N400 and P600 Effect of Chinese Words Recognition

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ABSTRACT

Word recognition is an important part of the processing in reading comprehension. N400 component is generally considered as semantic index of word processing, and P600 component is used to interpret syntactic processing. But the discovery of "Semantic P600" effect prompts people to interpret the meaning of P600 again. This study takes normal developing teenagers (ages 12-14) as research subject by using the event-related potentials (ERP) to examine the N400 and P600 effect of Chinese words processing of the true words and pseudo words recognition. The results show that the reaction time of the pseudo words are longer than that of the true words and N400 can also be evoked by the independent Chinese words; the pseudo words evoked larger amplitude of N400 than that of the true words. Compared with the true words, the latency of P600 of pseudo words are significantly delayed. The amplitudes of P600 evoked by true words are larger than by the Pseudo words. The present results suggest that N400 and P600 have different functions and significance in words recognition, N400 reflects the semantic priming effect, P600 reflects the semantic integration in the late stages of semantic processing.

Key Words: Words Recognition, True Word, Pseudo Word, N400; P600

Introduction

Words recognition is the acquisition of vocabulary meaning, which including confirmation process of the form and sound of the word features, as well as extraction and integration process of the meaning of the word. It is generally believed that there has a lexical extraction processing first which is automatic, and then a post-lexical integration processing which is controlled (Holcomb PJ, 1993). Much of the evidence for this hypothesis has come from traditional behavioral measures for a long time, but traditional research methods can't investigate automatic processing and immediate processing in language understanding accurately. Event-related potential (ERP) provides the ideal research tools to examine the automatic processing in cognitive system. N400 and P600 are commonly used ERP (event-related potential) index in the research of language cognition (Bornkessel-Schlesewsky, Schlesewsky, 2008).

N400 is generally considered about semantic index of word processing, which was first reported by Kutas and Hillyard (1980). In their experiment, the sentence was presented word by word. In some cases, the last word is an inappropriate word which does not agree with the participants' expectation. The inconsistent tail word evoked a large N400 component than the consistent tail word. The amplitude of N400 is related with the predictability of ambiguity word in a sentence context, the more unpredictable ambiguous words, and the larger of amplitude N400. With this paradigm, N400 effect has been found in different languages (Bai & Hou, 2013; Kutas & Federmeier, 2011; Regel, Meyer & Gunter, 2014; Shu, Bai, Han & Bi, 2003), indicated that N400 is a component of lexical semantic processing reflecting language context.

Some research also found N400 with target word in the word context (Otten LJ, Rugg MD, Doyle MC, 1993; Ruz M, Madrid E, Lupicinez J, *et al.* 2003), a greater N400 amplitude can be elicited by the pseudo words than the true words. Though there are different views on N400 about whether it reflect the post-lexical integration processing or the automatic processing of the word as well as other issues (Annette Hohlfeld, Manuel Martín-Loeches & Werner Sommer, 2015; Borwn, Hagoort, & Chwilla, 2000; Daltrozzo J, Wioland N, Kotchoubey B, 2012; Deacno, *et al.,* 2000; Kiefer, 2002; Titone & Salisbury, 2004), we expect that N400 can also be evoked by the independent Chinese words, the pseudo words evoked a larger amplitudes of N400 than that of the true words.

P600 component was firstly reported by Osterhout and Holcomb (1992). It was called syntactic positive shift (syntactic positive shift, SPS) according to its functional characteristics. P600 effect is usually appeared around 600ms after stimulus presentation, it was widely distributed and the maximum amplitude is located in the central top area, which can be sustained for hundreds of milliseconds. According to the early study (Osterhout & Holcomb, 1992), P600 effect was specific wave induced by abnormal syntactic processing and this component has been considered as processing of syntactic reanalysis, which made P600 as the syntactic processing index. However, some other researchers have found that P600 effect can also occur at the condition of semantic conflict in the sentence (Hoeks, Stowe & Doedens, 2004; Kim & Osterhout, 2005; Kuperberg, Sitnikova, Caplan & Holcomb, 2003), which is called "Semantic P600" effect. This P600 effect was observed with semantic reversal anomalies, for example "The cat that fled from the mice ran through the room" (Kolk, Chwilla, van Herten & Oor, 2003; Van Herten M, Kolk HHJ & Chwilla DJ, 2005), semantic anomalies such as semantic-thematic attraction, animacy and semantic-thematic violations, plausibility all showed a P600 effect (Kuperberg GR, 2007), it is said that P600 is also sensitive to lexical semantic information. The "semantic P600" effect triggered a debate on the functional significance of the P600. Kolk and colleagues have suggested that P600s reflect "conflict monitoring" during language comprehension, i.e., a check for a possible processing error which is initiated when the processing system encounters conflicting information (2003). It is important to note that the semantic P600 reported in the above-mentioned studies was mostly found in the sentence, Vissers and colleagues investigated this effect with picture-sentence matching task, they observed a P600 effect for the mismatch trials (2008). We expect that P600 can also be evoked by the independent Chinese two-character pseudo words, because there is a mismatch between the two words.

