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Research Article

The Memory Bias Toward Negative Context in Episodic Memory in Anxiety Individuals—An Exploratory Study Through ERPs

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Abstract

In order to explore the memory bias toward negative context in anxiety individuals, this study explored the cognitive neural mechanisms of at different cognitive process amongst 30 college students (high and low anxiety groups of 15 people each) by using event-related potentials (ERPs) measurement and source memory multiple-task paradigm. At first, it was found that the ERPs of fearful was stronger than the neutral background in the condition of hit $_{\text{item w/ source}}$ (both the old item and the source were judged correctly), hit item $_{\text{w/o source}}$ (the old item was judged correctly and the source was not judged correctly) and latter forgotten (both the old item and the source were not judged correctly) generally in the encoding phase. Combined with the behavior data, reaction times of hit item $_{\text{w/o source}}$ in fearful context were fasten than neutral context. Secondly**,** as for the memory bias, ERPs were more positive in fear context than neutral context at Fcz/Cz/Cpz in the 700-900ms in the high anxiety group under the condition of hit $_{\text{item w/o source}}$. In addition, ERPs were more positive in fear context than neutral context in the 300-500ms under the condition of latter forgotten in the high anxiety group. In conclusion, the memory bias towards negative stimuli in anxiety individuals was found in the encoding phase, indicating that anxiety still had an impact in the early stages of processing, but not in the deep processing.

Keywords

Anxiety, Memory Bias, Emotion Effect

1. Introduction

Why high-anxiety individuals intend to value a place as more dangerous than low—anxiety ones do? That is because anxiety individuals have been found to exhibit selective processing of threatening stimuli. Specifically, it may be related to selective attention and selective memory of threat stimuli [1-4].

At the same time, the evidence for the anxiety-related attentional biases is conclusive. The evidence for anxiety-related attentional biases is well-established, encom-

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passing facilitated attention, difficulty in disengagement, and attentional avoidance [5, 6]. However, the evidence for an anxiety-related memory bias remains limited. Mitte [7] distinguished between recollection (the process of retrieving detailed information) and familiarity (the sense of recognizing a stimulus without recalling specifics) in memory. Recall relies more on recollection, which is a conceptual and top-down process, whereas recognition depends more on familiarity, a perceptual process driven by data that may be less influenced by mood. Herrera, Montorio [3] found evidence of an anxiety-related memory bias in free recall tasks, but no such bias was observed in cued recall, recognition, word completion, or lexical decision tasks.

In order to test whether the memory bias increases the occurrence of memory bias, the encoding and retrieval phases should be studied at the same time to examine the relationship between the coding and retrieval phases. Unfortunately, few studies have reported the link between them. Cimrová, Riečanský [8] conducted a study aimed at distinguishing the effects of encoding and retrieval processes. Participants with high or low trait anxiety watched both a frightening and an emotionally neutral film during the encoding phase, and then recalled these films a week later during the recollection phase. The result showed the quantity of recollected facts were predicted by the emotion ratings in recollection phase, but not the encoding phase. This suggests that trait anxiety may be associated with retrieval of memories rather than encoding. However, the study was conducted from the behavioral experiment, and the result was not enough convincing through the fact that the emotional ratings predict quantity of recalled emotional facts.

The previous study had studied the memory bias of high anxiety individuals in the past through the ERPs and found the different characteristics of familiarity and recall [9]. In the current study, we will future explore memory biases by exploring the encoding phase. Specifically, the stimulus in the encoding phase are classified according to the correctness of the subsequent retrieval phase.

Then, the cognitive and neural mechanisms of memory bias on negative stimulus in anxiety people were examined using ERP measurements and a source memory multiple-task paradigm. The recollection and familiarity could be compared at the same time through this paradigm. According to the dual-process theory, if Chinese characters and corresponding emotion context learned in test phase were judged correctly, these trials would be classified as correct source retrieval (w/ source), which was based on recall or recollection; if Chinese characters for the old were judged correctly, and the context were misjudged, these trials would be classified as incorrect source retrieval (w/o source), which was based on recognition or familiarity [10, 11]. The differences in ERPs observed during recall and recognition will enhance our understanding of the relationship between attention and memory bias in anxious individuals across varying levels of processing. In conclusion, it’s hypothesized that the memory bias toward negative context would be found in encoding phase in anxiety individuals.

