



# The Influence of Word Attribute Information and Word Frequency Information on the Concreteness Effect of Words

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**Abstract.** Using ERP recording technology our purpose is to explore the neural mechanism of the effect of word attribute information and word frequency information on concreteness. Experiment 1: under the lexical judgment task, the relationship between the two variables was investigated. The results showed that in N2 and P3 time window, there were differences between noun and verb processing. In P3 time window, concrete words and abstract words appear separate. In the process of N400, there are differences in the processing of nouns and verbs, concrete words and abstract words. In experiment 2, under the vocabulary judgment task, frequency and vocabulary type were taken as independent variables. The results showed that in N2 time window, high frequency vocabulary and low frequency vocabulary processing were separated. In P3 time window, noun and verb processing differences, concrete and abstract words began to appear separate. In N400, there are differences in the processing of nouns and verbs, concrete words and abstract words. The results suggest that word attributes and word types affect concreteness effect; the concreteness effect occurs in low-frequency words. The processing of concreteness effect of Chinese two-character words supports a single semantic processing model.

**Keywords:** Concreteness effect · Word attributes · Word frequency · Chinese two-character word

## 1 Introduction

Speech comprehension is a social phenomenon [1, 2]. Word recognition is the first stage of speech understanding. Word concreteness information and word frequency information affect word recognition. Concrete words refer to words that express specific concepts, such as table, bread and others. Abstract words refer to thoughts, feelings and other words that represent abstract concepts. In many experimental tasks, concrete words are processed faster than abstract words, that is, concrete effect.

Dual coding theory holds that there are two independent but interrelated processing systems in the human brain. They are semantic - based processing system (verbal system)

and image - based processing system (non-verbal system). Concrete words are processed in verbal and non-verbal systems, while abstract words are mainly processed in the verbal system [3]. The Context Availability Model holds that when concrete and abstract words are processed in a system. The comprehension of verbal information depends heavily on the information of “context”. It is more difficult to retrieve the “context” information of abstract words than that of concrete words when the words are presented separately. However, if appropriate context is provided, there is no significant difference in the processing of the two types of words, that is, the concreteness effect disappears [4].

Holcomb et al. investigated the concreteness effect of words under three different context conditions (appropriate, abnormal and neutral), and found that in abnormal and neutral sentences, concrete words produced larger N400 components than abstract words [5]. The Kounios and Holcomb studies also found that concrete words elicit larger N400 components than abstract words; In addition, in the right anterior brain region, concrete words and abstract words appear more separate, which indicates that concrete words have the advantage of right brain processing. But the study also found that the repetition of words makes the difference between concrete and abstract words weaken or even disappear [6]. Roberta and Alice took Italian as the experimental material and adopted the lexical judgment task, which resulted in significant concreteness effect. Different from the past, there was no N400 component. Concrete words in the middle occipital lobe produced larger N365 component than abstract words, and P3 component was found in the prefrontal lobe (the amplitude of abstract words was larger than that of concrete words) [7]

Using the PET technique and the vocabulary judgment task, Perani, Cappa, et al. found that the processing of abstract words was related to the selective activation of right temporal pole, right amygdala and bilateral inferior prefrontal cortex, while the processing of specific words did not find brain regions more active than that of abstract words [8]. Kiehl et al. [9] used the same experimental task as Perani et al. [19], and combined with fMRI technology, obtained consistent results. Fiebach and Friederici [10] followed the experimental task technique of Kiehl [9], but obtained different results. The processing of abstract words was related to the left inferior frontal triangle, while the processing of specific words was related to the left temporal lobe base. The results show that the processing of concrete words and abstract words is different, but they all have left brain dominance. However, Binder et al. [11] concluded another conclusion that the processing of abstract words activates the left inferior frontal lobe, while the processing of specific words activates bilateral angular gyrus and bilateral prefrontal cortex back.

Zhang qin [12] investigated the concreteness effect of Chinese words by manipulating word frequency, and found that there was a significant concreteness effect in the recognition of Chinese double-character words, but this advantage of specific words only existed in the range of low-frequency words. They also used repetition priming paradigm to investigate the influence of word context on the concreteness effect of two-character words, and found that repetition priming could not eliminate the concreteness effect.