The ERP research of word recognition deepened people's knowledge of brain mechanisms in language processing, determination of different ERP components expands the research scope of language and provides objective index to investigate different level of language cognitive processing. According to the current research results, research on alphabetic writing on behalf of English are much more than Chinese. As an ancient ideographic character, Chinese character has some similarity with other languages, but also has some unique characteristics in word formation, pronunciation, grammar and so on. Chinese character is a writing system composed of Chinese character component (radical and pictographic characters) and signs of none meaning and none phonetic in the perspective of Morphologic. Furthermore, the glyphs and voice of Chinese characters can be isolated (Zhang QF, Yang YF, 2004), and the radical and pictographic characters can exist as independent means (Zhou XL, Lu XM, Shu H, 2000). Chinese words recognition can provide an abundant of experiment materials for the study of language processing differences; it is helpful to understand universality and difference of human language processing and to clarify the function and significance of existing EEG component further.

Event-related potentials is a very effective research tools for the study of word recognition processing, the high time resolution can be obtained by using ERP technology. This study will do a preliminary study on N400 and P600 effect of Chinese words recognition by using Chinese two-character true words and pseudo words.

Methods
Subjects
The students of 20 junior high schools were selected and all of them have consistency at selection criteria including age, gender, family background, etc. They have no learning disabilities and ADHD, normal IQ and no previous history of brain damage or had received treatment-related drugs. What is more, all

subjects are right-handed, they had normal or corrected-to-normal vision above 1.0 and aged 12-14 years (average 13 years). All subjects and their parents have provided with written informed consent before the experiment, and all the subjects have the consent of their guardian, all of them would be paid after experiment.

Tools

Stimuli were presented using the program E-Prime 2.0. Desktop PC 14.7-inch display with a resolution of 1024 × 768 pixels, the background of screen is black and the fonts color is white. EEG is equipped with Brain Cap 32 Brain Product lead Ag/AgCL electrode cap, which is produced by Germany, and the electrode uses international 10-20 system expansion to record Horizontal EOG and vertical EOG, and corresponding EEG were recorded by EEG recording and analyzing system by utilizing Ag/AgCL electrode cap.

Materials

The materials for formal experiment are 200 Chinese two-character words, including 100 true words and 100 pseudo words. The true words commonly use Chinese two-character words (such as "工作"), and pseudo words are composed of Chinese two-character words but have no real meaning in Chinese (such as "片月"). The materials were chosen according to "frequency of Modern Chinese Dictionary", these words are all high frequency words, 60 per million. These two sets of stimuli have consistency in the word frequency and the number of strokes as well as other factors.

Program

The experimental procedure was shown in Figure 1, true words and pseudo words were randomly presented. In each trial, a "+" fixed gaze point was presented on the screen first for 200 ms, and then there is a 400~1000 ms blank screen spaced by random time, followed with a presented stimulation for 1000 ms. The subjects needed to decide quickly whether it is true words or pseudo words when stimulation appeared. The subjects were asked to press "J" key on the keyboard quickly and accurate with their right index finger when the true words appear, while press "F" key with their left index finger with the appearance of pseudo words. The experiments have two blocks, and each lock contains 50 real words and 50 pseudo words. At the end of the first block, the

subjects will have proper rest. Before the experiment, all subjects can practice the same formal procedure of experiment until they are familiar with the procedure and can press the key expertly.
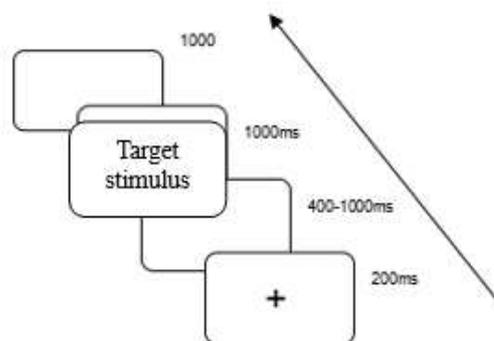

