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ARTICLES

Differences of relevance in implicit and explicit memory tests: An ERP study

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An ERP study was conducted to explore the differences between other-relevant words and possessor-relevant words in implicit and explicit memory tests. The results show that other-relevant words are associated with a more negative ERP than possessor-relevant words during 300－900 ms whether in the implicit or the explicit memory tests. The N400 effect is also found in semantic processing of social materials. There is an ERP dissociation of retrieval formats between the implicit and the explicit memory tests during 700－900 ms, namely, there is no difference between other-relevant words and possessor-relevant words in the implicit memory while there is a significant difference between them in the explicit memory. Observed through Curry 6.0, the analysis of neural sources for other-relevant words and possessor-relevant words indicates that they have different locations. At 400 ms, activity is found in the left precuneus during possessor-relevant words processing. Both the right and the left precuneus are activated during other-relevant words processing. However, at 600 ms their location is both in the left precuneus. In a word, our results show that there exists a cognitive difference between other-relevant words and possessor-relevant words, and other-relevant words closely related to the percipient himself/herself are strongly responded to, which reflects that there is a bigger attention bias to the stimuli concerning the percipient himself/herself than to processor-relevant words.

implicit memory test, explicit memory test, relevance, ERP, LORETA

PSYCHOLOGY

Human memory has a complex cognitive function. The influence of previous experience on human memory may be either unconscious or conscious. According to the standard of unconscious and conscious retrieval, memory can be divided into implicit memory and explicit memory. The results of many experiments have suggested that implicit memory and explicit memory rely on different memory systems that are connected to different regions of the brain[1,2].

Early psychologists have made great efforts on the abstract concept information processing in implicit and explicit memory. With increasing integration of cognitive psychology and social psychology, the social cognitive research has made much headway. According to the standard of unconscious and conscious cognitive processing, social cognition can be divided into implicit and explicit cognition. Some studies have revealed that implicit memory has made greater contributions to the social cognition than explicit memory has[3]. This result provides a theoretical base for the research on the dissociation of implicit and explicit memory.

As an influential factor of social information processing, the characteristics of the stimuli evoked a great many researches. Recent studies indicated that during the social information processing, the reactor automatically categorized stimuli into positive ones and negative ones in the subthreshold. Only due to the difference between positive valence and negative valence, stimuli

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in the same category had different effects on the cognitive tasks[4]. For example, Pratto et al.[5,6] carried out a research on “the power of different stimuli valences to grab attention” by using the Stroop paradigm. The results suggested that the response time taken to identify the color of negative words was longer than that to identify the color of positive words. This indicated that negative words had greater interference than positive words in the color identification. That is to say, the attention-grabbing power of negative words was stronger than that of positive words[5,6]. However, further researches found that there existed a variety of contradictories. For instance, by using emotional Stroop paradigm, Hout et al.[7] found that the same valence of negative words had a different experimental effect, which meant that they found negative effect of the words (the response time to identify the color of negative words was longer than that to identify the color of neutral words) in such adjectives as “threatening” and “fearful”, while they did not find such effect in the adjectives such as “anxious” and “depressive”, which suggested that negative effect of the words did not exist in all cases. Therefore, we can not explain the complexity of human information processing only by using the valence indicator to distinguish the stimuli.

British psychologist Peeters proposed an important dimension to distinguish the characteristics of words-relevance[8–10]. From his point of view, apart from its own meaning, the valence of a certain characteristic also depends on the evaluator's perspective. A person's trait that is either more harmful or more beneficial to the social environment around the holder than to the holder himself/herself is called other-relevant (such as “tolerance” and “harsh”). A person’s trait that is more harmful or more beneficial to the holder himself/herself than to the social environment around the holder is called possessor-relevant (such as “self-confidence” and “weak”). Based on Peeters’ theory, Wentura et al.[11] have proved that people can automatically distinguish other-relevant words from possessor-relevant words in the sub threshold through further experiments[4,11].

The other-relevant trait means that the trait of a person keeping company with A has a beneficial or harmful influence on A. That is to say, the other-relevant trait is related to A’s perception of the safety or danger surrounding him/her. The possessor-relevant trait means that in the perspective of A, the trait of a person who associates with A has a greater influence on the holder himself/herself. In other words, the possessor-relevant trait is related to A’s perception of the mental state of the people around him/her. James[12] thought that to some extent all the things related to oneself would become a part of self. Cognitive psychologists believed that the term "self" was about the mental representation of people themselves, and they were mainly concerned about whether the mental representation about self was different from the representation about others, and via the study of self-knowledge effect during the information processing they examined whether the self was unique or not. However, very few studies have been carried out on the issue as to whether the representation of the influence of other people's harmful or beneficial traits on the surrounding people is different from that on the holder himself/herself.

ERP results in a large number of semantic researches revealed that the N400 effect was found[13–15] in the semantic processing of various words. For example, in a variety of experimental tasks on concrete and abstract words[13,15], the experimenters found that N400 of concrete words was more negative than that of abstract words during 300－500 ms. According to the dual coding theory, concrete words are processed by both the verbal system and the image system, while abstract words are processed primarily by the verbal system. So concrete words obtain more information than abstract words, showing a more negative ERP waveform. As far as relevance is concerned, Wentura et al.[11] believed that negative other-relevant words drew more attention, so it would obtain more information during processing. Therefore, we can presume that, similar to concrete words and abstract words, the ERP of other-relevant words will be more negative than that of possessor-relevant words.