2. Method

2.1. Participants

At the beginning, in several universities in Beijing, 232 participants were recruited through advertising campaigns. The participants completed the scale of STAI-T, and the top and down 30% of the scores of STAI-T were recruited for this study. Thirty four right-handed adults (mean age was 22.51, SD 1.58) were eventually recruited in present experiment and got paid ￥20/hr. All reported being in good physical condition without a history of psychiatric or neurological illnesses. Four subjects were ruled out because of the insufficient number of trials in critical conditions. Eventually, there were 30 subjects. High and low anxiety groups of 15 people respectively, each group had 11 women and 4 men. The protocol was approved by the Institutional Review Board at Capital Normal University. This study was completed in 2020.

2.2. Materials

2.2.1. State-Trait Anxiety Inventory: T-AI

The STAI [12] was used as the measure of anxiety symptoms. For the 20 trait items in the T-AI, students were instructed to identify the numeral that most accurately reflects your typical affective state" by employing a four-point frequency scale: 1 (almost never), 2 (sometimes), 3 (often), and 4 (almost always). Li and Qian [13] revised it to the Chinese versions, which aslo had a good reliability (Cronbach's α was 0.88). And the norm score of T-AI in Chinese Undergraduates was 43.31 ±9.20.

In this study, the mean score of trait anxiety for high trait anxiety group was 54.56±3.78 (range from 50 to 61) and the mean score of trait anxiety for low trait anxiety group was 33.24 ± 4.32 (range from 27 to 38). The results of an independent sample T-test revealed trait anxiety score differed significantly among the two groups ($p < 0.001$).

2.2.2. Stimuli

1056 Chinese characters were selected from Modern Chinese Frequency Dictionary [14] (Beijing Language College, 1986). Of these, 576 characters were randomly chosen as old words presented in both the study and test phases, 432 characters were selected as new words presented only in the test phase, and 48 characters were designated as filters in the study phase. The average frequency of the new and old words presented in each emotional context was 25.0 occurrences per million, with a range of 6 to 116 occurrences per million. In addition, the use of an additional 48 animal names in the study stage, which were not presented in test phase.

A total of 80 facial images were selected from the Chinese Facial Affective Picture System [15], comprising 40 images of fearful expressions and 40 images of neutral expressions. The pictures were displayed in a white box, which clearly contrasted with the black background and highlighted the images effectively. Firstly, 8 pictures of fearful and neutral were presented for the practice, filters and the animal names. The remaining 64 pictures were taken as the context of the Chinese characters, and each picture was presented nine times. And the arousal means for each motion was for neutral, 3.75±0.10; for fearful, 6.57±0.20. The ANOVAs of arousal indicated that the arouse were different significantly between two emotion pictures, $F(1,31)$ =944.16, $p<0.001$ (see figure 1).

2.3. Procedure

Participants were seated 100 cm from a 17-in Dell monitor in an electrically shielded room. All picture stimulations were centrally presented in the screen, extending a 8.02×9.19° viewing area.

The current study concluded 6 blocks through the study-test paradigm. Each block included the study phase, distraction phase, and test phase. In each study phase, a total of 64 trials were presented, with the first two and last two trials serving as fillers. The remaining 60 trials included 12 trials with the animal names presented on face pictures, 48 trials with the normal words presented on face pictures. The pictures of the two emotions were pseudo-randomly arranged, and there would not be more than three pictures of the same kind emotion presented in succession. In each trial, the inter-stimulus interval lasted between 800 and 1000 milliseconds, during which a white fixation cross was displayed centrally. Then the stimulus (a word presented on the face) was presented on the screen, presenting time group was 1500ms (see figure 1).

