudes (baseline to peak) of P2 and LPC were analyzed using repeated-measures ANOVA with electrode site, block and valence as factors. The Greenhouse-Geisser epsilon correction was applied to adjust the degrees of freedom of the *F*-ratios.

LRPs were obtained from the bipolar recordings of the difference between electrode sites C3 and C4 according to a published formula [5]: $\mathrm{LRP} = (\mathrm{C3–C4})_{\text{right hand}} - (\mathrm{C3–C4})_{\text{left hand}}$. The S-LRP epoch was 1200 ms including a 200 ms pre-onset baseline. The R-LRP epoch was 1000 ms, beginning from 800 ms before response and having the first 200 ms as the baseline.

Onset latencies were obtained for each subject's average S- and R-locked LRP in each block × valence condition. Because of the low signal-to-noise ratio of the LRPs, a set of published criteria [21] was adopted to determine the onset time point. The S-LRP and R-LRP latencies were analyzed using repeated-measures ANOVAs with block and valence as factors. The Greenhouse-Geisser epsilon correction was applied to adjust the degrees of freedom of the *F*-ratios.

The repeated-measures ANOVA indicated that valence had a highly significant main effect on mean RT [$F(1, 15) = 41.96$, $p < 0.001$]. Mean RT was faster with emotional stimuli than with neutral stimuli. As for the accuracy rate (ACC), block had a main effect [$F(1, 15) = 6.69$, $p < 0.05$]. Subjects appear to have had more difficulty discriminating positive and neutral pictures than discriminating negative and neutral pictures. None of the other main effects or interactions for mean RT or ACC was significant.

The grand averages of P2 elicited by each block × valence condition are shown in Fig. 1A and B. The positive minus neutral (in positive block) difference waves and the negative minus neutral (in negative block) difference waves are also shown in the figure. There was a significant main effect of P2 latency for valence [$F(1, 15) = 10.04$, $p < 0.01$]. Follow-up pairwise