In the current research field of social cognitive neuroscience, Chiao et al.[16] and Han et al.[17] performed an fMRI experiment, in which fear faces of both the Japanese and the Caucasian were shown to the Japanese and the Caucasian, respectively. They found that the Japanese had greater amygdala activation upon seeing the fear faces of the Japanese, so did the Caucasian upon seeing the fear faces of the Caucasian. This result suggested that in the processing of the stimuli closely related to the percipient himself/herself, the subject had greater amygdala activation in the brain. The ERP study of Lin et al.[18] showed the same result. In their experiment, two groups of Chinese subjects were in the independent self-construal and interdependent self-construal priming environment, respectively. The experimenters asked the subjects to perceive the object and background. They found that the subjects in the independent self-construal priming environment had a greater P1 to the object and the subjects in the interdependent self-construal priming environment had a greater P1 to the background. In addition, the study of Baumeister et al.[19] on ordinary and threatening information showed that in the processing of threatening information closely related to the percipient himself/herself, the brain had greater activation. Similar to previous studies[16–19], other-relevant words that are social cognitive materials in this experiment are more closely related to the percipient himself/herself than possessor-relevant words are, so in this way we can presume that other-relevant words can prompt a stronger response than possessor-relevant words.

To sum up, preceding studies on relevance all have focused on the behavior experimentation. So far, no ERP studies on relevance have been available. Whether relevance which is distinguished at the implicit level has the same characteristics in implicit memory, whether relevance will be influenced by the implicit or explicit retrieving formats, what characteristics they will have in ERPs, and what kind of cognitive processing they will reflect, are all what we hope to explore in this study.

1 Methods

1.1 Subjects

Sixteen right-handed subjects (8 males and 8 females, aged 20－25) were employed in the study. All subjects were healthy, with normal or corrected-to-normal vision, and none of them had any history of brain diseases. After experiments they were paid some money.

1.2 Stimuli

Trait adjectives used in this experiment were looked up in the literature[20–24]. The experimenter asked the subjects to evaluate the adjectives, and the evaluator should tell in his/her own point of view whether the trait had a bigger impact on the holder himself/herself or on the people around him/her including the evaluator himself/herself. If the trait had a bigger impact on the holder himself/herself, the word was classified as possessor-relevant; while it was classified as other-relevant if the trait had a bigger impact on the people around him/her. Then the subjects were asked to evaluate whether the words were positive or negative. Then we would get four types of words-positive other-relevant, negative other-relevant, positive possessor-relevant and negative possessor-relevant. Finally, according to the balance of frequency and stroke, we selected 420 words as experiment materials. There was no statistical difference between other-relevant words and possessor-relevant words in frequency and stroke (Frequency: $t = 0.483$, $P = 0.629$; Stroke: $t = -1.512$, $P = 0.131$). In this study 140 nouns were looked up in *Modern Frequency Dictionary of Chinese Character*[20]. 140 non-words were coined by combining two characters randomly.

Based on the above criterion, 700 words were used as experimental stimuli, namely, 140 filling nouns, 140 non-words, and 420 words of relevance. 210 words in the 420 words of relevance were other-relevant words and the rest were possessor-relevant words. Furthermore, the 210 possessor-relevant words were divided into two equal groups: 105 positive possessor-relevant words and 105 negative possessor-relevant words. Similarly, the 210 other-relevant words were divided into two equal groups: 105 positive other-relevant words and 105 negative other-relevant words. All items were randomly divided into 14 blocks, with seven blocks related to other-relevant words and seven blocks related to possessor-relevant words. The sequence of the blocks was counterbalanced across subjects. Each block was made up of 3 phases: study, implicit memory test and explicit memory test. There were 10 words of relevance (5 positive words and 5 negative words) in the study phase. There were 10 old words of relevance (the words in the study phase), 10 new words of relevance (5 positive words and 5 negative words) and 10 non-words in the implicit memory test. There were 10 old words of relevance (the words in the study phase), 10 new words of relevance (5 positive words and 5 negative words) in the explicit memory test.

1.3 Procedure

The subjects sat comfortably in front of a computer monitor in a sound-proof room with dim light. All stimuli were shown at the center of a black-background screen. The font was black, size 40. Subjects were requested to focus on the center of the screen. The distance between subjects and the screen was 80 cm, with a perspective of 1.86° × 4.37°. The three phases of each block were: (i) the study phase. Firstly the two filling words were shown and then the formal experiment stimuli were presented. Each stimulus lasted 800 ms, ISI 1100 ± 100 ms. The task of the experiment was to ask the subjects to determine whether a word was a noun or an adjective and make a key-pressing response. If the word was a noun, the subjects were supposed to press the left key, otherwise the right key. At the end of the study phase, a number was presented on the screen .On seeing the number, the subjects were asked to count down by 3 and give a vocal report for 10 s. (ii) The lexical decision. After the study phase, the lexical decision was carried out. Then the subjects were asked to press the key as soon as possible after making a judgment. If the stimulus was a word, they should press the left key, otherwise the right key. (iii) The recognition test. After the lexical decision, the recognition test was carried out. The subjects were asked to judge whether the word had been seen in the study phase or not and make a key-pressing response. If the word had been seen, they should press the left key, otherwise the right key. The duration of stimuli and ISI in the two test phases above were the same as in the study phase. The right and left key were counterbalanced among subjects. The experimental sequence was indicated in Figure 1.