During this time subjects made a judge for the word, whether it was animal name or not. If the word was animal name, did key reaction and without memory. If not, no key, subjects were asked to remember the words and the emotional valence of the face context (see figure 1). The emotional pictures were gender-balanced, and the words were neutral and not repeated during the study phase.

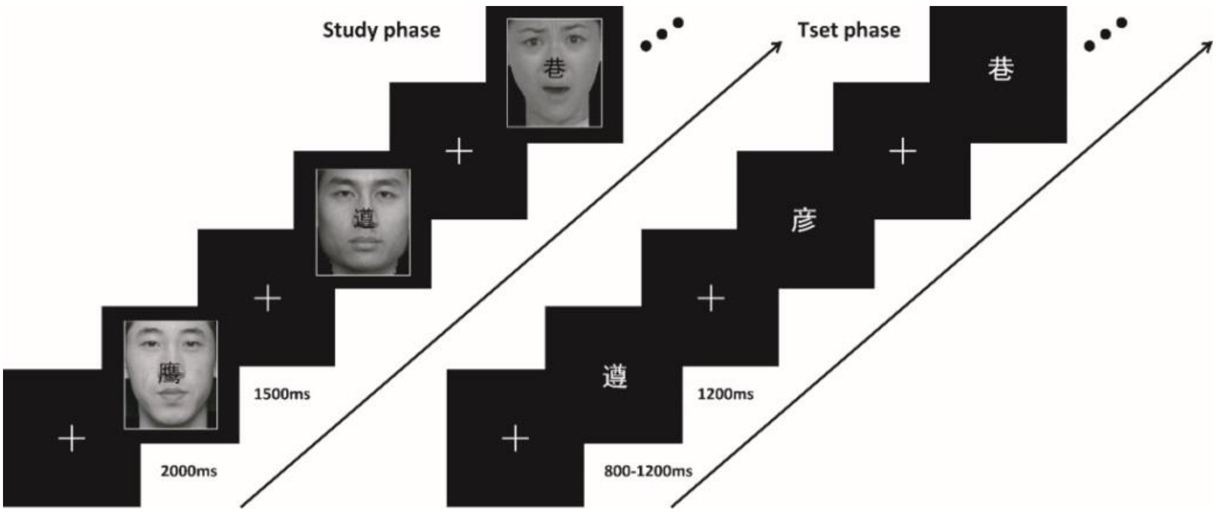

Figure 1. *Experimental paradigm. In the study phase, the stimulus was initially presented on 1500ms, subjects made a judge for the word firstly, whether it was animal name or not. If the word was animal name, do key reaction and without memory. If not, no key, asked subjects to remember the word, and remember the emotional valence of the face context (fearful /neutral). In the test phase, subjects attempted to discriminate the word was presented in the prior study phase with fear face picture, with happy face picture, with neutral face picture, or whether it was new.*

The test phase was performed after a delay of about 1 minute, during which the subjects should complete a series of subtraction task to prevent recall.

Each block, in test stage, concluded 48 learned words, 36 new words and 4 fillers. Each word was appeared for 1200 milliseconds. The inter-stimulus interval (ISI) ranged from 800 to 1200 milliseconds. Every participant was asked to response with pressing one of three buttons to showed whether the word was learned in the previous study stage with fearful face picture, or with neutral face picture, or whether it was new (see figure 1). The finger and key responses were balanced across all subjects. To avoid confusion, the buttons associated with each emotion type during the study phase were consistent with those used during the test phase. Before the formal experiment, subjects practiced to ensure that subjects were familiar with the experimental process.