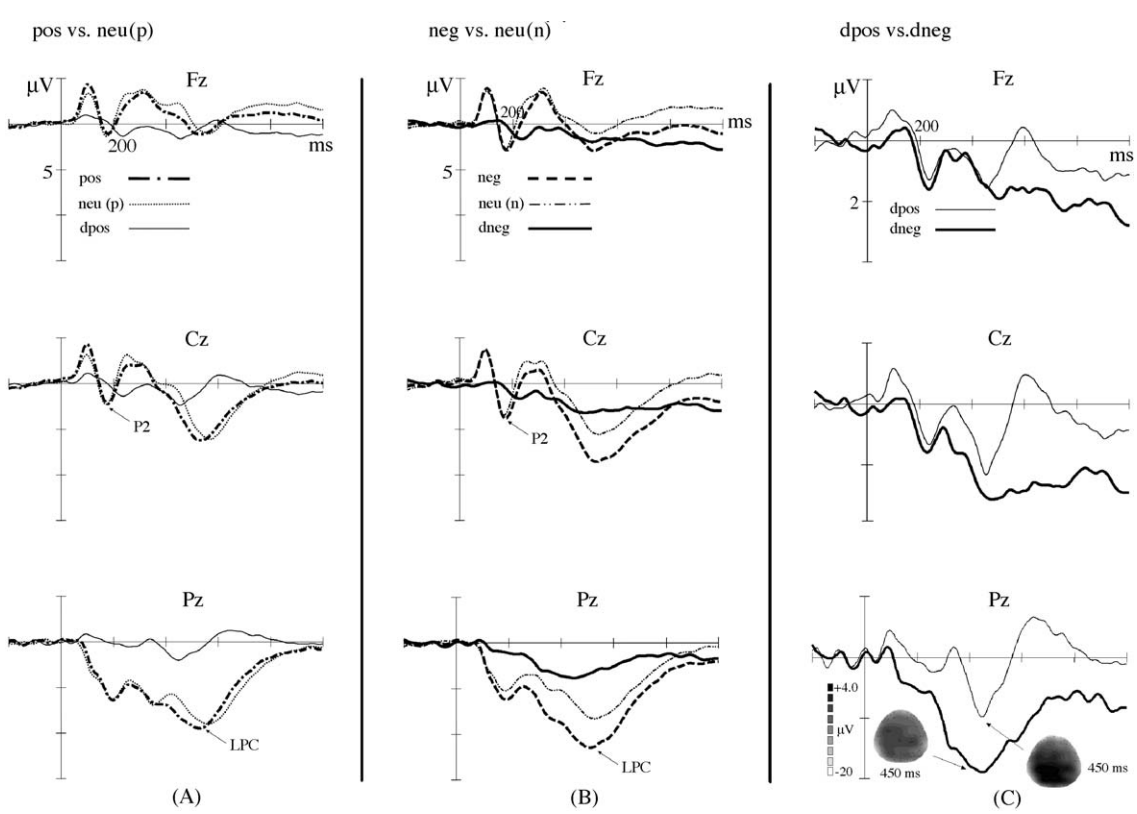

Fig. 1. (A) Averaged ERPs for the positive and the neutral condition in the positive block, and positive minus neutral difference waves [pos: positive; neu (p): neutral in the positive block; dpos: pos − neu (p)]. (B) Averaged ERPs for the negative and the neutral condition in the negative block, and negative minus neutral difference waves [neg: negative; neu (n): neutral in the negative block; dneg: neg − neu (n)]. (C) Positive minus neutral difference waves, negative minus neutral difference waves and their topographical maps. Note that the difference waves shown here are same with that in (A) and (B) in nature.

comparisons indicated that neutral stimuli had a shorter latency than emotional stimuli. There were significant main effects of P2 amplitude for electrode site and block [$F(16, 240) = 7.24$, $p < 0.001$; $F(1, 15) = 20.82$, $p < 0.001$]. The largest amplitude appeared on the central sites (e.g., Cz, C1 and C2). The block effect was due to the larger amplitude in negative block. No other significant main effects or interactions were found in P2.

Fig. 1 also displays the grand average waveforms of LPC from each experimental condition. Main effects were found in LPC latency for electrode site and valence [$F(9, 135) = 4.85$, $p < 0.05$; $F(1, 15) = 11.18$, $p < 0.01$]. The latencies in parietal sites were shorter than those in central-parietal sites. The emotional stimuli had a shorter latency than neutral stimuli. Main effects of LPC amplitude were found in electrode site and valence [$F(9, 135) = 3.01$, $p < 0.05$; $F(1, 15) = 28.53$, $p < 0.001$]. The medial-parietal sites (e.g., Pz, P1 and P2) recorded larger amplitudes than other sites. Emotional stimuli elicited larger LPC than neutral stimuli. There was also a valence × block interaction [$F(1, 15) = 16.51$, $p < 0.01$]. Simple effects analyses were conducted to explore this interaction further. Simple effects of block revealed that positive and negative stimuli elicited larger LPCs than neutral stimuli, $F(1, 15) = 8.22$, $p < 0.05$ and $F(1, 15) = 42.37$, $p < 0.001$, respectively. This is shown by the difference waves and topographical maps in Fig. 1C. Simple effects of valence revealed that negative stimuli elicited a larger LPC than positive stimuli [$F(1, 15) = 15.80$, $p < 0.01$], but that the amplitudes from neutral stimuli did not differ in different blocks [$F(1, 15) = 0.05$, $p > 0.05$].

The grand average waveforms of S-LRP and R-LRP are shown in Fig. 2. Only the onset latencies were analyzed here since we were particularly interested in the chronometry property of LRP. There was a significant main effect in S-LRP onset latency for valence [$F(1, 15) = 13.97$, $p < 0.01$]. The S-LRP onset was reached earlier for emotional stimuli than for neutral stimuli. R-LRP onset latency showed main effects for block and valence, and a significant interaction of the two factors [$F(1, 15) = 6.20$, $p < 0.05$; $F(1, 15) = 6.33$, $p < 0.05$; $F(1, 15) = 6.13$, $p < 0.05$]. Further analysis determined that all the effects were due to a shorter R-LRP latency of negative stimuli.

In this experiment all three index components, P2, LPC and LRP, showed differences in response to negative and positive stimuli. This indicates that the emotional negativity bias can occur at multiple time points of the whole duration of information perception and responding. It may take on different characteristics at different time points and thus, depend on different underlying mechanisms.

In the P2 time window, about 200 ms after stimulus onset, the amplitude of the negative block was significantly larger than that of the positive block. In view of the relationship between attention allocation and P2 amplitude [3], this indicates that negative events can occupy more attention resources than can positive events. Since 200 ms is an early time stage and P2 is an index at the boundary of unconsciousness and consciousness, the attention bias appears to occur automatically. The amplitude elicited by neutral stimuli was comparable to that elicited by emotional (negative or positive) stimuli matched in the same block, so the two groups of neutrals also showed differences. Because the neutral groups were matched in valence and arousal, it is evident that this difference resulted from the emotional background of the stimuli in the same block. This interpretation would be stronger if the two neutral groups had been counterbalanced across subjects. It seems that the neutral material was not clearly discriminated from the emotional material, suggesting that although attention can be allocated to more emotional, or valuable information rapidly and even automatically, the inputs are not necessarily processed carefully and thoroughly. Probably, in this short time, only some features of the stimuli are captured by the nervous system and people respond quickly to their outer environment according to the limited information available. Alternatively, emotional stimuli elicited longer latencies than neutral stimuli, so emotional stimuli may require longer attentional engagement due to a greater informational burden.