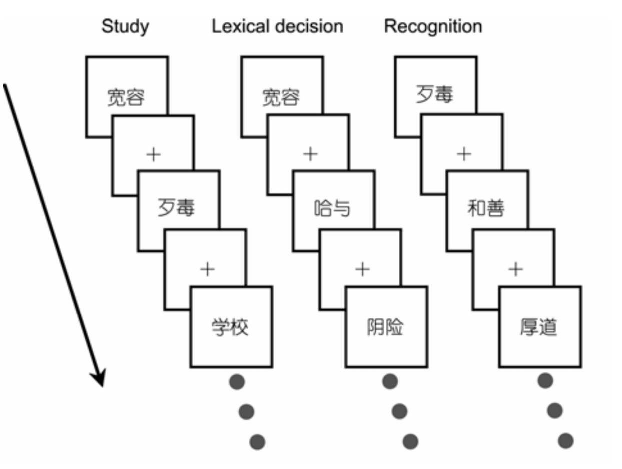

Figure 1 Subjects were presented with a series of words and were required to decide whether a word was a noun or an adjective during the study phase (left). The lexical decision task was to judge whether an item was a word or a non-word (middle). Recognition task was to judge whether an item was a new word or an old word (right). Each word was presented for 800 ms.

1.4 ERP recordings

Electroencephalographic recordings were made from 62 scalp sites using Ag/AgCl electrodes embedded in an elastic cap of ESI-64-channel EEG recording System made by Neuroscan Co. Vertical electrooculographic (EOG) was recorded by electrodes placed directly above and below the supra-orbital of the left eye, and horizontal EOG and blinks were monitored via a bipolar Montage at the outer canthi of both eyes. Reference electrodes were located on left mastoids during recording and re-referenced by both the right and the left mastoid off-line. The ground electrode was between FPz and Fz. EEG signals were filtered with a band-pass of 0.05－40 Hz and sampled at a rate of 500 Hz. The impedances between scalp and electrodes were reduced below 5 kΩ. EEG recordings were averaged off-line. Ocular artifacts were reduced and the 50 Hz interference was removed by the method of FIR in the CNT data. Trials with a voltage, relative to the 100 ms baseline, exceeding ±75 μV at any electrode, were excluded from analysis as artifacts. Only the ERPs of the the words in the trials with correct responses were averaged. Each epoch lasted 900 ms with an additional 100 ms recorded prior to stimulus onset to allow for baseline correction. There were 12 ERPs including ERPs of old words of relevance, new words of relevance and merged ERPs of old and new words of relevance. According to the scalp distribution, wave, topographic features and previous literature, we selected 3 time windows (300－500, 500－700 and 700－900 ms)[25,26] and 5 brain regions (prefrontal, frontal, central, pretrial, occipital). We selected 3 electrodes in each brain region, namely FP2, FPz, FP1, F4, Fz, F3, C4, Cz, C3, P4, Pz, P3, O2, Oz and O1, and chose the average amplitude of the 3 electrodes in each brain region as the representative of that region[27,28] (Figure 2). For data analysis we used the SPSS15.0 software package and the Greenhouse-Geisser correction was applied to adjust the *P*-values.

2 Results

2.1 Behavioral results

A repeated-measure 2×2×2 ANOVA was conducted to evaluate the response time among relevance (other-relevant and possessor-relevant), retrieval formats (lexical decision and recognition test) and item types (the old words and the new words). We found that the main effect of relevance was significant, $F(1,15) = 12.38$, $P < 0.01$, and the main effect of item types was also significant, $F(1,15) = 67.08$, $P < 0.001$.

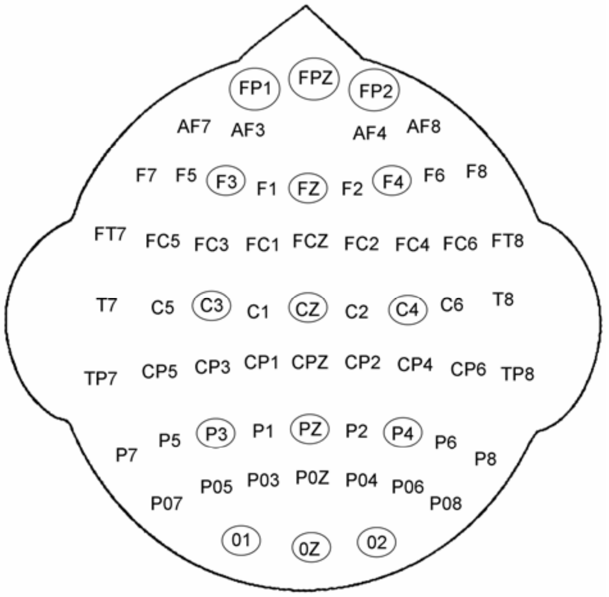

Figure 2 Distributions of electrodes.

A repeated-measure 2×2×2 ANOVA was conducted to evaluate the accuracy among relevance (other-relevant and possessor-relevant), retrieval formats (lexical decision and recognition test) and item types (the old words and the new words), and we found that the main effect of retrieval formats was significant, $F(1,15) = 50.71$, $P < 0.001$. There was no main effect of relevance and old/new effect, $P > 0.05$ (Table 1).

