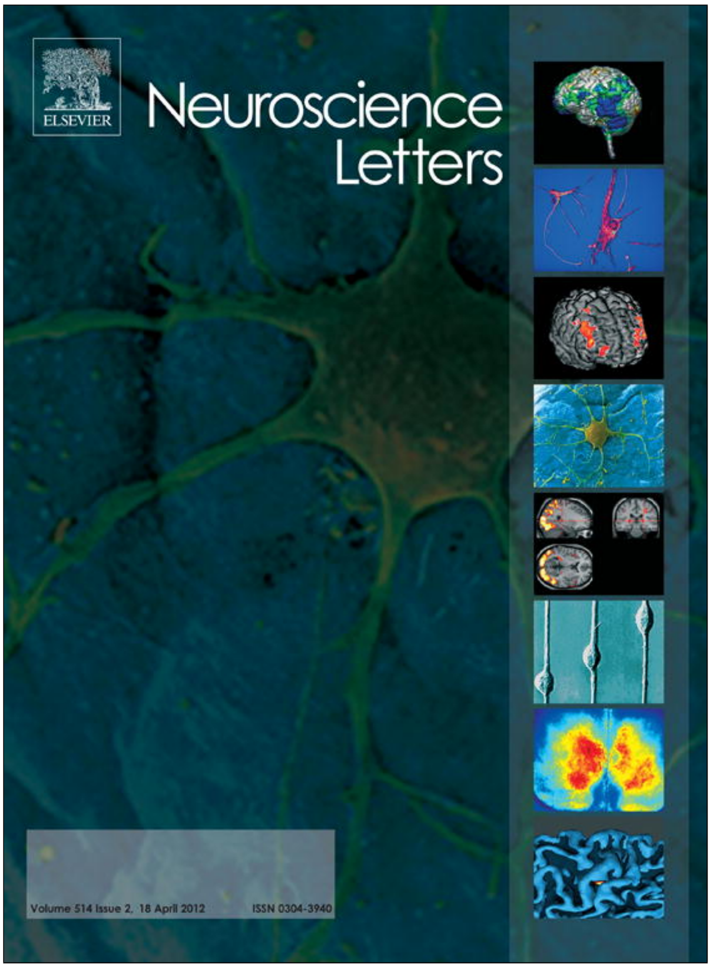
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Expectation decreases brain susceptibility to fearful stimuli: ERP evidence from a modified emotion evaluation task

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ABSTRACT

Expectation decreased the susceptibility to fearful stimuli in prior studies using distracting tasks. The present study tests whether expectation remains effective in decreasing this susceptibility, when subjects focus attention on emotional properties. Event-related potentials were recorded for fearful and neutral faces, while subjects performed a modified emotion evaluation task during unpredictable and predictable conditions. Behavioral data showed faster response latencies during predictable versus unpredictable conditions. ERP data showed prolonged peak latencies in N1 (80–130 ms) and larger amplitudes in P2 (130–180 ms) and N200-300 components, for unpredictable fearful versus neutral faces. Conversely, all these components showed similar responses to predictable fearful and neutral faces. Source analysis suggested that medial temporal lobe mediated ERPs elicited by unpredictable fearful faces, while ventromedial prefrontal cortex mediated those elicited by predictable fearful faces, in the 130–180 ms interval. Thus, we propose emotional expectation as a cognitive regulation strategy that reliably dampens human susceptibility to fearful stimuli.

1. Introduction

In real-life situations, the occurrence of emotional events is unpredictable in most cases [10,28]. Considerable research showed a preferential processing of unpredictable salient stimuli over other stimuli, probably because it is evolutionarily beneficial to be sensitive to unexpected dangers [23,28]. However, emotional events are not necessarily unpredictable [12,13,18]. This is noticeable in social situations, where individuals anticipate others' emotional states through theory of mind [21]. Many studies investigated neural underpinning during anticipation of emotional stimulus [4,17]. However, the impact of expectation on the susceptibility to emotional stimuli and its neural mechanisms remain insufficiently understood. Though Onoda et al. [18] showed reduced visual cortex processing of negative stimuli during affective cue versus null cue conditions, the lack of a neutral baseline and the sole activity in visual cortex, made it difficult to conclude the impact of expectation on brain susceptibility to emotional stimuli. Recently, our ERP study observed that expectation decreased the brain responding to fearful facial expressions, when subjects were required to perform a distracting, non-emotional cognitive task [26].