Since LPC is regarded as a component related to the evaluative meaning, examining the LPC results reveals that the negativity bias also exists in evaluation stage and manifests some different characteristics from the attention bias discussed above. In this stage, the emotional stimuli had a shorter latency than neutral stimuli. This implies that information with emotional value can be analyzed and evaluated preferentially. The evaluation bias toward negative events is more distinct in LPC amplitude. Negative pictures evoked a larger LPC than positive pictures, and neutral pictures elicited the smallest amplitude with no difference between the two neutral groups. This is consistent with a previous research done using an oddball paradigm [10]. It is well known that cognitive evaluation plays an important role in generation and regulation of

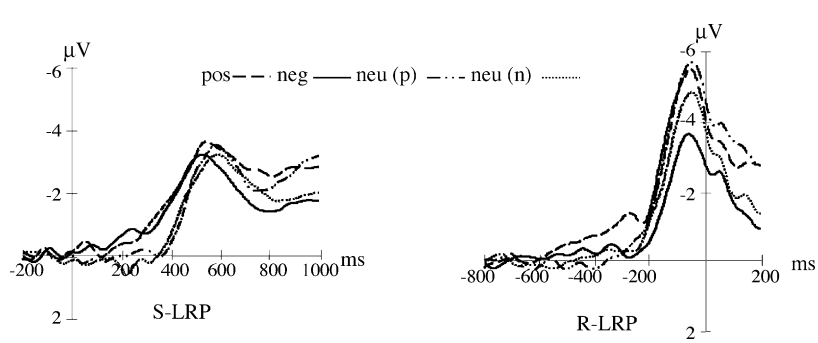

Fig. 2. Grand averages of stimulus- and response-locked LRP in response to the four groups of stimuli.

emotion. Differentiated from the quick and automatic process, a deliberative and controlled process is involved in the evaluation bias. In this stage, information is represented and analyzed more fully, with more factors considered and more experiences referenced. Stimuli with different emotional valences can be discriminated clearly in this period, and negative information recruits more physiological and psychological resources, presumably because of its importance for survival and daily life.

It is commonly accepted as the working definition for emotion that emotions are action dispositions—states of vigilance that vary widely in reported affect, physiology and behavior [11]. Generally, negative events require higher action readiness than do positive events. Negative events often elicit a fight/flight action that can be organized and triggered in a rather short time in order to ensure the organism's survival or predominance in natural or social environments. This rapid response course can be divided into two stages: (1) information perception and (2) response priming and execution. Findings from the S-LRP onset latency suggested that less time is needed to finish psychological processing of emotional stimuli than do that of neutral information. The time saving shows the value of emotional information, which recruits more psychological energy and enables organisms to adapt to environments quickly. On the other hand, negative stimuli had shorter R-LRP latencies (i.e., from the finish of valence judgment to response execution) than other kinds of stimuli. Negative material required little time for reaction readiness, while there was no difference between R-LRP latencies for positive and neutral information. This response bias for negative material would allow organisms to take action as quickly as they can to deal with dangerous situations.

The present results imply that both automatic and controlled processes are involved in the negativity bias. It is reported that multiple neural structures, such as the amygdala, the basal ganglia, and the lateral prefrontal and association cortices, are involved in the emotional information processing [13,15,22]. The complexity of multiple mechanisms and neural structures for negativity bias may explain the not-so-consistent characteristics between attention bias and evaluation bias. They occur at different time stages of information processing and are manipulated by different neural substrates, and perhaps perform different functions. Accordingly, the differences existing in the amplitude and latency trend between P2 and LPC are understandable. It is also assumed that positive and negative evaluative processes resulted from the operation of separable positive and negative motivational substrates, respectively [1]. Therefore, it is reasonable to conclude that the big-and-small relationship of amplitude elicited by positive and negative material is not so consistent in different electrode sites or various experiments, although the current results demonstrated that the negative pictures elicited bigger amplitudes than the positive pictures at several different time points.

The present study illustrates that emotionally negative information is treated differently, and perhaps preferentially during attention, evaluation and reaction readiness periods of the information processing stream. However, many questions remain regarding the nature of the negativity bias: How early does the negativity bias occur in information perception? Does it hold for all negative stimuli or for only a specific subset (e.g., learned versus innately fearful stimuli [14,17])? What neural substrates are involved in the bias and how do they function in the process? How can we systematically depict the psychological and physiological mechanisms? Answers to these questions will contribute greatly to our understanding of emotion.

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