Table 1 Accuracy rate and mean response time of relevance in new and old words in the lexical decision and the recognition test[a)]

		Lexical decision		Recognition	
		Old	New	Old	New
ARs (%)	Other-relevant	93.4(1.6)	90.8(1.3)	84.6(2.0)	80.3(2.4)
	Possesor-relevant	93.0(1.6)	94.7(3.2)	86.1(2.4)	83.1(2.5)
RTs (ms)	Other-relevant	548(12)	597(13)	627(15)	669(14)
	Possesor-relevant	521(13)	578(14)	606(15)	664(16)

a) Standard errors are given in parenthses.

From Table 1 we can see that the response time taken to process other-relevant words was longer than that to process possessor-relevant words in both the lexical decision and the recognition test whether in the old words or in the new words. In order to comprehensively study relevance, we combined the data of the new words of relevance with that of the old words of relevance in the two retrieval formats respectively. We combined the data of the new other-relevant words with that of the old other-relevant words of and the data of the new possessor-relevant words with that of the old possessor-relevant words in the two retrieval formats respectively.

We made a 2-way repeated-measure analysis between retrieval formats (lexical decision and recognition test) and item types (the old words and the new words), and we found that with regard to the response time, there was a main effect of item types, $F(1,15) = 39.62$, $P < 0.001$. The response time taken to process the new words was longer than that to process the old words. But there was no interaction between retrieval formats and item types. Accuracy results showed no main effect of item types and no interaction between item types and retrieval formats, $Ps > 0.05$ (Table 2).

Table 2 Accuracy rate and mean response time in the lexical decision and the recognition test[a)]

	Lexical decision		Recognition	
	RTs (ms)	ARs (%)	RTs (ms)	ARs (%)
Old	533(12)	93.0(1.4)	619(15)	87.8(1.9)
New	582(14)	92.7(0.7)	661(14)	82.4(2.5)
Other-relevant	571(12)	92.1(1.2)	650(14)	84.9(2.0)
Possesor-relevant	545(14)	93.7(1.2)	627(14)	85.3(1.6)

a) Standard errors are given in parentheses.

A 2-way repeated-measure analysis was conducted between retrieval formats (lexical decision and recognition test) and relevance (other-relevant and possessor-relevant), and we found that there was a main effect of relevance with respect to the response time, $F(1,15) = 16.78$, $P < 0.01$.The response time taken to process other-relevant words was longer than that to process possessor-relevant words. But there was no interaction between retrieval formats and relevance. There was no main effect of relevance and no interaction between relevance and retrieval formats with respect to accuracy, $Ps > 0.05$ (Table 2).

2.2 The basic characteristics of ERPs

On the whole, there was consistency in the basic characteristics of the ERPs. Possessor-relevant words were associated with a more positive ERP than other-relevant words. At about 350 ms in average, ERP of other-relevant words and possessor-relevant words separated and at about 600 ms the separation was the most obvious in the central region. Specifically, a larger discrepancy of relevance was shown in the wave of the new words than in that of the old words in the lexical decision. Relevance ERP of the old words was flatter than that of the new words in the recognition test.

2.3 The statistical analysis of ERPs data

(i) The analysis of the old relevance words and the new relevance words in the two retrieval formats. A 2×2×2×3×5 ANOVA of repeated measures was conducted among relevance (other-relevant and possessor-relevant), retrieval formats (lexical decision and recognition test), item types (the old words and the new words), time epochs (300—500, 500—700 and 700—900 ms) and brain regions (prefrontal, frontal, central, parietal and occipital). The results revealed that the interaction among relevance, retrieval formats, item types and brain regions was significant, $F(4,60) = 4.09$, $P < 0.05$. So we analyzed relevance in the two retrieval formats, respectively.

In the lexical decision test, there was a significant interaction among relevance, item types and time epochs, $F(2,30) = 4.30$, $P < 0.05$.

From 300 to 500 ms, there was a significant main effect of item types, $F(1,15) = 8.50$, $P < 0.05$. In the old words, a significant interaction was found between relevance and brain regions, $F(1,15) = 4.26$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the prefrontal region, the frontal region and the central region, $Ps < 0.05$. In the new words, a 2-way interaction between relevance and brain regions was found, $F(1,15) = 7.63$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the prefrontal region, the frontal region and the central region, $Ps < 0.05$.

From 500 to 700 ms, there was a significant interaction among relevance, item types and brain regions, $F(1,15) = 6.70$, $P < 0.01$. In the old words, a significant interaction was found between relevance and brain regions, $F(1,15) = 5.43$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the central region, $F(1,15) = 7.83$, $P < 0.05$. In the new words, a significant interaction was found between relevance and brain regions, $F(1,15) = 6.52$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the prefrontal region, the frontal region, the central region, and the parietal region, $Ps < 0.05$.

From 700 to 900 ms, an interaction among relevance, item types and brain regions was found, $F(1,15) = 4.27$, $P < 0.05$. In the old words, the main effect of relevance and the interaction between relevance and brain regions were not significant, $Ps > 0.05$. In the new words, a significant interaction was found between relevance and brain regions, $F(1,15) = 3.65$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the prefrontal region, the frontal region, the central region, and the parietal region, $Ps < 0.05$.

In the recognition test, the main effect of relevance was significant, $F(1,15) = 7.65$, $P < 0.05$. The main effect of time epochs was significant, $F(1,15) = 20.74$, $P < 0.05$.

300—500 ms, the main effect of relevance was significant, $F(1,15) = 5.80$, $P < 0.05$.