In life settings, emotion often occurs accidentally in a non-emotional, cognitive context [10,27]. Accordingly, a task that does not require subjects to evaluate emotion may allow emotional responses in the lab to closely resemble that in natural situations [28]. Despite this strength, the non-emotional cognitive task distracts subjects' attention from emotion dimensions of the stimuli, consequently leading to a reduction of emotional brain responding [6,11,20]. This is evidenced by smaller P3 amplitudes for emotional versus neutral stimuli in ERP studies [6,9]. In contrast, attention focus on emotion dimensions, as is the case of emotion evaluation tasks, enhances emotional brain responding and is associated with symptoms of depression [14,22,24]. Thus, the attention engaged in emotional events is effective in predicting the magnitude of emotional brain responding.

Consequently, though our prior study observed that expectation decreased brain susceptibility to fearful faces, this effect is likely a result of attention distraction from emotional stimuli, not necessarily due to the impact of expectation [6,9,11]. Therefore, it is necessary to conduct another study, addressing whether expectation really decreases fearful emotion susceptibility after excluding the effect of attention distraction. The solution to this question is important, especially when considering expectation as a potential strategy to regulate unpleasant emotion.

Therefore, using ERP measures, the present study investigated the impact of emotional expectation on human brain susceptibility to fearful faces. Instead of using a covert emotional task

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which reduces brain responding to emotional stimuli [6,9,11], the present study used an adapted emotion evaluation task that is known for enhancing brain responding to emotional stimuli [22]. Different from the traditional emotion evaluation task that requires judging the valence of pictures by immediate key-pressing, the present study required subjects to judge the emotion of the faces by careful observation, in the absence of immediate responses. The purpose of this design is to avoid the contamination of motor selection and execution on the emotion effect during face presentation [5]. Specifically, the performance of emotion evaluation in the absence of a motor task, allows subjects to focus on the emotion of face pictures without the interference of irrelevant motor processes, consequently to ensure the full generation of emotional brain reaction to fearful faces. It would be reliable to conclude that expectation reduces the susceptibility to fearful emotion; if predictable fearful faces are unable to produce an emotion effect in a task that entails intensified attention to fearful information.

2. Method

2.1. Subjects

As paid volunteers, 16 college students (8 males) participated in the experiment (19–23 years; mean = 20.87). All subjects were healthy, right-handed, had normal or corrected to normal vision, and had no history of affective disorder. All participants signed an informed consent form for the experiment. The experimental procedure was in accordance with the ethical principles of the 1964 Declaration of Helsinki (World Medical Organization, 1996).

2.2. Materials

The present study employed a modified cue-target paradigm whereby the valence of the cue picture validly indicated the emotion of the subsequent face. Two-factors, cueing status (cue, no cue) and target emotion (fearful, neutral), were manipulated in the experiment. Therefore, there were four conditions in the experiment: neutral cue–neutral faces, fearful cue–fearful faces, no cue–neutral faces, and no cue–fearful faces. The experiment consisted of four blocks, with each block including 64 trials equally distributed into four conditions. The onset sequence of the four conditions was randomized across the trials.

The target face stimuli consisted of 16 face photographs (8 models posing a fearful or neutral expression) taken from the Facial Expression of Emotion: Stimuli and Tests (FEEST) [29] originated by Ekman and Friesen (1976). All facial images removed the models' hair and other non-facial features. In addition, 32 pictures (16 fearful pictures, 16 neutral pictures) taken from the Chinese Affective Picture System (CAPS) served as the pre-face cues whose valence validly predicted the emotionality of the subsequent faces [2].