Figure 1. Words Protocol

Recording and analysis of ERP

The EEG recording system to record EEG by transimpedance amplifier 32 and 32 electrically conductive electrode cap comes from Germany Brain-Product Company, it locates at the middle point of FCz and Fz connection, the Horizontal EOG was recorded by outer electrode at the lateral eyes, while vertical EOG was record by outer electrode up and down the right eye. Taking the left ear mastoid as the reference electrode point, scalp resistance of each electrode is below 5kΩ, Bandpass filter is 0.05~100 Hz and Sampling frequency is 500 Hz. Taking average potential of ears mastoid as reference to offline (Offline) analysis, the lowpass of offline filter is 50 Hz. Volatility is greater than ± 200μV, considered as excluding artifact. The observation time window of ERPs is -200~1000ms, and the average amplitude of -200~0ms was used to baseline correction. Some artifact data with blinking, eye movement, electromyography, etc. are excluded. ERPs of true words condition and pseudo words condition will get through category superposition of brain waves induced by different experimental conditions.

According to the former experience (Kuperberg, 2007) and the purpose of this study, data of 14 electrode points was selected to analysis, that is F3, Fz, F4 of Frontal area; C3, Cz, C4 of Central area; T7, T8, P7, P8 of Bilateral area; P3, Pz, P4 of Top area and Oz of Occipital area. This study pays close attention on Components and Characteristics of ERP induced by words (true

78

and pseudo words), takes two (types of words) × 14 (dot electrode) as method to do data analysis and compare the total average wave of electric potential induced by different types of words condition. The above analysis uses SPSS software for processing, along with Greenhouse-Geisser correction method.

Results

Behavioral outcomes

According to preliminary wave form analysis, blink and artifacts of two subjects were too much, and their data was deleted. About 18 subjects accept effective EEG test finally. The correct rate and reaction time are shown in Table 1. There are significant differences between true words and pseudo words according to reaction time, $F(1,17) = 50.76$, $P<0.001$, that is processing reaction time of pseudo words are longer than true words; While based on correct rate, the average correct rate of true words and pseudo words are both more than 90%. The results of variance analysis indicated that there is no significant difference between true words and pseudo words on correct rate, $F(1, 17) = 1.44$, $P>0.05$.

Table 1. Variance analysis on correct rate and reaction time of true words and pseudo words

	Reaction Time (ms)	Correct Rate (ms)
True words	594.61±48.41	0.95±0.07
Pseudo words	674.79±80.19	0.93±0.05

Table 2. Average amplitude and latency of N400 and P600 recognition of true words and pseudo words (n=18)

		N400	P600
True words	Amplitude	0.10 ± 4.4	9.82 ± 5.2
	Incubation period	355.6 ± 42.4	554.9 ± 46.1
Pseudo words	Amplitude	-2.3 ± 4.8	8.30 ± 4.9
	Incubation period	359.2 ± 45.3	580.3 ± 47.7

Results of ERP

The average amplitude and latency of N400 and P600 of true words and pseudo-words recognition are shown in Table 2. The basic ERP characteristics of true words and pseudo words are very similar, but obvious separation of positive or negative of ERP amplitude was obtained under different experimental conditions, and the target stimulus was presented at 400ms, a significant component of N400 with a more extensive Scalp Distribution, was induced under conditions of true words and pseudo words. A positive wave of P600 was observed at 500-700 ms after the target stimulus presentation. This

study is mainly paying close attention to two-time windows of 300-500 ms and 500-700 ms.

Time window of 300 ms-500 ms (N400)

The analysis of repeated measures ANOVA with 2 (words type) plus 14 (electrode point) was used. There was no significant effect of word type found by Latency ANOVA, $F(1, 17) = 3.08$, $p>0.05$, which is in contrast with the result of amplitude analysis of variance, $F(1, 17) = 18.32$, $p<0.001$. The amplitude of N400 of pseudo words is significantly greater than true word for further comparison.

Time window of 500 ms-700 ms (P600)

According to Latency ANOVA, the main effect of words type is significant, $F(1,17)=10.68$, $p<0.01$, the latency was delayed obviously under the condition of pseudo words. The results of amplitude analysis of variance also confirmed a significant main effect of words type, $F(1,17)=5.89$, $p<0.05$. The amplitude of P600 of true words is significantly greater than pseudo word for further comparison.