500—700 ms, there was a remarkable main effect of relevance , $F(1,15) = 7.26$, $P < 0.05$. A significant interaction was found between relevance and brain regions, $F(1,15) = 4.14$, $P < 0.05$. A significant interaction was found between item types and brain regions, $F(1,15) = 9.34$, $P < 0.05$. In the old words, a significant interaction was found between relevance and brain regions, $F(1,15) = 4.83$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the central region, $F(1,15) = 7.67$, $P < 0.05$. In the new words, the main effect of relevance was significant, $F(1,15) = 5.37$, $P < 0.05$.

700—900 ms, the main effect of relevance was significant, $F(1,15) = 3.54$, $P < 0.05$. Further analysis found that in the old words, the main effect of relevance and the interaction between relevance and brain regions were not significant, $Ps > 0.05$. In the new words, the main effect of relevance was significant, $F(1,15) = 7.18$, $P < 0.05$.

(ii) The overall analysis of relevance. It can be seen from Figure 3 that in both the old words and the new words of the lexical decision and the recognition test, other-relevant words were associated with a more negative ERP than possessor-relevant words. So we could conclude that the trend remained unchanged as to whether the words were old or new and had nothing to do with retrieval formats. In order to comprehensively study the relevance, we superposed the possessor-relevant stimuli of both the old and new words in the lexical decision and the recognition test respectively, and superposed the other-relevant stimuli of both the old and new words in the lexical decision and the recognition test respectively (Figure 4).

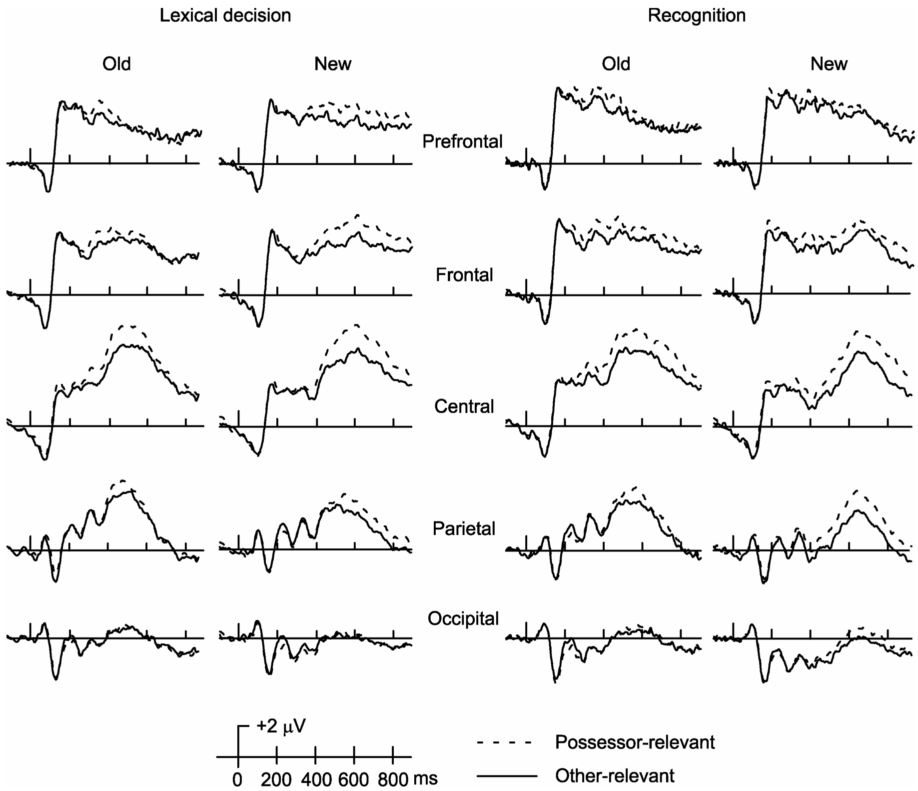

Figure 3 Grand averaged ERPs elicited by possessor-relevant words (dashed lines) and other-relevant words (solid lines) in the lexical decision and the recognition test. Data were depicted at 5 brain regions: prefrontal, frontal, central, parietal and occipital. Amplitudes were displayed in μV.

A 2×3×2×5 ANOVA of repeated-measure was conducted among relevance (other-relevant and possessor-relevant), time epochs (300—500, 500—700 and 700—900 ms), retrieval formats (lexical decision and recognition test) and brain regions (prefrontal, frontal, central, parietal and occipital). The results revealed that a significant interaction was found between relevance and brain regions, $F(1,15) = 8.01$, $P < 0.01$. A main effect of time epochs was significant , $F(1,15) = 25.16$, $P < 0.001$.

For the 300—500 ms interval, a significant interaction was found between retrieval formats and brain regions, $F(1,15) = 14.73$, $P < 0.001$. In the lexical decision, there was a remarkable interaction between relevance and brain regions, $F(1,15) = 10.46$, $P < 0.001$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the prefrontal region, the frontal region and the central region, $Ps < 0.01$. In the recognition test, a significant interaction was found between relevance and brain regions, $F(1,15) = 3.42$, $P < 0.05$, Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the central region, the parietal region and the occipital region, $Ps < 0.05$.

For the 500—700 ms interval, a significant interaction was found between relevance and brain regions, $F(1,15) = 8.04$, $P < 0.01$. In the lexical decision, a significant interaction was found between relevance and brain regions, $F(1,15) = 6.00$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the frontal region, the central region and the parietal region, $Ps < 0.05$. In the recognition test, a significant interaction was found between relevance and brain regions, $F(1,15) = 4.26$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the central region, the parietal region and the occipital region, $Ps < 0.05$.

