A Review of ERP Study on Classifier Processing

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Abstract: Whether there are articles in Chinese has become a hot topic, and some people equate Chinese classifiers to articles. This paper aims to summarize the factors that affect the psychological processing of classifiers by reviewing the ERP research literature on classifiers, and then provide suggestions for ERP experimental design to address the controversy over whether classifiers are articles. Research has shown that the strength of sentence constraint, the specificity of classifiers and the animacy of the corresponding nouns could influence classifier processing, which provides reference for the design of further experiments.

Keywords: classifier; Mandarin Chinese; N400; sentence comprehension

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1.Introduction

Psycholinguistics studies the psychological process in language activities. It involves how human individuals master and use the language system, how to make the language system play a role in actual communication, and what knowledge and abilities should be possessed to master and use the system. One of the most commonly used methods for detecting psychological processes is Event-related potential experiment.

Classifiers are a unique kind of vocabulary in Chinese. Different from Indo-European languages, to combine with nouns in Chinese, numerals must be followed by classifiers[11]. Classifiers are divided into sortal classifiers and general classifiers. Sortal classifiers are semantically more specific, while general classifier are more commonly used and sometimes can replace specific classifiers, such as *gè* in Chinese[10]. Because *gè* in Chinese has a definite or indefinite function in different contexts, some scholars equate it with English articles[13]. If so, the same effect should be observed for *gè* and English articles *the* and *a* during language processing. Therefore, it is of great significance to study the psychological processing of classifiers.

Many researchers have begun to use ERP to examine the cognitive neural mechanism of classifier processing[1], but few have focused on proving its grammatical status. This paper aims to make a review of ERP research on classifier processing, summarize the factors that affect classifier processing and propose suggestions for future research, to provide experimental evidence for the controversy over whether classifiers are equal to articles.

2.Event-related Potential Technique

Event-related Potential (ERP) refers to an electrical signal generated by the cerebral cortex in response to stimuli after people are stimulated. This signal is also known as cognitive potential. It belongs to near-field potential and can reflect the neuroelectrophysiological changes of the brain in the cognitive process. During specific cognitive processing, we can record this potential from the surface of the skull using the average superposition method[12]. The N400 component, a negative going deflection around 400 ms after word onset, reflects semantic integration[6]. Syntactic integration is found to be related to two different components: one is Early Left Anterior Negativity (ELAN), appearing in the 100-200 millisecond time window after the presentation of the target stimulus and is associated with violation on category; the other is Left Anterior Negativity (LAN), appearing in the 300-500 millisecond time window and is related to morphological processing[3]. Therefore, ERP is widely used in exploring syntactic and semantic processing.

The application of ERP plays an important part in the investigation of language processing. First, due to the ability of this technique to monitor the brain activity with a millisecond-by-millisecond resolution, the temporal structure and coordination of different subprocesses of language processing could be accurately evaluated. Second, it can provide qualitatively correlation between syntactic and semantic processes, which can not be achieved by

reaction time measures[4]. However, the current ERP technique is not full-blown. Due to the relative lack of spatial resolution of ERP technique, it is often necessary to cooperate with other cognitive research methods in many studies involving cognitive brain regions[14]. Therefore, the application of ERP should be fully integrated with other cognitive imaging technologies to enable them to leverage their respective advantages and provide better experimental basis for exploring language processing.

3.ERP Research Methods and Paradigms for Classifier Processing

3.1.The Definition and Characteristics of Classifier Processing

In Mandarin Chinese, there must be an classifier between numerals and Chinese. For instance, *four books* should be sibenshu "four Classifierbooks book". Besides, the classifier should be chosen based on the semantic properties of the modified noun. For example, "ben", the classifier for books, can not be used for cars, and expressions like sibenche "four Classifierbooks car" is therefore semantically incorrect. According to the definition of the N400 component, if, in and ERP experiment, the participants observe the inappropriate use of classifier before a noun, which means that the presented classifier is not in line with the semantic features of following noun, the N400 effect would be observed. Since the ELAN component is the sign of word class violation, the observation of the replacement of a classifier with a word of other class, such as sichishu "four eat book", the ELAN effect would be evoked in the early time window.

3.2.Research and Design of ERP for Classifier Processing

Chou et al(2014)[1], Qian & Garnsey(2016)[9], and Frankowsky et al(2022)[8] conducted ERP research on classifier processing separately. Their research has indirectly demonstrated the impact of a certain factor on classifier processing. Due to their different research objectives, they adopted different ERP research methods and paradigms. Chou's research aims to examine the time and the way that the semantic constraint of Chinese classifiers affect the processing of their following nouns. Qian & Garnsey aims to determine which ERP components are sensitive to classifier-noun mismatches, so as to explore the nature of the underlying processes. Their study also examines effects of classifier constraint strength on anticipation of a subsequent noun. Frankowsky' research is to testify higher compatibility of the general classifier gè for low-animacy animate terms than for intermediate and high animacy animate terms, as well as to examine overall differences between the general classifier gè and the sortal classifier for animate terms zhī. The above three studies all adopt a visual paradigm.