2.4. ERPs Recording and Analysis

EEG data were collected from 62 scalp sites, utilizing Ag/AgCl electrodes that were integrated into elastic caps and aligned with the extended International 10-20 System. During the recording process, the electrodes initially referenced to the right mastoid, and subsequently, the data were re-referenced to the mean of the right and left mastoids. Monitoring of eye movements was facilitated by two additional channels dedicated to horizontal and vertical electrooculographic (EOG) recordings. Impedance levels were maintained below 5 KΩ for all electrodes. The EEG signals were processed with a band-pass filter set to 0.05–40 Hz and sampled at a rate of 500 Hz. Each data epoch encompassed a duration of 1600 milliseconds, with a 200-millisecond pre-stimulus period included. Trials that exhibited voltage spikes exceeding ±75 μV at any electrode in comparison to the baseline or those with artifacts in the EOG channels were omitted from further analysis. Event-related potentials (ERPs) were quantified by calculating the average amplitude across five distinct latency intervals: 300-500 ms, 500-700 ms, 700-900 ms, 900-1100 ms, and 1100-1600 ms, during the study/test phase. These measurements were normalized relative to the pre-stimulus baseline period, which spanned from -200 to 0 milliseconds. Similar intervals have been used in prior studies of related ERPs phenomena and were chosen based on a visual inspection of grand-average ERPs. The topographic analysis indicated that these middle line positions captured the most important effects, thus the final analysis was mainly focused on the five midline positions (Fz/Fcz/Cz/Cpz/Pz). The averaged ERPs were calculated for study phase, when the stimulus (a word presented on the face) was presented on the screen. The averaged ERPs were calculated for the test phase, during which words were presented centrally on a blank background.

The stimulus in the study or encoding phase are classified according to the correctness of the subsequent retrieval phase. Thus, there are three conditions in the study phase: (1) hit $_{\text{item w/ source}}$, (2) hit $_{\text{item w/o source}}$, and (3) latter forgotten. Trials were defined as hit $_{\text{item w/ source}}$ or hit $_{\text{item w/o source}}$ in test phase, the corresponding simulations was defined as hit $_{\text{item w/ source}}$ or hit $_{\text{item w/o source}}$ in study phase. Trials were defined as missing in test phase, the correspond simulations was defined as latter forgotten in the study phase.

ANOVAs with repeated measures were performed for each dependent variable. All ANOVAs were conducted as two-tailed tests with a significance level set at α=0.05, and where appropriate, were complemented with pairwise or simple effects comparisons. Adjustments for potential sphericity violations were implemented in instances where the effects possess two or more degrees of freedom in the numerator, a standard practice in analyses of variance (ANOVAs). This was achieved by applying the correction formula proposed by Greenhouse and Geisser [16]. Midline ERPs data were measured across each latency interval through ANOVA. The main effects related to electrode location were not included in the report.

3. Results

3.1. Behavioral Results

Behavioral results from the test phase were analyzed under three conditions: hit $_{\text{item w/ source}}$, hit $_{\text{item w/o source}}$, latter forgotten. This analysis was conducted within two emotional contexts—fearful and neutral—and across two levels of anxiety: high and low. The mean hit rates and reaction times (RTs) of different conditions were seen in Table 1.

3.1.1. Hit Rates

Repeated-measures ANOVAs were performed with three factors: emotional context (fearful, neutral), anxiety level (high, low), and condition (hit $_{\text{item w/ source}}$, hit $_{\text{item w/o source}}$ rates). The analysis revealed no significant effects.

Table 1. *Means (and SEs) for the Accuracies and Reaction Times (RTs) for each condition.*

		High anxiety group			Low anxiety group		
		Fearful context	**Neutral context**	**Correct rejection**	**Fearful context**	**Fearful context**	**Correct rejection**
Accuracy (SE)	hit item w/ source	0.43 -0.1	0.47 -0.12	0.77	0.45 -0.12	0.43 -0.14	0.7
	hit item w/o source	0.28 -0.07	0.24 -0.07	0.14	0.3 -0.09	0.3 -0.11	0.12
Reaction time in ms (SE)	hit item w/ source	1007.67 -129.31	1024.9 -150.35	888.19	991.37 -145.3	1008.66 -143.16	900.21
	hit item w/o source	1030.93 -160.82	1040.42 -169.5	79.92	1026.07 -140.1	1003.93 -160.94	149.09