The cue pictures used in the experiment were validated by another group of subjects (N = 49). These subjects were recruited to rate the degree of fearful emotion experience by a 3-point scale (from 1 = neutral to 3 = highly fearful) during viewing these CAPS pictures. The selected 16 fearful pictures were consistently rated by all subjects as highly fearful (scored "3") in the fear assessment. The paired neutral pictures were selected in such a way that the fearful and neutral pictures differed in valence [mean: fearful cue = 2.12, neutral cue = 5.24; $F(1,30) = 225.539$, $p < 0.001$] but were overall matched in arousal [mean: fearful cues = 6.10, neutral cues = 5.92; $F(1,30) = 1.24$, $p > 0.1$].

2.3. Procedure

Subjects were seated in a quiet room at approximately 150 cm from a computer screen, with the horizontal and vertical visual angles below 6°. Prior to the experiment, they were told that the faces were sometimes preceded by emotion-congruent CAPS pictures. Each trial was initiated by a 500 ms presentation of a small black fixation on the white computer screen. A white blank screen of random duration between 500 and 1000 ms was followed by the presentation of either a cue picture or the fixation cross (i.e., no cue) for 500 ms. Subjects solely needed to passively view the cue pictures or the cross. The cue picture, or the cross, was then replaced by a variable 500–1000 ms blank screen which, again, was followed by the presentation of face stimuli for 500 ms. Subjects were required to carefully observe the face stimuli and to evaluate the facial emotion (fearful or neutral), in the absence of motor response requirement. The face stimulus was then replaced by a 300 blank screen which, subsequently, was followed by the presentation of a blue cross. Half of the subjects were required to press the "F" key when the blue cross followed fearful faces, and to press "J" key when the cross followed neutral faces (see Fig. 1). The response hands were reversed for the other half of subjects. The blue cross presentation was terminated by a key-pressing. Prior to the experiment, 20 practice trials were used to familiarize subjects with the experimental procedure.

2.4. ERP recording and analysis

The EEG was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (Brain Products), with the average reference on the left and right mastoids and a ground electrode on the medial frontal aspect. The vertical electrooculograms (EOGs) were recorded supra- and infra-orbitally at the left eye. The horizontal EOG was recorded from the left versus right orbital rim. The EEG and EOG were amplified using a DC ~ 100 Hz bandpass and continuously sampled at 500 Hz/channel. All inter-electrode impedance was maintained below 5 kΩ. Averaging of ERPs was computed off-line. Trials with EOG artifacts (mean EOG voltage exceeding ±80 μV) and those contaminated with artifacts due to amplifier clipping or peak-to-peak deflection exceeding ±80 μV, were excluded from averaging.

EEG activity for correct responses in each condition was separately averaged. Thus, four types of ERPs, composed of each combination of cueing status (cue versus no cue) and face emotion (fearful versus neutral), were obtained (i.e., neutral cue and neutral faces, fearful cue and fearful faces, no cue and neutral faces, no cue and fearful faces). To test whether subjects were able to discriminate fearful and neutral cue pictures through which they predict the emotions of the subsequent faces, we first tested the emotion effect elicited by the cueing pictures. ERP waveforms were first time-locked to the onset of cue pictures and the average epoch was 800 ms, including a 200 ms pre-stimulus baseline (Fig. 1). Enhanced positive amplitude was induced by fearful relative to neutral cues across frontal and central sites, which began at about 200 ms and ended at about 600 ms post stimulus. Thus, the following 9 centro-to-frontal sites: Af3, Af4, FC3, FC4, FCz, Cz, CPz, CP3, CP4, were selected to analyze the cue-induced emotional effects. A repeated measures analysis of variance (ANOVA) was conducted on the averaged amplitudes in each 100 ms interval of the 200–700 ms time window, with the emotion (fearful, neutral) and electrode sites (9 sites) as repeated factors.