In Chou's study, participants need to perform an acceptability judgment for the classifier-noun pair based on a 5-point scale, with 1 equaling "totally unacceptable", and 5 equaling "highly expected and totally acceptable".The stimuli materials are as follows. SC refers to strongly constrained sentences and WC refers to weakly constrained sentence. Whether a sentence is strongly or weakly constrained is determined by the cloze probability of the best completion for a sentence frame. If agreement for the best completion achieved 70%, the sentence is a strongly constrained sentence. Sentences with no more than 40% agreement for the best completion are defined as weakly constrained sentences.

SC	High cloze nouns	one ding(CLhats) hat
	Low cloze nouns	one jia(CLframed objects) airplane
	Implausible nouns	one ding sailor/one jia king
WC	High cloze nouns	one ping(CLbottles) drink
	Low cloze nouns	one tiao(CLstrips) road
	Implausible nouns	one ping credit/one tiao capital

Participants in Qian & Garnsey's experiment need to responded to a comprehension question by pressing one of two buttons after each sentence. The example sentences are as follows.Classifier specificity is determined by usage frequency. General classifiers are used more frequently than specific ones and they can be used with more different

nouns.

general	Match	On the table/de-MOD/two bei(CLcups) /coffee/already /cold.
	Mismatch	On the table/de-MOD/two zhang(CLsheets)/coffee/already/cold.
specific	Match	In the lawn/de-MOD/three duo(CLflowers)/flower/already/withered.
	Mismatch	In the lawn/de-MOD/three zhen(CLwind)/flower/already/withered.

In Frankowsky' research, participants are asked to judge the acceptability of the classifier-noun (or adjective noun) combination, by button press. The adjective-noun pairs are used as an index for ERP modulations of semantic violations in Chinese noun phrases.

gè–high animacy level noun	three gè(CLgeneral) water buffalos
gè – intermediate animacy noun	three gè(CLgeneral) goldfish
gè – low animacy level noun	three gè(CLgeneral) flies
zhī – high animacy level noun	three zhī (CLsortal) water buffalos
zhī–intermediate animacy noun	three zhī (CLsortal) goldfish
zhī – low animacy level noun	three zhī (CLsortal) flies
congruent adjective-noun pair	luxurious car
incongruent adjective-noun pair	flustered car

4.Discovery and Results of ERP Research on Classifier Processing

4.1.ERP Waveform Components and Time Windows in Classifier Processing

In Chou's study, different effects are found in the processing of classifiers and nouns. For classifiers, weakly constrained classifiers elicited enhanced negativity, e.i. the frontal negativity between 300 and 700 ms on nine frontal electrodes. For nouns, there are three main findings. Firstly, P200 is found over nine frontal electrodes between 170 and 250 ms in all conditions . Second, the N400 amplitude is broadly distributed and it is largest at the centro-posterior sites. It appeared to be more negative for implausible nouns no matter the constraint condition. Third, in the time window of 600 to 900 ms, the high cloze nouns elicited a greater positivity in frontal electrodes than low cloze nouns, especially in the strongly constrained condition.

Qian & Garnsey's discovery is mainly for the critical noun. It mainly studies two components, N400 and P600. For N400, the mismatching nouns elicited a more negative N400 component than the match conditions. More specific, visual inspection of the waveforms suggests that the noun's match effect was larger following specific classifiers than following general classifiers. For P600, the noun's waveforms were more negative following specific classifiers than following general classifiers at right frontal sites only. Therefore there was no evidence of a larger P600 in response to nouns that did not match their classifiers.

Frankowsky' study found that, for gè-noun pairs, there is a sustained negativity in anterior and centro-parietal regions relative to zhī-noun pairs in the late time window. This negativity is only observed for high-animacy nouns. Since this sustained negative waveforms of the high-animacy gè-noun pairs resemble those of the semantically incongruent adjective-noun condition, and waveforms of the zhī-noun pairs resemble those of the semantically congruent adjective-noun condition, it can be inferred that the high-animacy gè-noun pairs are also semantically incorrect. For zhī-noun pairs, high animacy nouns elicited less negative ERP waveforms than intermediate and low animacy nouns in the late time window. All above, is can be seen that the difference between the gè-noun pairs and the zhī-noun pairs could only be observed for high animacy level and not for intermediate or low animacy level.