3.1.2. RTs

ANOVAs of RTs with three factors (as above) were analyzed on condition of hit $_{item\ w/\ source}$ showed a significant main effect of emotional context, $F(1, 28)=5.05$, $p=0.033$, $\eta^2_{=}.153$, further analysis showed that Reaction times (RTs) for hit $_{item\ w/\ source}$ were significantly faster in the fearful context than in the neutral context. ANOVA of hit $_{item\ w/o\ source}$ RTs showed no significant effects. The ANOVAs of hit $_{item}$ RTs with three factors (as above) revealed the main effect of emotion context, $F(1, 28)=3.840$, $p=0.06$, $\eta^2_{=}.121$, further analysis showed that hit $_{item}$ RTs in fearful face context were faster than neutral face context ($p < 0.05$). ANOVAs of RTs conducted on missing showed no significant effects.

3.2. Event-Related Potential Data

Analyze the average ERPs for each unique case. Furthermore, the average ERPs for each unique condition were based on contributions from more than fifteen trials, which met the requirements of data analysis of ERPs. After stimulus began, we observed a distinct difference at 300ms and last for 1600ms. We were most interested in the memory bias in anxiety individuals, thus we conducted the analysis as follows. Repeated-measures ANOVAs with three factors (as above) were conducted to examine memory bias in conditions of hit $_{item\ w/\ source}$, hit $_{item\ w/o\ source}$ and latter forgotten in study phase. The mean amplitude data were analyzed through these repeated-measures ANOVAs for five time intervals, 300–500, 500–700, 700-900, 900–1100, 1100-1600ms. The selection of these temporal window regions was based on visual observations of current data and previous studies [17, 18]. The results are follows (see Figure 2).