For the 700—900 ms interval, a significant interaction was found between relevance and brain regions, $F(1,15) = 3.78$, $P < 0.05$. In the lexical decision, the main effect of relevance and the interaction between relevance and brain regions were not significant, $Ps >$

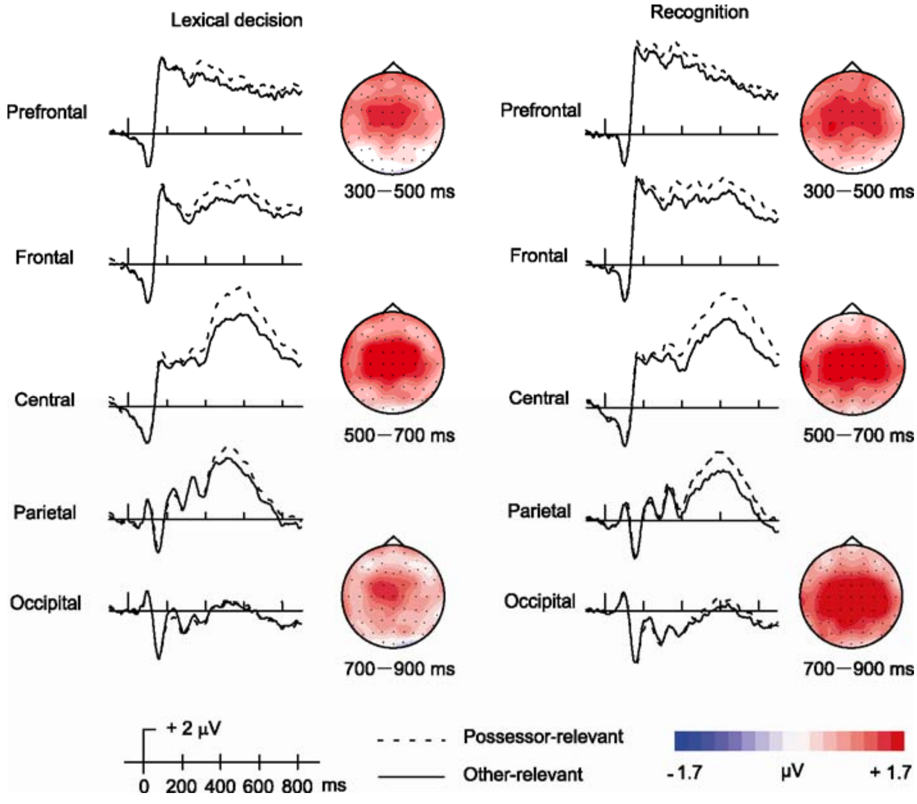

Figure 4 Grand averaged ERPs elicited by possessor-relevant words(dashed lines) and other-relevant words (solid lines). Surface potential maps based on the waveforms of possessor-relevant words and other-relevant words (possessor-relevant — other-relevant) for 300—500, 500—700 and 700—900 ms. Red and blue regions stand for the positive and the negative activity, respectively. Dots represent the 62 scalp electrode positions. And the activities were displayed in μV.

0.05. In the recognition test, a significant interaction was found between relevance and brain regions, $F(1,15) = 3.59$, $P < 0.05$. Simple effect analysis showed that possessor-relevant words were associated with a more positive ERP than other-relevant words in the central region and the parietal region, $Ps < 0.05$.

(iii) ERP source analysis to relevance in the lexical decision and the recognition test. Results from the intracranial source analyses for ERPs of the different types using the LORETA (Low Resolution Electromagnetic Tomography) method via Curry6.0 were shown in Figure 5. In this method, the grand averaged ERPs for different tasks were put into a standardized realistic volume conductor MRI model derived by using a boundary element method with three layers. According to the total average ERPs in the lexical decision and the recognition test, we examined the source results of 300—900 ms and found the activation region was similar. Based on the previous literature[13–15] and the analysis of ERP component data, we chose relevance data at 400 ms and 600 ms in the lexical decision and the recognition test to make location analysis, shown in Figure 5. Table 3 displayed the Talairach coordinates of each source generator based on the low-resolution current density reconstruction. The precuneus (BA7) was activated in the processing of other-relevant words and possessor-relevant words.

Table 3 Talairach coordinates of intracranial generators for different tasks [a)]

	Time (ms)	Brain regions	BA	X	Y	Z	RD (%)
Other-relevant	400	L precuneus	7	–7.5	–52.2	53.1	9.88
		R precuneus	7	18.1	–53.6	53.1	9.88
	600	L precuneus	7	–12.2	–52.2	58.2	8.26
Possessor-relevant	400	L precuneus	7	–11.2	–49.1	60.3	8.67
	600	L precuneus	7	–11.3	–49.1	60.3	7.65

a) BA, Brodmann area; L, left; R, right; RD, residual deviation.