Chen baoguo [13] used the vocabulary judgment task to investigate the influence of concreteness effect on vocabulary recognition. The results showed that concreteness and frequency had an interaction, but the concreteness effect only existed in high-frequency words. Zhang qin et al. [14] used ERP technology to study the processing difference

between nouns and verbs and the relationship between concrete word and word attribute. The results showed that: in the 200–300 ms and 300–400 ms time Windows after the stimulus presentation, the ERP component induced by specific nouns in the whole brain was larger than that of specific verbs. Zhang, Guo, Ding, and Wang [15] used ERP technology to investigate the concrete effect of words by using word judgment task manipulation word frequency, and added concrete verbs and abstract verbs. The results show that, regardless of word frequency, concrete nouns produce more negative components between 200 ms–300 ms and 300 ms–500 ms than abstract nouns. They believe that concreteness and frequency of words may be two independent factors. The brain regions of concrete and abstract words were different in the 300 ms–500 ms time period, which supported the dual coding theory. Finally, the concreteness between verbs was smaller than that between nouns, and the difference was found in the middle left parietal lobe.

It can be seen that there is still controversy about the results of specific vocabulary processing. The first innovation of this study is to investigate the specificity effect by controlling word frequency and part of speech variables. The second innovation was the use of electroencephalography. The third is the Chinese double word as the experimental material

## 2 Experiment 1 the Influence of Word Attribute in Concreteness Effect

### 2.1 Method

**Participations.** The subjects were 22 college students of Liaoning normal university, aged 18–20 years old. All the subjects had not participated in similar experiments recently, and were healthy with normal vision or corrected vision. All the students who participated in the experiment received a nice gift and credits as a reward.

**Materials.** Material preparation and evaluation are as follows: (1) to select double-character concrete words (concrete nouns and concrete verbs) and abstract words (abstract nouns and abstract verbs) from the modern Chinese frequency dictionary. (2) these two-character words were randomly arranged and 20 students who did not participate in the formal experiment rated concreteness on a seven-point scale. 7 represents the strongest concreteness and 1 represents the strongest abstraction. (3) control the frequency of double-character words, the number of strokes of the first character, the number of strokes of the last character and the total number of strokes, and avoid the use of emotional words. (4) finally, 60 concrete nouns, concrete verbs, abstract nouns and abstract verbs were obtained respectively. (5) any word in a true word is modified to become a false word. Control the influence of the number of strokes of false words on the experimental results, and try to avoid false words with the same pronunciation, similar or ambiguous. (6) statistical information of 240 selected double-character words is shown in Table 1.

**Experimental Apparatus.** The experimental program was developed with e-prime 1.0, and the experimental materials were presented with a 15-in. monitor. EEG was recorded

**Table 1.** Statistics of experimental materials

| C-A    | CR             | AWF             | ASIC           | ASLC           | OMS             |
|--------|----------------|-----------------|----------------|----------------|-----------------|
| C-noun | 6.44<br>(0.33) | 67.73<br>(0.01) | 7.77<br>(2.64) | 7.62<br>(2.46) | 15.38<br>(3.84) |
| A-noun | 1.93<br>(0.23) | 64.93<br>(0.01) | 8.10<br>(2.90) | 8.45<br>(2.35) | 16.55<br>(3.76) |
| C-verb | 5.39<br>(0.45) | 72.29<br>(0.01) | 8.53<br>(2.38) | 7.75<br>(2.81) | 16.28<br>(3.80) |
| A-verb | 2.52<br>(0.25) | 60.79<br>(0.00) | 8.60<br>(2.39) | 7.13<br>(2.13) | 15.73<br>(3.02) |

Note: frequency units are times/million. C-A: Concreteness - attribute. CR: Concreteness rating. AWF: The average word frequency. ASIC: Average stroke of initial character. ASLC: Average stroke of last character. OMS: Overall mean stroke

using EGI-128 channel recording system produced by EGI Corporation. The electroencephalogram was recorded by the international 10–20 system. With the Cz point as the reference electrode, electrodes were placed on the outside of the eyes, on the top and bottom of the eyes respectively to record the horizontal ophthalmic (HEOG) and vertical ophthalmic (VEOG). Sampling frequency is 250 Hz, and scalp electrode contact resistance is less than 50 k $\Omega$ .

**Experimental Procedure.** In this experiment, the experimental design is 2 (word type: concrete word, abstract word)  $\times$  2 (word attribute: noun, verb) completely repeat two factors design. The experiment adopted the word judgment task, and each subject was tested separately. Each subject completed the judgment task of 480 words.