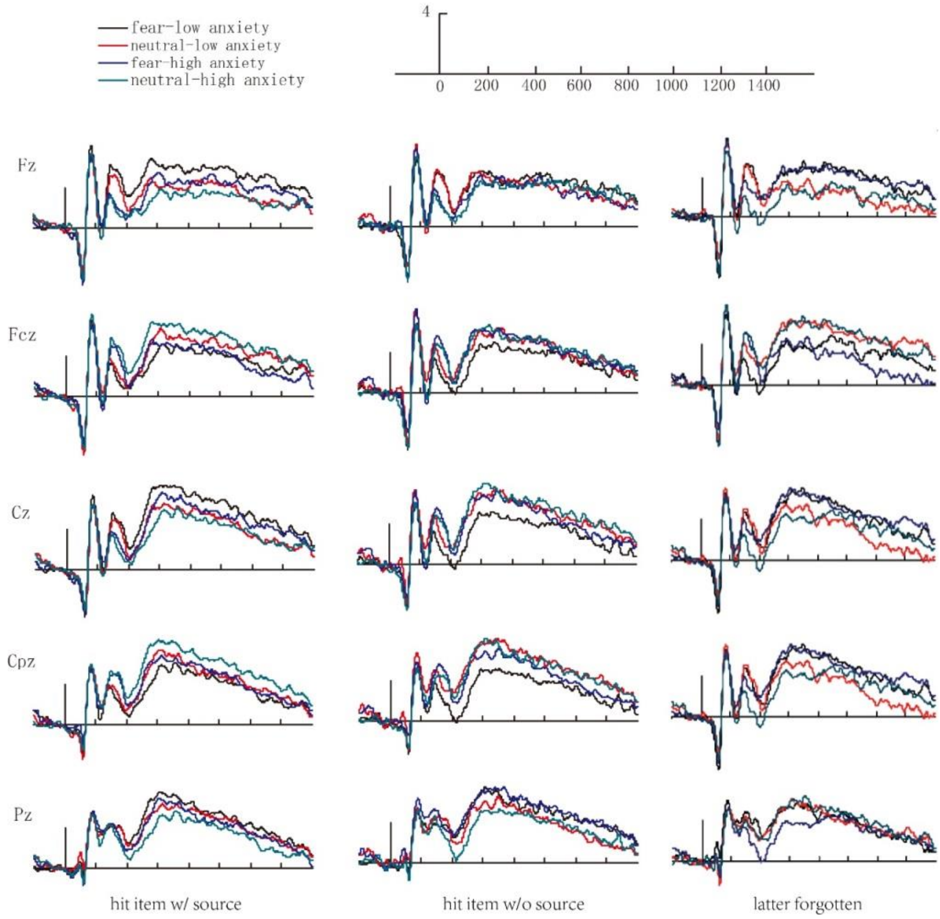

Figure 2. *ERPs waveforms in studying phase (conditions: hit item w/o source, hit item w/o source, latter forgotten; anxiety group: high and low; emotion context: fear and neutral).*

3.2.1. Hit Item w/ Source

For 300-500, 500-700 and 700-900ms, ANOVA of the data showed a main effect of emotion, the F-values are 7.072, 35.661 and 26.348 respectively, all P-values were less than 0.05, further analysis indicated that ERPs in the fearful context exhibited a more positive amplitude compared to those in the neutral context. For the 900–1100 ms, the ANOVA of the ERPs showed an interaction effects between electrode location and emotion, $F(4, 112)=4.561$, $p=0.016$, $\eta^2=.140$, indicating that ERPs of fearful context was more positive than neutral context under the condition of hit $_{item\ w/\ source}$ at Fz/Fcz/Cz/Cpz ($ps<.05$). For the 1100–1600 ms region, the result of ANOVA showed an interaction effects between electrode location and emotion, $F(4, 112)=3.617$, $p=0.032$, $\eta^2=.114$, indicating that ERPs of fearful context was more positive than neutral context under the condition of hit $_{item\ w/\ source}$ at Fz/Fcz/Cz ($ps<.01$).

3.2.2. Hit Item w/o Source

For the 300-500ms, the results found no significant difference. The repeated-measures ANOVA of 500–700ms showed an interaction effects between electrode location and emotion, $F(4,112)=4.231$, $p=0.027$, $\eta^2=.131$, further analysis revealed that ERPs of fearful context was more positive than neutral context at Cz/Cpz/Pz ($ps<.01$). For the time region of 700–900, the ANOVA showed significant interaction effects among emotion, anxiety and electrode location, $F(4,112)=5.264$, $p=0.029$, $\eta^2=.158$, indicating that ERPs of fearful context was more positive than neutral context under the condition at Fz/Fcz/Cpz ($ps<.05$).

3.2.3. Latter Forgotten

For the 300-500 time region, the repeated-measures ANOVA showed an interaction effects between anxiety and emotion, $F(4,112)=8.603$, $p=0.007$, $\eta^2=.235$, further analysis indicated that ERPs of fearful context was more positive than neutral context under the condition of latter forgotten in high anxiety group ($ps<.01$). The repeated-measures ANOVA of 500–700ms revealed a main effect of emotion, $F(1, 28)=16.003$, $p<0.000$, $\eta^2=.364$, further analysis revealed that ERPs of fearful context was more positive than neutral context under the condition of latter forgotten. ANOVA of the 1100–1600 ms region showed an interaction effects among emotion and electrode location, $F(4,112)=6.204$, $p=0.001$, $\eta^2=.181$, and ERPs were more positive for fearful latter forgotten compared to neutral latter forgotten at Fz/Fcz/Cz ($ps<.05$). The results of repeated-measures ANOVA of 1100–1600ms showed no significant effects.

4. Discussion

4.1. Behavioral Results

Behavioral data was based on the test phase because there was no test task during the study phase.