The wave difference of true words and pseudo words recognition processing is the numerical difference of EPR of pseudo words and true words. The average amplitude and wave difference of true words and pseudo words were shown in Figure 2, and the different topographic wave is shown in Figure 3. It indicated that statistical results are consistent with different wave topographic map.
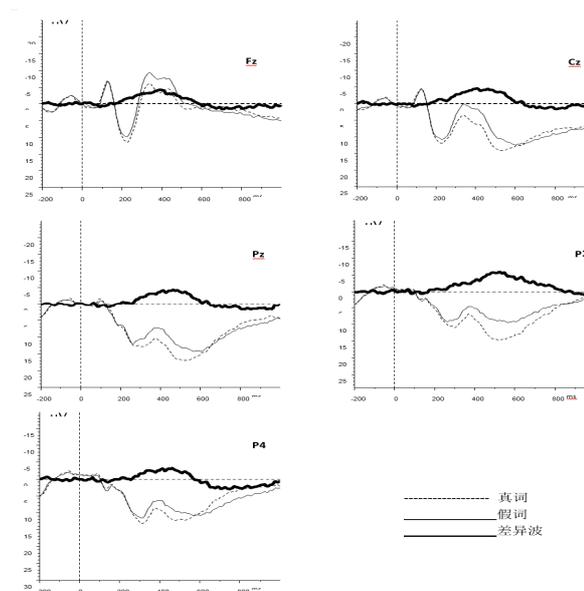

Figure 2. Average ERP diagram and wave difference under conditions of true words and pseudo words
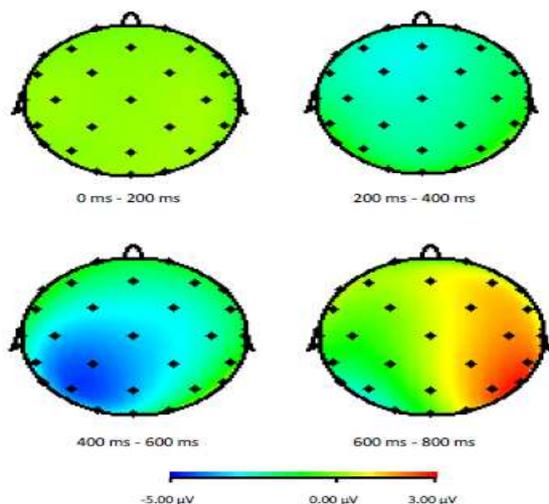
Figure 3. Difference waves topographic map of ERP of true words and pseudo words

Discussion

This study focusses on the time process and processing characteristics using words judgment task. It is turned out that the reaction time of pseudo words are significantly longer than that of the true words, the perception process of pseudo words has more conflict and integration of semantic features within the whole words, so it need more time to make a judgment.

N400 is always recognized as an important semantics index related to language processing; the amplitude of N400 is related with the predictability of ambiguity word in a sentence context. The former research mainly focused on sentence context, Van petten and Luka (2006) indicated that N400 not only occur in the sentence processing in alphabetic writing, N400 could be also induced if the words appeared semantic violation in the sentence. This study confirmed that an independent word can also induce N400, which is consistent with the findings of Nobre and McCarthy (1995). The N400 amplitude widely distributed in the brain is very sensitive to various of semantics conditions, and the maximum wave peak of which is located at postmedian area. Otherwise, the N400 amplitude of pseudo words are greater than true words, the possible reason is that the task of stimulating processing of pseudo words is difficult than true words, which required more mental resources.

There still has a debate on N400 whether it reflects automatic processing process or control processing process, but there is a relative consensus about semantic priming effect of N400. The latest view think that N400 is a simple activation index of the word, it is only a kind of priming and has nothing to do with any high level of integration process (Whitney, 2010). Whitney explained that most studies about words recognition had been conducted in sentence context where the target words have obvious semantic relation with other words, so the researchers believed mistakenly N400 reflect the semantic integration. Some research supports the point that

N400 reflect the automatic processing in words level (Hoeks, Stowe & Doedens, 2004; Kim & Osterhout, 2005; Van Herten, Kolk & Chwilla, 2005). This study make a preliminary study of words recognition by using Chinese two-character true words and pseudo words, the pseudo words evoked a larger N400 than that of the true words, it is consist with the previous results (Holcomb, Grainger & O'Rourke, 2002; Pulvermuller, Mohr & Lutznberger, 2004).

The stable P600 effect can also be induced by Chinese words judgment task according to this study, the latency of P600 was significant delayed under conditions of pseudo words, compared with the true words. After semantic processing conflicts between the two Chinese characters, the first Chinese character need search the second candidate of Chinese characters which best match it, so the second Chinese characters, the pseudo words need more search and certification which are longer in the form of latency than the true words.