After the electrode installation, the subject sat down facing the computer screen with a visual range of 80 cm. This experiment is divided into four blocks, each containing 120 trials. Firstly, the fixation point “+” is presented for 200 ms, followed by the target word, which is presented in black and white on the center of the computer screen. Each screen presents a word with a maximum view Angle of 2.5°. The subject pressed the key “1 or 4” to judge whether the word is the true or false word, and then the empty screen lasted for 500 ms. And then the next trial continues.

**Data Analysis.** The response time and error rate of the target words were analyzed statistically. Data whose response time of the target word is less than 250 ms and greater than 1500 ms are deleted. The subjects whose error rate was less than 80% were excluded. Finally, 20 valid subjects were obtained. SPSS16.0 statistical software was used to analyze the variance of repeated measures in response time

30 Hz low-pass filtering was performed off-line for the continuously recorded original EEG data. The analysis duration starts with the target word presenting, lasts 1000 ms, and the baseline is 200 ms before the target word presenting. After removing the data

segments containing eye movement artifacts, the data segments under the same conditions were averaged. After baseline correction and whole-brain averaging, the average waveforms of each subject in each experimental condition were obtained. According to the previous literatures [5–7] and the total average ERP waveform in this experiment, the average amplitude of N2 (150–280 ms), P3 (280–420 ms) and N400 (420–570 ms) were taken for analysis

## 2.2 Results

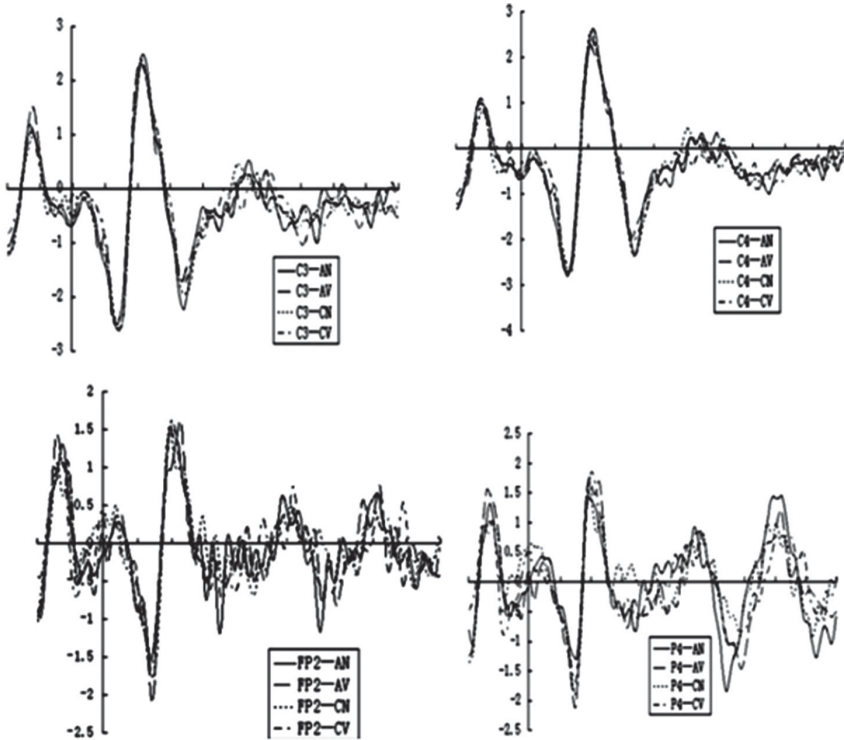
Twenty effective subjects were analyzed. The response time of true words and false words were 584.41 ms and 662.93 ms, respectively, and the response error rate was 0.06% and 0.05%, respectively. The variance analysis of response time shows that the main effect of lexical type is significant, subject analysis:  $F(1,19) = 21.301$ ,  $P = 0.001$ ; item analysis:  $F(1,59) = 1.672$ ,  $P = 0.201$ . The main effect of lexical attributes is marginal significance, subject analysis:  $F(1,19) = 0.413$ ,  $P = 0.0528$ ; item analysis:  $F(1,59) = 0.115$ ,  $P = 0.0735$ . There is no significant interaction between word types and lexical attributes, Subject analysis:  $F(1,19) = 0.062$ ,  $P = 0.807$ ; item analysis:  $F(1,59) = 0.065$ ,  $P = 0.800$ . To identify the EEG sources of these differences, we further analyzed the ERP data. Repeated measurement ANOVA was performed on average amplitude, and Greenhouse-Geisser correction method was applied.