Subsequently, the ERP waveforms were time-locked to the onset of face stimuli and the average epoch was 1200 ms, including a 200 ms pre-stimulus baseline. As shown by Fig. 2, facial expressions, irrespective of emotion and cueing status (cue versus no cue), induced a prominent face-sensitive P2 (vertex positive potential, VPP) component that was largest at central sites. Additionally, all facial expressions elicited an early N1 (80–130 ms) and a late N200-300 activity. Thus, the following 12 electrode sites were selected for statistical analysis: Fz, FCz, FC3, FC4, Cz, C1, C2, C3,

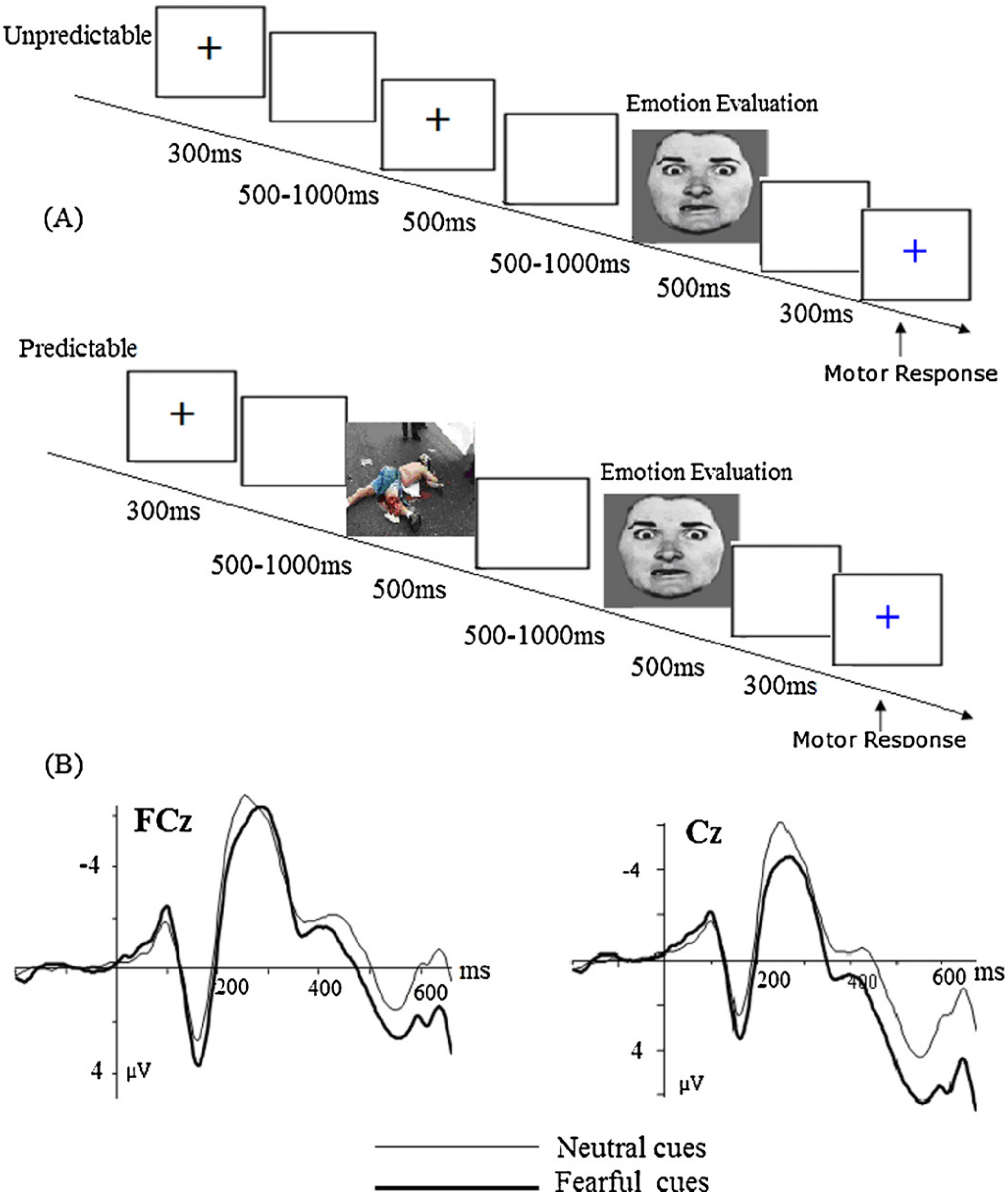

Fig. 1. Schematic illustration of the experimental procedure and the stimulus examples (A), and the averaged ERPs elicited by cueing pictures.

C4, CP1, CP2, Pz. The amplitudes (baseline to peak) and peak latencies of the N1 (80–130 ms) and the P2 (130–180 ms) components were measured and analyzed with cueing status (cue, no cue), emotion (fearful, neutral) and electrode sites (12 sites) as repeated factors. In addition, the averaged amplitudes for facial expressions during the 200–300 ms interval, which displayed pronounced differences across conditions, were analyzed accordingly. The degree of freedom of the *F*-ratio was corrected according to the Greenhouse–Geisser method.

3. Results

3.1. Behavior data