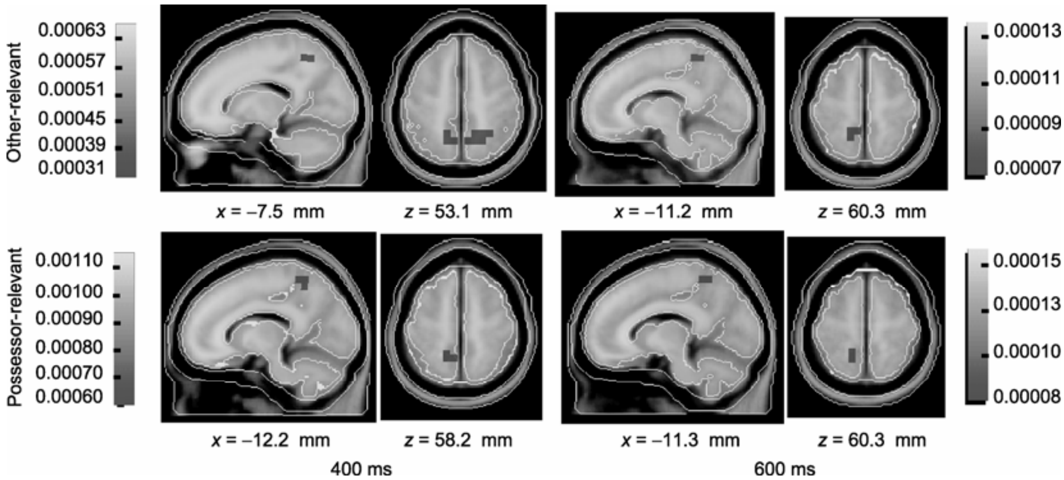

Figure 5 Results of the intracranial source analysis of possessor-relevant words and other-relevant words in different time epochs.

3 Discussion

3.1 Behavioral results

The response time taken to process the new words was significantly longer than that to process the old words both in the lexical decision and in the recognition test, namely, the old/new effect was existent. The results of this study were consistent with those of non-social materials processing[29]. Whether in the implicit or the explicit memory tests, and whether the words are old or new, the response time taken to process other-relevant words was significantly longer than that to process possessor-relevant words. It showed that the difference of response time between them remained stable. The result was consistent with the findings of Hout et al.[7] who believed that the negative effect existed in negative other-relevant words, while it did not exist in possessor-relevant words. That is, in negative words, the response time taken to process other-relevant words was longer than that to process possessor-relevant words. Buchner et al.[30] found that the amount of the memorized target words was the least if the target words were accompanied by negative other-relevant words. They believed that valent distractors provided significant information about the person himself/herself or about the state of the environment that needed to be paid attention to. The processing of affective content-particularly, negative other-relevant stimuli automatically alerted the cognitive system to redirect processing resources to the behavioral demands that were signaled by the valent stimuli. Vonk et al.[31] also found that the interpersonal behavior attracted more attention than personal behavior.

The result of this study once again showed that other-relevant words were more powerful to grab attention. In behavior, human-beings firstly will focus on the information that may have a bigger beneficial or harmful effect on themselves. And then they will focus on the information that may not have a bigger beneficial or harmful effect on them but may have a bigger impact on the owner with certain type of trait. English words often were used as experiment materials in previous studies, with all studies coming to the same results[7,11]. It shows that there is no cultural difference in this phenomenon, which is also the outcome of human-beings' long-term cognitive behaviors in continuous evolution.

3.2 ERP results of relevance in the lexical decision and the recognition test

Wentura et al.[11], Williams et al.[32], Algom et al.[33], Estes et al.[34] found that the response time taken to process negative stimuli was longer than that to process positive and neutral stimuli in the color naming task, the lexical decision task, as well as the word naming task. They thought that if the negative stimuli grabbed more attention of people, there would be less attention to be paid to other properties of the stimuli (such as color, part of speech and sound), resulting in a longer time in completing the task of color naming, lexical decision and word naming. Negative stimuli can bring a bad impact, while other-relevant words are related to the risk of the surroundings and play a crucial role in people's decision-making. Therefore, negative stimuli and other-relevant words have something in common. In addition, from the standpoint of attentional component[35], attention includes a variety of components, such as orientating, maintaining, releasing and transferring. Furthermore, in different experimental tasks, attention has a bias towards different components. From behavioral data as well as Figure 3 and 4, we could see that other-relevant words were associated with a more negative ERP than possessor-relevant words and meanwhile the response time taken to process the other-relevant was longer, whether in the old or new words and whether in the implicit or the explicit memory tests. According to the explanation of the literature[11,32–34], as well as attentional component view[35], we believe that during the initial orientation, the attention is captured by the meaning of other-relevant words and difficult to transfer, so less attention is paid to other properties of other-relevant words (such as the words and non-words, new words and old words). Possessor-relevant words grab less attention and are less related to percipient than other-relevant words, and meanwhile less information is involved in the processing of possessor-relevant words than that of other-relevant words. Hence, it is easier for the attention paid to possessor-relevant words to be released and transferred and there will be more attention to be paid to other properties of possessor-relevant words. Due to the attention bias and different amount of information in processing, other-relevant words associated with a more negative ERP were responded to more slowly than possessor-relevant words, and the difference between possessor-relevant words and other-relevant words was statistically significant.