**N2 (150–280 ms).** Repeated measure ANOVA of 2 (concrete and abstract)  $\times$  2 (noun and verb)  $\times$  19 (electrode) was performed for the average amplitude of this period. The results showed that the electrode had a main effect,  $F(18,324) = 38.429$ ,  $P = 0.001$ . There was interaction between word attribute and electrode,  $F(18,324) = 10.0267$ ,  $P = 0.001$ .

Further analysis of the interaction between word attribute and electrode showed that there was a main effect of word attribute on C4 electrode,  $F(1,18) = 6.667$ ,  $P = 0.019$ ; on the P4 electrode,  $F(1,18) = 3.873$ ,  $P = 0.065$ ; on the O2 electrode,  $F(1,18) = 3.360$ ,  $P = 0.083$  (marginal significant).

**P3 (280–420 ms).** Repeated measure ANOVA of 2 (concrete and abstract)  $\times$  2 (noun and verb)  $\times$  19 (electrode) was performed for the average amplitude of this period. The results show that the main effect of word type is marginal significant,  $F(1,18) = 3.880$ ,  $P = 0.064$ . At the same time, the main effect of the word attribute of the target word is also near the marginal significant,  $F(1,18) = 4.343$ ,  $P = 0.052$ . The main effect of electrode was also significant,  $F(18,324) = 21.859$ ,  $P = 0.001$ . No interaction between the variables was found.

**N400 (420–570 ms).** Repeated measure ANOVA of 2 (concrete and abstract)  $\times$  2 (noun and verb) was performed separately for the average amplitude at each electrode. The results showed that there was a main effect of word type on C3 electrode,  $F(1,18) = 6.559$ ,  $P = 0.02$ ; On the PZ electrode, the main effect of word type was marginal significant,  $F(1,18) = 3.913$ ,  $P = 0.063$ . On the O2 electrode, the main effect of word attributes was marginal significant,  $F(1,18) = 3.379$ ,  $P = 0.083$  (Fig. 1).



**Fig. 1.** Comparison of ERP waveform on some electrodes. Note: The abscissa represents time (–200 ms–1000 ms), and the ordinate represents the average amplitude (V). AN stands for abstract noun; AV stands for abstract verb; CN stands for concrete noun; CV stands for concrete verb.

### 2.3 Discussion

The behavioral data of experiment 1 show that there is a word superiority effect, that is, the real word reacts faster than the pseudoword word. The subjects were more likely to judge the correct word as wrong, but less likely to judge the wrong word as right. Moreover, the error rate of abstract words is lower than that of concrete words, perhaps because of the influence of the speed-accuracy tradeoff. But it hasn't been proven conclusively by other studies.

The study found that the difference between nouns and verbs began to appear about 200 ms after the target word was present. Statistical analysis of individual electrodes showed that EEG differences between nouns and verbs were significant at C4 (right center), P4 (right parietal), and O2 (right occipital) electrodes. The studies by Preissl etc. [16] and Pulvermüller etc. [17] have shown that about 200 ms after the target word onset, nouns and verbs processing differences began to emerge. Pulvermüller et al. [17] found that about 200 ms after stimulus presentation, EEG differences of content words and functional words began to emerge. In this study, the number of strokes, frequency and concreteness of experimental materials were strictly controlled. Therefore, the word

attribute effect may reflect the semantic level difference of words with different properties. In this period, no main effect of word types was found, indicating that the processing of concrete words and abstract words had not been separated.

The difference between noun and verb processing continues to emerge in the next time window. Statistical analysis of individual electrode data shows that there is a significant difference in the processing of vocabularies of the two properties on FP2 (right frontal pole) and P4 (right parietal) electrodes. In this time window, the processing of concrete words and abstract words appeared different on the electrodes of P4 (right top), C3 (left center) and CZ (center point). In the 420–570 ms window, differences in the processing of nouns and verbs, concrete words and abstract words remain. The difference between noun and verb is shown by O2 (right occipital) and PZ (vertex) electrodes, while the difference between concrete and abstract words is shown by C3 (left center) and PZ (vertex) electrodes. N400 is closely related to language processing such as lexical access or semantic representation of words. In this study, it is believed that the presence of N400 components is more related to semantic representation. Whether there is word attribute effect or concreteness effect in the experiment, nouns are more related to perception, while verbs are more related to action procedures.