Each subject achieved more than 85% accuracy rate for fearful and neutral faces, irrespective of cueing status (cue versus no cue). In addition, we included trials with correct responses and reaction times (RT) within 1000 ms for the subsequent RT analyses. The two-way repeated measures ANOVA of RT data, with the cueing status (cue, no cue) and emotion (fearful, neutral) as factors, demonstrated no other main or interaction effects except for a significant main effect of cueing status. Cued faces (372 ± 21 ms) elicited faster response times than did uncued faces (435 ± 19 ms), irrespective of whether the facial expression is fearful or neutral [$F(1,15) = 15.26$, $p = 0.001$]. This indicated that the presentation of a cueing picture facilitated the subsequent emotion evaluation of the face stimuli. This coincided with the results of post-experiment debriefing where each subject reported detection of the link between the cueing pictures and the subsequent facial expressions.

3.2. ERP data

3.2.1. Emotional effect of cues

200–300 ms: there was a significant main effect of electrode sites ($F(8,120) = 4.11$, $p < 0.05$), and a significant emotion by electrode sites interaction ($F(8,120) = 4.77$, $p < 0.02$). Fearful pictures elicited more positive amplitudes than neutral pictures, and this effect was most pronounced at central-to-parietal sites. Additionally, the averaged amplitudes were larger at frontal versus central sites.