After making a statistical analysis on relevance of old and new words, we found that for the new words, in the lexical decision and the recognition test, from 500 to 700 ms, the difference between other-relevant words and possessor-relevant words was shown in the prefrontal region, the frontal region, the central region and the parietal region. However, for the old words, the difference of relevance was shown only in the central region. For the old words, there was no difference of relevance in any brain regions from 700 ms to 900 ms whether in the lexical decision or the recognition test. While for the new words, the difference of relevance was shown in the prefrontal region, the frontal region, the central region and the parietal region. And this result was similar to the results of Maratos et al.[26] who made a research on the recognition of negative words and neutral words, and found that after 800 ms, for the old words there was no difference between negative words and neutral words while for the new words the difference was found in the same brain regions. But they did not explain this phenomenon. According to the characteristics of old and new words as well as the Context-Availability Model[36], we believe that the words in the study phase are analogous to episodic information. If they occur repeatedly, the difference among various types of words will be weakened. Relevance is implicit and closely related to the automatic capture of attention resource. For the old words, as they were seen in the encoding stage, the difference of attention-grabbing between other-relevant words and possessor-relevant words diminished in the retrieval stage. With the extension of recognition time, the difference gradually tapered off. Thus, in 500—700 ms, the difference of relevance for the old words was only shown in the central region, while in 700—900 ms, there was no difference in any brain regions. For the new words, as they were not seen in the study phase, the difference of attention-grabbing between other-relevant words and possessor-relevant words would be bigger so that it could be automatically distinguished. This suggested that in the later processing stage the distinction of relevance was related to the familiarity of the words.

On the overall analysis of relevance, from 300 ms to 500 ms, the waveform was similar to the N400 effect generated from the processing of concrete and abstract words[13,15]. This showed that whether in social or non-social materials cognition, the automatic semantic processing was associated with the N400 effect. The ERPs in 300—500 ms indicated that for the old and new words, a more negative wave and a robust activation were found in the prefrontal region, the frontal region and the central region in the lexical decision and the recognition test, namely, the brain responded stronger to other-relevant words than to possessor-relevant words. The result was consistent with the previous results on social cognition. In fMRI experiment, Chiao et al.[16,17] found that whether they were Japanese or Caucasian, people showed greater activation in amygdale upon seeing the faces of their own races, which suggested that the stimuli closely related to the percipient himself/herself evoked a stronger reaction in the brain. From 500 to 700 ms, the difference of relevance in the lexical decision was shown in the frontal region, the central region and the parietal region, while the difference in the recognition test was shown in the central region, the parietal region and the occipital region. This indicated that with more information and more robust processing obtained, other-relevant words were associated with a more negative wave than possessor-relevant words in the central region and the parietal region in both the lexical decision and the recognition test. A social cognition ERP study by Baumeister et al.[19] found that there was greater amplitude of P300 for the threatening information than for the ordinary information, which reflected a robust processing in the brain regions for the stimuli closely related to the percipient himself/herself. In our experiment, similar results were found by using materials of social cognition. From 700 to 900 ms, in the lexical decision there was no difference between other-relevant words and possessor-relevant words in any brain regions while in the recognition test, the difference was obvious between the two types of words, which were shown in the central region, the parietal region and the occipital region. This shows that from 500 to 900 ms, the processing of relevance was more sensitive to explicit retrieval and less sensitive to implicit retrieval, which was epitomized in 700—900 ms. The processing of relevance was sensitive to unconscious retrieval and insensitive to conscious retrieval, so there was an ERP dissociation between implicit retrieval and explicit retrieval. According to the different amount of required attention in conscious and unconscious retrieval, we can presume that because it is easier to make a word or non-word decision than to judge whether a word is new or old, after 500 ms less amount of attention is required to process relevance in unconscious implicit task than in conscious explicit retrieval, and the amount of attention influence the processing of possessor-relevant words and other-relevant words. Therefore, there was no difference between possessor-relevant words and other-relevant words in the lexical decision while there was a difference in the recognition test.

Source analysis showed that whether in 400 ms or in 600 ms, the precuneus (BA7) was activated when other-relevant words and possessor-relevant words are processed. Studies have shown that the precuneus is activated by processing self-related mental representation, especially when people process the behavior memory of those people who communicated with the percipient himself/herself in the past[37]. This was consistent with Kelly's results in fMRI studies on self[38]. The precuneus was activated steadily when other-relevant words and possessor-relevant words were processed, which showed that relevance was a part of self in terms of the neural mechanism. It was noteworthy that not only the left precuneus but also the right precuneus were activated when other-relevant words were processed at 400 ms, which was consistent with the fMRI finding on self of Platek[39]. He believed that activity in the right hemisphere was related to the processing of the information about self. In our experiment, source analysis result suggested that other-relevant words and possessor-relevant words had different locations in the brain from the spatial information perspective. To be specific, only the left precuneus was activated in the processing of possessor-relevant words. In contrast, when other-relevant words were processed the activity was shown in the right precuneus additionally. The source analysis at 600 ms showed that there was the same activation position for the two types of words. Studies have shown that P3 has something to do with the effort of information retrieval and has nothing to do with the difference of semantic information[40]. In this study, at 600 ms, the processing of other-relevant words and possessor-relevant words reflected the effort on retrieving information, so there was no difference in activated brain regions.

4 Conclusions

We made a research on relevance in implicit memory test and explicit memory test in the study - test pattern. It is shown that other-relevant words are associated with a more negative ERP waveform than possessor-relevant words, which reflects an attention bias to the stimuli concerning the percipient himself/herself. The existence of the N400 effect reflects the general differences in semantic processing. From 700 to 900 ms, there is an ERP dissociation of retrieval formats in the processing of relevance between the implicit memory test and the explicit memory test, which indicates that the processing of relevance requires different amounts of attention in conscious and unconscious retrieval. Other-relevant words and possessor-relevant words differ in ERP waveforms as well as in the source generator in the brain.

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