The difference between concrete words and abstract words is embodied in imaginability. Concrete words are more likely to make people produce representations. Thus, differences in semantic representation are likely to be reflected in electrical activity in the brain. However, the affirmation and clarification of this conclusion need further study.

### 3 Experiment 2 the Influence of Frequency on Concreteness Effect

#### 3.1 Methods

**Participation.** The subjects were 24 college students of Liaoning normal university, aged 18–20. None of the participants had recently taken part in a similar experiment and were healthy with normal vision or corrected vision. All the participants received a nice gift and credits as a reward. None of the participants in experiment 2 participated in experiment 1

**Materials.** The material preparation and evaluation of this experiment includes the following steps: (1) Select concrete and abstract words from the dictionary of modern Chinese frequency. Among them, the low-frequency words are the words with a frequency below 10 times per million, and the high-frequency words are the words with a frequency above 90 times per million. (2) Print these two-character words in random order on a piece of paper. Twenty students who did not participate in the formal experiment rated the word's concreteness on seven-point scale. "7" means the word refers to very specific content, and "1" means the word refers to very abstract content. (3) Control the number of strokes of the first character, the number of strokes of the last character and the total number of strokes, and try to avoid the use of emotional words. (4) 400 double-character words were selected, including 100 high-frequency concrete words, 100 high-frequency abstract words, 100 low-frequency concrete words and 100 low-frequency abstract words. (5) The composition of the 400 false words was the same as in experiment 1. The statistical information of the 400 selected two-character words is shown in Table 2.

**Table 2.** Statistics of experimental materials

| C-F  | CR             | AWF              | ASIC           | ASLC           | OMS             |
|------|----------------|------------------|----------------|----------------|-----------------|
| C-HF | 5.00<br>(0.92) | 260.42<br>(0.02) | 7.13<br>(2.44) | 7.19<br>(2.83) | 14.32<br>(3.58) |
| A-HF | 2.42<br>(0.61) | 4.02<br>(0.00)   | 7.36<br>(2.13) | 7.67<br>(2.45) | 15.03<br>(3.55) |
| C-LF | 5.75<br>(0.78) | 248.17<br>(0.01) | 7.92<br>(2.25) | 7.11<br>(2.43) | 15.03<br>(3.17) |
| A-LF | 2.58<br>(0.60) | 4.11<br>(0.00)   | 7.67<br>(2.23) | 7.41<br>(2.41) | 15.16<br>(3.30) |

Note:C-F: Concreteness - frequency. CR: Concreteness rating. AWF: The average word frequency. ASIC: Average stroke of initial character. ASLC: Average stroke of last character. OMS: Overall mean stroke. HF-high frequency, LF-low frequency, Frequency unit is in order per million

**Apparatus.** The experimental instrument is the same as experiment 1.

**Design and Procedure.** In this experiment, 2 (word type: concrete word, abstract word)  $\times$  2 (word frequency: high frequency, low frequency) two-factor measurement experiment design was adopted. Using the word judgment task, each subject was tested separately, and each subject judged 800 words. This experiment is divided into four blocks, each containing 200 trials. The rest of the experiment followed the same procedure as experiment 1.

**Data Analysis.** The response time and error rate of the target words were statistically analyzed. Data whose response time of the target word is less than 250 ms and greater than 1500 ms are deleted. The subjects whose overall accuracy rate was less than 80% were excluded. Finally, 21 subjects had valid data. A 30 Hz low-pass filter was performed offline for the recorded continuous original EEG data. The time epoch of analysis is the beginning of the target word presentation, lasting 1000 ms, and the baseline is 200 ms before the target word presentation.

After removing the data segments containing eye movement artifacts, the data segments under the same conditions were averaged. After baseline correction and brain average, the average waveform of each subject in each experimental condition was obtained. The average amplitude of N2 (150–280 ms), P3 (280–420 ms) and N400 (420–620 ms) were taken for analysis according to the previous literatures and the total ERP waveform in this experiment.

### 3.2 Results

The data of 21 effective subjects were analyzed. The response time of true words and false words were 603.84 ms and 674.48 ms, respectively, and the response error rate was 0.06% and 0.05%, respectively.