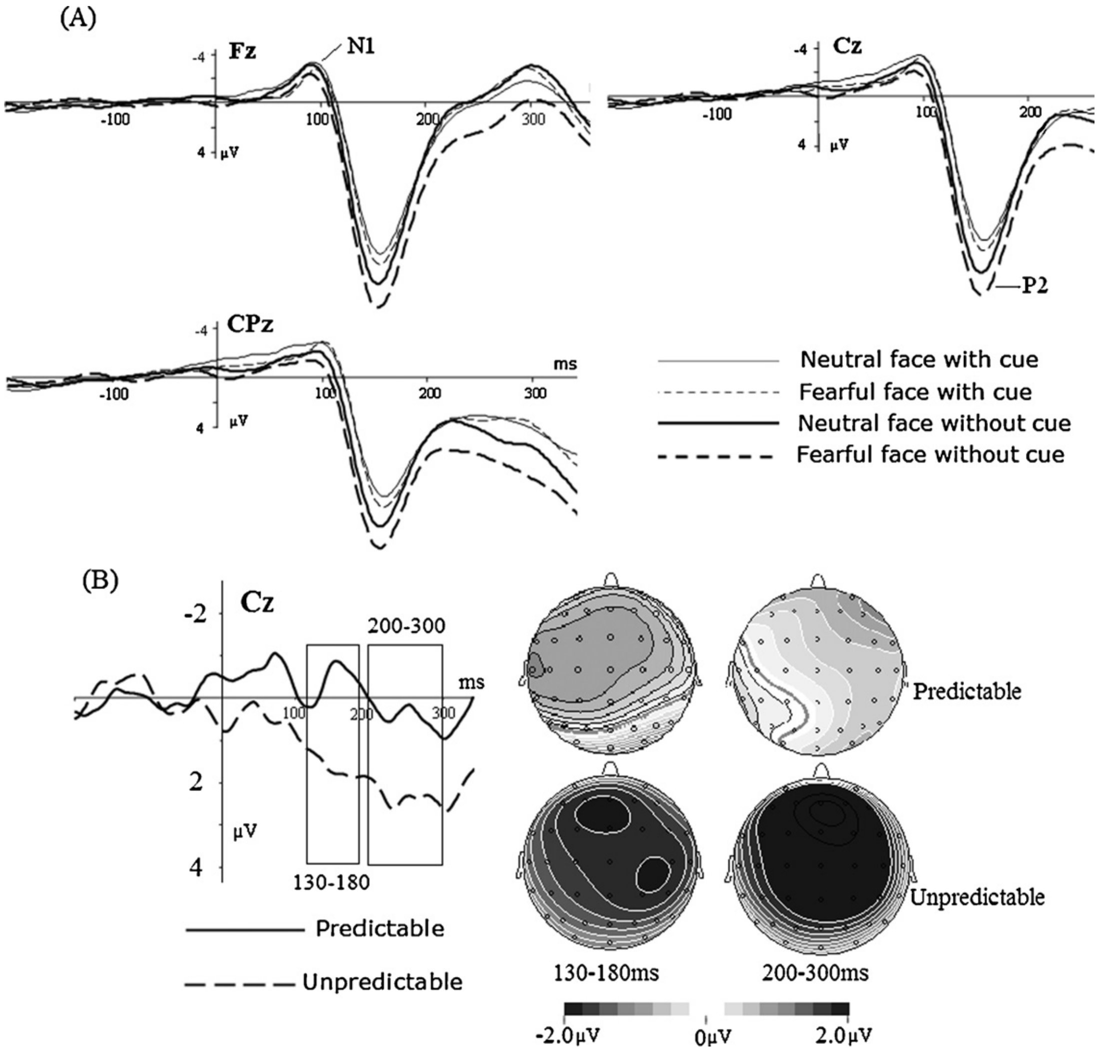

Fig. 2. T op panel (A): Averaged ERPs elicited by face stimuli during cued neutral (thin solid lines), cued fearful (thin dashed lines), uncued neutral (bold solid lines) and uncued fearful (bold dashed lines) conditions. Bottom panel (B): Fearful–neutral difference ERPs during cued (predictable) and uncued (unpredictable) conditions, and the topographical maps for fearful emotion effect during cued and uncued conditions. It is apparent that fearful faces elicited more pronounced emotion effect during uncued versus cued conditions.

300–400 ms: there was no other main or interaction effects, except for a significant main effect of emotion ($F(1,15) = 8.03$, $p < 0.02$). Fearful pictures elicited larger positive amplitudes than neutral pictures.
400–500 ms: there was no other main or interaction effects, except for a significant main effect of emotion ($F(1,15) = 10.73$, $p < 0.01$). Fearful pictures elicited more positive amplitudes than neutral pictures.
500–600 ms: there were significant main effects of emotion ($F(1,15) = 12.27$, $p < 0.01$) and electrode sites ($F(8,120) = 5.81$, $p < 0.01$), as well as a significant emotion by electrode sites interaction ($F(8,120) = 5.75$, $p < 0.01$). Fearful pictures elicited more positive amplitudes than neutral pictures, and this effect was more pronounced at central-to-parietal sites than at frontal sites. Additionally, the averaged amplitudes were largest at central-to-parietal sites. However, the amplitude differences between fearful and neutral cueing pictures were non-significant in the 600–700 ms interval ($F(1,15) = 1.08$, $p > 0.3$).