The more important is that the amplitude of P600 effect induced by the judgment of true words is greater than that of pseudo words, which cannot be explained by "conflict monitoring". The results of this study indicated that P600 effects is not only the unique wave induced by syntactic processing abnormalities or semantic violation, but also can be induced by normal words processing task, how to explain the P600 effect presented in this study?

There are three theories to explain "semantic P600" effect currently, the Monitoring Theory (Kolk & Chwilla, 2007; Kolk, Chwilla, van Herten & Oor, 2003; van Herten, Kolk & Chwilla, 2005; Van Herten, Chwilla & Kolk, 2006) believes that P600 effect is not the result of syntactic reanalysis, since the nature of P600 effect induced by semantic violation and syntax violation is identical, both of them are induced by the conflicts of language processing, and the conflicts lead to the processing system to monitor and resolve the possible errors of processing. Although the monitoring theory was confirmed by

80

some findings (Spotorno, Cheylus, Van Der Henst & Noveck, 2013; Vissers, Chwilla & Kolk, 2006; Vissers, Kolk, van de Meerendonk & Chwilla, 2008; Ye & Zhou, 2008), it cannot explain the P600 effect induced by the true words judgment of this study. The dynamic model of non-syntactic center (Kuperberg, 2007) believes that there are two independent and interaction paths of sentence processing. P600 effect is the reflection of continuous analysis of conflicts of different pathway processing results. According to this view, there should some consistency between N400 and P600 amplitude, but it cannot explain the inversion of N400 and P600 in this study. The extended argument-dependent model has divided the sentence processing into three stages (Bornkessel & Schlesewsky, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008). "Semantic P600" effect is different from that of traditional syntactic P600, because they were induced by different stages of sentence processing. "Semantic P600" effect occurs at the comprehensive mapping process of the third stage, while P600 effect of traditional syntactic is the results of ultimate explanation process. It seems reasonable to explain P600 effect from processing stage, but whether the comprehensive mapping process is independent or interacted with the ultimate explanation process in the sentence processing and can they be separated when process is still a major dilemma of this theory. Meanwhile, all of the above three theories based on the semantic conflict which cannot explain some findings of this study.

Since all above theories cannot explain the findings of this study, it is necessary to make some new interpretations for the functions and meaning of P600 effect. Based on the results of this study, we try to make some preliminary explanations for P600 effect. Ryan believed that most ERP effect depends on the working memory capacity (2005). Working memory itself is a resource-limited system (Caplan, Alpert & Waters, 1998; Just & Carpenter, 1992). The total cognitive resources needed to analyze the true words and a pseudo word is constant, but the allocation of limited cognitive resources on the process is flexible. Since more cognitive resources needed to coordinate the conflicts of pseudo words in early processing, which showed stronger N400 amplitude and thus have reducing cognitive resources to late words judgment, the decrease of P600 amplitude was exhibited. On the contrary, no more cognitive resources involved in the processing of true words in the early semantic processing, which showed decreased N400 amplitude, and an enhanced P600 effect was exhibited as the results of more used cognitive resources at the late semantic processing. Brouwer and colleagues suggested that the N400 reflects only the retrieval processes of the linguistic features of a current word from long-term memory. Furthermore, they suggested that semantic integration, which has previously been linked to the N400, might be reflected in the P600 instead. Meanwhile, P600 reflects the late semantic integration as common sense (Brouwer, Fitz & Hoeks, 2012).

Conclusion

N400 and P600 have different functions in words recognition. N400 is the reflection of semantic priming effect, because internal lexicon can be activated by true words easily, the pseudo words evoked a larger N400 than that of the true words. While P600 is the reflection of semantic integration in late semantic processing, this can be occurred under the condition of semantic conflict as well as semantic consistency. The processing conflicts of semantic conflict in the early words recognition induced the delayed latency of P600, which performed as the decision of the advanced processing is significantly later than that of semantically consistent condition.

The above is only a preliminary conclusion and explanation, whether it is suitable for explaining the semantic processing of alphabetic writing or other languages need more research. Otherwise, all subjects selected for this study are 13-year-olds teenagers, so the results of this study are only limited to this present age, and whether P600 has some age effects needs more research. Furthermore, this study pays close attention to time course of words recognition with less electrode leads, which results in a less clear spatial orientation of ERP, which suggests us to discover more features of brain by using multi-source analysis in the follow-up study.

Acknowledgments

81

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82

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83