The variance analysis of response time data shows that the main effect of word types is significant, Subject analysis:  $F(1, 20) = 19.653$ ,  $P = 0.001$ ; item analysis:  $F(1, 99) = 5.726$ ,  $P = 0.019$ . The main effect of word frequency was significant. Subject analysis:  $F(1, 20) = 3.573$ ,  $P = 0.001$ . Item analysis:  $F(1, 99) = 3.887$ ,  $P = 0.001$ . There is a significant interaction between word type and word frequency, Subject analysis:  $F(1, 20) = 9.768$ ,  $P = 0.005$ ; item analysis:  $F(1, 99) = 3.813$ ,  $P = 0.054$ . The simple effect analysis of the interaction is found that the main effect of the word type is not significant,  $P > 0.05$ ; When the target word is low-frequency, the main effect of word type is significant, subject analysis:  $F(1, 20) = 22.333$ ,  $P = 0.001$ . item analysis:  $F(1, 99) = 5.757$ ,  $P = 0.018$ .

In order to clarify the source of these differences, we analyzed the ERP data. Repeated ANOVA was performed on the average amplitude, and Greenhouse-Geisser correction method was applied.

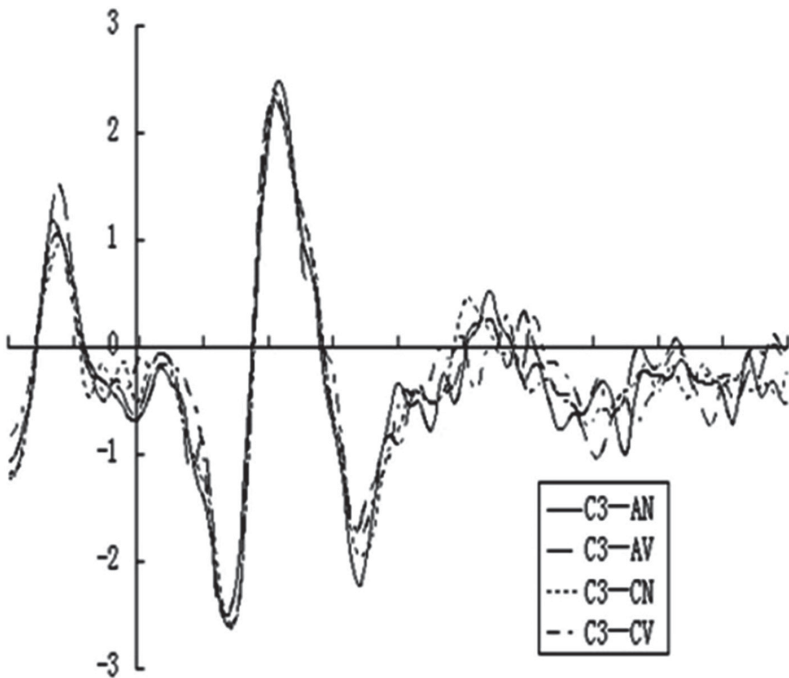
**N2 (150–280 ms).** The average amplitude of this epoch was analyzed by 2 (concrete and abstract)  $\times$  2 (high and low frequency)  $\times$  19 (electrode) repeated measurement ANOVA. The results showed that the main effect of the target word frequency was significant,  $F(1, 21) = 10.614$ ,  $P = 0.004$ . The main effect of electrode was significant,  $F(18, 378) = 40.284$ ,  $P = 0.001$ . There was interaction between word frequency and electrode,  $F(18, 378) = 4.762$ ,  $P = 0.008$ .

Simple effect analysis shows that there is a main effect of target word frequency on FP1 (left frontal pole) electrode,  $F(1, 21) = 10.787$ ,  $P = 0.004$ ; There is a main effect of target word frequency on the FP2 electrode,  $F(1, 21) = 9.072$ ,  $P = 0.007$ ; There is a main effect of target word frequency on F4 (right frontal) electrode,  $F(1, 21) = 4.803$ ,  $P = 0.04$ ; there was a main effect of target word frequency on the F8 (right anterior temporal) electrode,  $F(1, 21) = 4.534$ ,  $P = 0.045$ . In addition, there were significant frequency primary effects on T3 (left middle temporal), T5 (left posterior temporal), T6 (right posterior temporal), O2 (right occipital), FZ (frontal midpoint), and CZ (central point) electrodes.