Thus, the 200–600 ms interval, instead of later time points, exhibited a fearful emotion effect. This suggested that participants were able to predict fearful faces from the detection of fearful cues, and that the cue-induced emotion effect did not obscure the following target-induced effects. This coincided with the subjects' reports that unpleasant pictures reliably predicted the subsequent presentation of fearful faces.

3.2.2. *The expectation effect on the brain susceptibility to fearful faces*

The analyses of N1 amplitudes showed no significant main or interaction effects. The analysis of N1 latencies displayed significant main effects of cueing status ($F(1,15) = 6.97$, $p = 0.019$) and emotion [$F(1,15) = 10.51$, $p = 0.005$], as well as a significant emotion by cueing status interaction ($F(1,15) = 11.57$, $p = 0.004$). The peak latencies were longer for fearful (101 ms) than for neutral (96 ms) faces in uncued ($p = 0.003$), but not in cued (97 ms versus 96 ms, $p = 0.082$), conditions.

The ANOVA of P2 amplitudes revealed a significant main effect of cueing status ($F(1,15) = 10.52$, $p < 0.001$) and a significant main effect of electrode sites ($F(11,165) = 26.09$, $p < 0.001$). P2 amplitudes were larger for uncued than for cued faces, irrespective of the face emotions. In addition, P2 amplitudes were most pronounced at central sites. More importantly, there was a significant emotion and cueing status interaction in P2 amplitudes ($F(1,15) = 7.96$, $p = 0.013$). The breakdown of this interaction displayed increased amplitudes for fearful (M ± S.E.: 16.68 ± 1.31 μV) versus neutral faces

(14.99 ± 1.22 μV) during the uncued condition ($F(1,15) = 11.78$, $p = 0.004$). By contrast, the amplitude differences between fearful (13.57 ± 1.21 μV) and neutral faces (13.16 ± 1.01 μV) were not significant during the cued condition ($F(1,15) = 0.38$, $p = 0.55$). The analysis of P2 latencies displayed no significant main or interaction effects.

The repeated measures ANOVA of the N200-300 amplitudes revealed significant main effects of emotion ($F(1,15) = 16.19$, $p = 0.001$) and electrode sites($F(11,165) = 12.23$, $p < 0.001$), as well as a significant cueing status and emotion interaction ($F(1,15) = 5.27$, $p = 0.036$). The amplitudes in this interval, irrespective of cueing status and emotion, were largest at parietal sites. The breakdown of the cueing status and emotion interaction showed significant differences between fearful (4.32 ± 0.92 μV) and neutral (1.94 ± 1.04 μV) facial expressions during the uncued condition ($F(1,15) = 14.41$, $p = 0.002$). Conversely, the amplitude differences between fearful (2.31 ± 1.07 μV) and neutral (1.83 ± 0.86 μV) faces were not significant during the cued condition ($F(1,15) = 1.51$, $p = 0.24$). Therefore, the present study observed pronounced emotional responses to unexpected fearful faces. However, the emotional reactions were attenuated when the appearance of fearful faces was predictable (Fig. 2).

3.2.3. Source modeling

To unravel neural bases mediating this expectation effect, we conducted source analysis for ERPs elicited by predictable and unpredictable fearful faces, respectively. The results showed that medial temporal lobe mediated ERPs elicited by unpredictable fearful faces, and ventromedial prefrontal cortex mediated those elicited by predictable fearful faces, in the 130–180 ms interval (for details, see Supplementary Material 1).