4.2.Research Results and Effects of ERP on Classifier Processing

The sustained frontal negativity for classifiers in Chou's study may reflect working memory demands and the need to maintain and select among candidate items during recollection. That means when reading a strongly

constraining classifier, readers tend to form a strong prediction for its following noun. Therefore, the brain response elicited by the classifier showed a reduced frontal negativity. For nouns, the P200 may be sensitive to the state change, rather than the feature matching between expectation and the item actually presented. The N400 might reflect a joint effect for both the benefit and cost of the prediction due to an interaction between semantic constraint and cloze probability for the N400 in ANOVA. However, the nature of the frontal positivity between 600 and 900 ms is not yet precisely understood.

From Qian & Garnsey's discovery, it can be seen that combinatorial processing of classifier-noun sequences in Mandarin is primarily semantically based, as indexed by larger N400s when nouns mismatched the classifiers preceding them. The negligible P600 effect also proves this viewpoint. It also show that specific classifiers evoked stronger expectations about what noun might follow them than did general classifiers, as indexed by a larger sustained frontal negativity in response to general classifiers.

The ERP data in Frankowsky' study showed that animacy does have an impact on processing classifier-noun pairs, reflected by a sustained negativity in anterior and centro-parietal regions, when comparing nouns after general and sortal classifiers.These findings suggest that a graded animacy hierarchy influences noun classification in Mandarin Chinese. The different findings between gè-noun pairs and the zhī-noun pairs also show that speakers of Mandarin Chinese seem to process the general classifier and the sortal classifier differently.

4.3.The Influence of Different Factors on Classifier Processing

From the above studies, it can be seen that there are at least three factors influencing the psychological processing of classifiers.

First, whether a sentence is strongly or weakly constrained influences classifier processing. When reading a strongly constrained sentence, the strong prediction for the following noun reduces the difficulty of sentence processing and thus reduces the burden on readers in semantic processing. Therefore, the amplitude of the ERP component that signifies semantic processing may decrease with the strengthening of sentence constraint. The stronger the binding relationship between classifiers and their corresponding nouns, the smaller the amplitude of N400.

Second, the specificity of a classifier impacts classifier processing. Since general classifiers can be used for many different nouns, readers can not form a precise prediction of the noun after the classifier, which increases difficulty in semantic processing. Readers' expected nouns are more likely to not match the actual nouns, leading to the increase of N400 amplitude. The more specific the classifier, the more accurately the reader can locate the noun following it. When the noun meets the reader's psychological expectations, the N400 amplitude naturally decreases.

Third, classifier-noun processing is influenced by animacy hierarchy. Studies show that sortal classifier is obligatory for nouns for higher animals, while the combination of general classifier with high-animacy nouns causes semantic violation. That means, if a classifier is paired with a noun whose animacy does not match the classifier, readers' semantic processing will be hindered and the amplitude of N400 will also increase accordingly.

5.The Significance and Contribution of ERP Research on Classifier Processing

5.1.Overview of ERP Research on Classifier Processing

Classifiers are a unique category in Chinese compared to Indo European languages. Due to the need for different nouns to be paired with unique classifiers, some classifiers have their own semantic characteristics that match their corresponding nouns. From this perspective, these classifiers seem to belong to content words. However, there are still some classifiers that do not have clear restrictions on the nouns modified later, such as the general classifier gè. It seems that such classifiers should be functional words, only assuming grammatical functions without actual meanings. For this reason, the classifier gè has also begun to be classified by some scholars as an article in Chinese. Nevertheless, the above experiments show that even the commonly recognized classifier gè does not unconditionally match nouns. The combination of gè and high-animacy nouns can trigger N400, indicating that this

combination is not grammatically correct in the minds of native Mandarin readers. It also indicates that there is also a semantic processing process in the psychological process of processing this classifier. Besides, in the above three experiments, all classifiers triggered N400, but did not trigger components related to syntactic processing, such as P600. This finding is consistent with some ERP studies targeting nouns[2][5][7], providing a certain electrophysiological basis for linguistics to classify classifiers into content words.

5.2.Prospects and Suggestions for Future Research

In summary, the ERP research results of classifiers have some properties of content words. The EEG components triggered by classifiers are influenced by three factors: strongly or weakly constrained sentences, general or specific classifiers, and high or low animacy of the following nouns. However, there has been no experiment to prove the controversy over whether classifiers belong to articles. Current research can provide some suggestions to help prove this controversy.

First, compile the controversial gè into stimulus materials, and replace it with demonstrative word which are widely recognized as having the function of an article as the control group. Observe whether the gè and demonstrative word in these two groups trigger the same ERP components.

Second, combine the phonetically reduced gè, which is considered as the indefinite article by Luo and Deng(2022)[13], with high-animacy nouns which have been proved to be semantically inconsistent with the general classifier gè, and see whether this combination will trigger N400. The same stimulus materials that uses numeral-classifier phrase which is vaguely equated to indefinite article to take place of gè should be used as control groups.

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