**P3 (280–420 ms).** For the average amplitude of this period, 2 (concrete and abstract)  $\times$  2 (high and low frequency)  $\times$  19 (electrode) repeated measurement variance analysis was performed, and the results showed that the main effect of the electrode was significant,  $F(18, 378) = 23.175$ ,  $P = 0.001$ ; There was interaction between word types and electrodes,  $F(18, 378) = 32.112$ ,  $P = 0.001$ ; There was an interaction between the word frequency and the electrode,  $F(18, 378) = 5.651$ ,  $P = 0.001$ . A simple effect analysis of the interaction shows that there is a main effect of the target word type on the FP1 electrode,  $F(1, 21) = 4.282$ ,  $P = 0.051$  (marginal significance); There is a main effect of target word frequency on F3 electrode,  $F(1, 21) = 10.517$ ,  $P = 0.004$ ; There is a main effect of target word frequency on the C3 electrode,  $F(1, 21) = 3.872$ ,  $P = 0.062$  (marginal significance); There is a main effect of target word frequency on T3 electrode,  $F(1, 21) = 9.506$ ,  $P = 0.006$ . In addition, there are also major effects of lexical types on T4, T5,

O1, O2, FZ and CZ electrodes. Moreover, there was a significant interaction between target word frequency and word type on the T6 electrode,  $F(1, 21) = 14.874, P = 0.001$ .

**N400 (420–620 ms).** Repeated measure ANOVA of 2 (concrete and abstract)  $\times$  2 (high and low frequency) was performed separately for the average amplitude of each electrode. The results showed that there was a main effect of word frequency on C4 electrode,  $F(1, 21) = 6.130, P = 0.022$ ; on the P4 electrode,  $F(1,21) = 5.613, P = 0.027$ ; on CZ electrode,  $F(1,21) = 7.720, P = 0.011$ ; on the PZ electrode,  $F(1,21) = 3.158, P = 0.090$  (edge significant). There was a main effect of lexical type on the P4 electrode,  $F(1,21) = 10.764, P = 0.004$ ; on T6 electrode,  $F(1,21) = 5.710, P = 0.026$ ; on O2 electrode,  $F(1,21) = 6.033, P = 0.023$ ; on the PZ electrode,  $F(1,21) = 4.798, P = 0.040$  (Fig. 2).



**Fig. 2.** Comparison of ERP waveform on some electrodes. Note: The abscissa represents time (–200 ms–1000 ms), and the ordinate represents the average amplitude ( $\mu\text{V}$ ). HA stands for high frequency abstract words; HC stands for high frequency specific words; LA stands for low frequency abstract words; LC stands for low frequency specific words.

### 3.3 Discussion

Experiment 2 also found the word superiority effect, the error rate of false words is lower than that of true words, and the error rate of abstract words is lower than that of concrete words. Behavioral data show that there is a significant effect of word frequency and word

type, and there is an interaction between word frequency and word type. In the case of low frequency, the main effect of word type is significant, and the specific effect only exists in the range of low frequency words. It is common sense that the concreteness effect exists in low-frequency word. Whether abstract or concrete, the difference in processing disappears after the words are used quite a lot. The processing of high frequency abstract words is close to or equal to the processing of high frequency concrete words. However, for low-frequency word, the processing of abstract word and concrete word is still carried out in the original way. From this point of view, if a low-frequency abstract word has been used for quite a few times, it will not have a concrete effect. Therefore, faced with a new problem, what frequency range, word specificity effect exists; what frequency range, where does the concreteness effect disappear, and where is the critical point of that frequency? It deserves the attention of future research.

The results show that the main effect of the target word frequency is significant in 150–280 ms time window, and there is an interaction between the frequency and the electrode. From the beginning of word processing, word frequency plays a role, and the brain source of processing is also different. This result is consistent with the result of experiment 1. In experiment 1, the separation of noun and verb processing also occurs in this period. It can be speculated that this kind of word attribute effect may reflect the difference in semantic processing level of words with different properties.

In experiment 2, it was also observed that the separation of high frequency words and low frequency words with different properties also appeared in the 150–280 ms time window. Thus the results reinforced our hypothesis that differences on N2 waves indicate differences in the semantic level of words of different properties. In 280–420 ms, the processing of concrete and abstract words begins to separate. High and low frequency words continue to be processed differently.