4. Discussion

Using ERP measures, the present study investigated the impact of expectation on the susceptibility to fearful emotion during intensified attention to fearful faces. The predictable condition was realized by using CAPS pictures as cues whose valence predicted the emotionality of the faces. The unpredictable condition, where no cue was presented prior to the face onset, was used as the baseline. We used an emotion evaluation task without requirement of immediate responses, to exclude the contamination of motor-related processes on the emotion effects [5]. We observed that expectation decreased brain susceptibility to fearful faces in N1 , P2/VPP and N200-300 time intervals, and the processing of unpredictable and predictable fearful faces engaged different neural substrates.

With expectation for the face affect, subjects did not react more intensely to fearful versus neutral faces at N1, P2 and N200-300 time intervals. Firstly, the present study observed prolonged peak latencies of N1 for fearful versus neutral faces in the unpredictable, but not in the predictable, condition. This suggests that unexpected fearful faces, due to its biological significance, elicited sustained engagement of early visual attention in comparison with neutral faces [16]. However, this preferential processing of fearful information vanished with antecedent expectation. Thus, when subjects' attention was focused on the emotional attributes of the stimuli, expectation remains effective in decreasing brain susceptibility to fearful stimuli, and this effect happens even in the early visual attention stage around 100 ms post stimulus. This is in contrast to our prior study, where the expectation effect arose at around 200 ms post stimulus when subjects were engaged in a non-emotional, distracting task [26]. Thus, intensified attention to emotional attributes does not diminish, but increase, the impact of expectation on the susceptibility to fearful stimuli. Though this argument was reinforced subsequently by the significant cueing status & emotion interaction during both P2 and N200-300 intervals, caution should still be taken as the present study did not include both paradigms into a single experiment.

P2 elicited by faces, whose amplitudes were largest over central areas (Fig. 2), had a peak latency and morphology that fit the archetype of the classic vertex positive potential (VPP), a component sensitive to face stimuli [15]. Many studies demonstrated larger amplitudes for fearful than for neutral faces at VPP and later components, as a result of increased attention allocation for emotional stimuli [7,15,25,26]. Though we replicated these findings by showing enhanced VPP amplitudes for fearful versus neutral faces during the uncued condition, the VPP amplitudes were similar between fearful and neutral facial expressions in the cued condition. This finding confirmed that expectation decreased brain susceptibility to fearful emotion, even under focused attention to emotional properties that is known to enhance emotional brain responding. Consistent with the results of N1 and VPP components, the analysis of N200-300 amplitudes continued to show decreased emotion effects for fearful faces during predictable versus unpredictable conditions. Thus, predictable fearful faces did not produce a significant emotion effect in each processing stage whereas each stage exhibited pronounced emotional effects for unpredictable fearful faces. This indicated that beforehand expectation is effective in dampening the brain susceptibility to fearful stimuli. This effect exists reliably, irrespective of whether attention is focused on, or diverted away from [26], the emotion features of the stimuli. In addition, the observation of cueing status and emotion interaction most likely results from the impact of expectation, instead of emotion habituation, because we used an inter-stimulus interval (ISI, 500–1000 ms) far beyond the criterion used to induce an emotion habituation effect [13].

In life settings, pre-awareness of incoming salient events often helps to prepare cognitive resources and behavioral measures. Consequently, people better cope with potential dangers and accordingly, emotional reactions are reduced [18]. In this regard, expectation might be considered as an emotion regulation strategy that dampens the emotional consequence of a coming event. This inference was supported by the results of source modeling in the 130–180 ms interval, which represents an early processing stage before the access of consciously controlled resources [8]. In this interval, we observed that the processing of predictable fearful faces involved ventromedial prefrontal cortex that is known for top-down frontal regulation of subcortical affective inputs [3,19]; while unpredictable fearful faces involved medial temporal lobe which has been established in unconscious, automatic processing of salient faces [1,3] (see Supplementary Material 1). Evidently, neural substrates implicated in executive control should not have been activated in this automatic processing stage, if there were no expectation and pre-mobilization of control processes prior to the onset of fearful stimuli. These results further suggest that emotional expectation is an effective cognitive strategy that reliably dampens the brain's susceptibility to fearful stimuli.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.neulet.2012.02.094.

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