As for RTs, the condition of hit $_{item\ w/\ source}$ in the fearful context were faster than the neutral context. This indicated that the processing intensity in the fear context was large, so the speed of the reaction became faster. Emotional stimulation had the characteristics of automatic processing, and the attention to emotional stimulation could cause the body to increase the processing degree. It was the attention priority of emotional stimulus that had a stronger effect than neutral stimulus. In addition, in the coding phase, people would use deeper processing for emotional stimulation than neutral stimulus, to be specific, people may be inclined to combine emotional content with additional semantic information or their own experience [19, 20]. These coding strategies based on the richness and diversity of these memory representations form the basis of emotional enhancement [21].

4.2. Event-Related Potential Data

With regard to the emotional effects in encoding phase, in the condition of hit $_{item\ w/\ source}$, the ERPs of fear background were stronger than the neutral background generally. In the condition of hit $_{item\ w/o\ source}$, in the 500-700ms, ERPs were more positive in fear expression than neutral expression in all people. In the condition of latter forgotten, in the 500-1100ms, ERPs were more positive in fear context than neutral context in all people. This was consistent with the result of prior studies [17, 22], the emotional background of the source memory had an effect on the processing, regardless of whether the item and background information needed to be memorized. At the same time, the degree of coding under the condition of hit $_{item\ w/o\ source}$ was reduced in duration (only 500-900ms). This was also consistent with the fact that the unsuccessful source retrieval was weaker than the successful source retrieval.

With regard to the memory bias of anxiety in encoding phase, ERPs were more positive in fear expression than neutral expression at Fcz/Cz/Cpz in the 700-900ms in the high anxiety group under the condition of hit $_{item\ w/o\ source}$. In addition, ERPs were more positive in fear context than neutral context in the 300-500ms under the condition of latter forgotten in the high anxiety group. This was the key findings of this study, under the condition of the hit $_{item\ w/o\ source}$, the high anxiety participants remembered the item, but didn't remember the context. And under the condition of the latter forgotten, the participants could not remember the item and context, but the fear context still had an effect on the processing. In accordance with previous studies, anxiety still had an impact in the early stages of processing, showing the facilitated attention of the anxious individual to negative stimulation [5]. It was suggested that high-anxious individuals, while encoding threatening information with a superficial encoding task, may have engaged in some conceptual encoding at an early stage of information processing. However, when the encoding task involved deeper processing (semantic self-referential or semantic not self-referential), the differences in encoding decreased, possibly due to a ceiling effect [7, 23], so the bias weren't found in the condition of hit $_{item\ w/\ source}$ in encoding phase. Additionally, the finding regarding electrode location aligns with previous studies, suggesting that both attentional control ability and emotion regulation may be centered around prefrontal cortex functioning [8, 24]. The amygdala, the most important brain structure in emotional memory, plays a major role in the coding and coding of emotional memory [19, 25].

There are several limitations to the current study. First, the experiment task should not demand the depth processing or semantic self-referential in the encoding task which would decrease the differences due to a ceiling effect [7, 23]. Secondly, the emotion effect that the fear was stronger than the neutral background was obvious in current study, however current study didn't account of the positive emotions because of the limitation of the time of experiment. Lastly, the number of subjects is relatively small. Future studies can explore the influence of positive emotions, better understanding the emotional effects based on the elimination of emotional valence. In addition, further studies can explore the association among textual parameters anxiety and ERPs [26].

5. Conclusion

In conclusion, the main effect of emotion revealed that the fear context had a stronger influence than the neutral context during the encoding phase, regardless of whether the item or background information was memorized. Then the memory bias towards negative stimuli in anxiety individuals was found in the encoding phase. This study has implications for cognitive behavioral therapy for anxiety, including modules that address attentional and memory biases toward negative thoughts and content and establish strategies to overcome this bias.

Abbreviations

ERPs	Event-related Potentials
Hit Item w/ Source	Both the Old Item and the Source Were Judged Correctly
Hit Item w/o Source	The Old Item Was Judged Correctly and the Source Was Not Judged Correctly
Latter Forgotten	Both the Old Item and the Source Were Not Judged Correctly

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Conflicts of Interest

The authors declare no conflicts of interest.

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