In the process of 420–620 ms, the processing of different frequency words and the processing of different word types continue to be separated. However, there was no significant interaction between the two variables, and the N400 component was not affected by the frequency of the target word. In the study of Kounios and Holcomb [18, 19], the inconsistency between this response and N400 results also appeared. They argue that response time and EEG cannot be reduced to the same cognitive operation. Zhang [32] also showed such inconsistencies in the lexical judgment task. They explained that the measurement method of response time may be more sensitive to lexical tasks than lexical integration.

## 4 General Discussion

This study used the word judgment task, combined with ERP technology, to investigate the factors influencing the concreteness effect of Chinese two-character words. N2 is typically found in tasks such as describing response stimulus recognition, attention switching, suppressing motor responses, overcoming stereotypical responses, or conflict detection. Naatanen [20] proposed the following characteristics of N2 component: it was induced by deviant stimulus, even with only a very small deviation; Its enhancement results from an increase or decrease in event deviations. In this study, the separation of nouns and verbs, high frequency words and low frequency words occurred in the period

of N2 component. This suggests that after processing the physical features of words, differences in brain processing begin to emerge. Word attributes and word frequency play an important role in the early stage of word processing.

P3 is regarded as a measurement index of resource allocation [21, 22]. The P3 amplitude increased as the subjects put more effort into the task. In our two experiments, the separation of the first processing of concrete words and abstract words occurred in this period. The processing of concrete words activates more brain regions than that of abstract words. This is consistent with the dual coding model we mentioned earlier. But the dual coding model emphasized that this difference occurred only in the right brain. Since the processing of specific words is performed by the verbal semantic processing system and the non-verbal (image) processing system, while abstract words are processed by the verbal semantic processing system, the difference between them is embodied in the non-verbal (image) system. This system is thought to exist in the right brain. The differences between the two kinds of words in this study are not limited to the right brain.

According to the extended dual coding model, the difference between concrete and abstract words can be expressed in speech semantic processing system and non-verbal (image) processing system. It is therefore difficult to say in which hemisphere the amplitude of the processing of concrete words is greater than that of abstract words. The results of this study found that the difference between concrete words and abstract words appeared not only in the left brain, but also in the right brain, so it was more consistent with the extended double-coding model. The contextual validity model holds that the processing of concrete words and abstract words is reflected in different degrees of processing in the same system. Therefore, this experiment does not support dual coding model.

From a certain point of view, the extended dual coding model has something in common with the context validity model. The extended dual coding model is the synthesis and extension of the dual coding model and the context validity model. More importantly, some viewpoints of dual coding model were removed and context validity model was added, which made it extremely difficult to distinguish the extended dual coding model from context validity model, not only from response time, latency of brain waves, amplitude or distribution of brain regions. More research is needed.

It is generally believed that the larger the amplitude of N400, the smaller the context priming amount of the target word. The smaller the amplitude is, the greater the amount of context priming of the target word is. N400 is also related to the successful completion of vocabulary integration. In the N400 time window, the difference in the processing of concrete and abstract words in the two experiments also did not exist in the unilateral brain region, thus further supporting our view that the dual coding model was not supported.

The nature of nouns and verbs is different and has been confirmed in many studies. In this study, when examining the influence of word attributes on the concreteness effect, it is found that word attributes are not the factors that affect the concreteness effect. Zhang et al. [13] used high frequency nouns, low frequency nouns and low frequency verbs to investigate the concrete effect. The study showed that the difference between verbs in ERP was smaller than that between nouns, but did not analyze the difference between nouns and verbs. Meanwhile, Tsai [23]'s study on the word judgment task showed that

there was a significant interaction between word attributes and the cerebral hemisphere, and the processing of verbs was weaker than that of nouns in right brain.

The two studies also failed to show the interaction between word attribute and word type. Therefore, it is reasonable to believe that although nouns and verbs are words with different properties, such differences have been offset or ignored by the differences in the processing of concrete words and abstract words when making lexical judgments, and the specific reasons need to be further studied.

Word frequency is an indispensable factor in the study of word. This study shows that there is a significant interaction between word type and word frequency, that is, word frequency affects the specific effect of words. Further analysis shows that the specific effect occurs in the range of low-frequency vocabulary. The reason may be that, within the range of high frequency words, the specificity effect is not sensitive to the way in which it is measured. It is worth noting that word frequency and word type may be two independent variables. But further research is needed. The critical point of occurrence and disappearance of concreteness effect is also a main direction of future research.

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