Dependent mechanism of Chinese prepositions processing in the brain: evidence from event-related potentials

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Abstract: Objective To compare the event-related potentials (ERPs) waves of verbs and prepositions in the brain.

Methods We recorded ERPs in the brain while participants judged the legality of the collocation for verbs and “preposition”.

Results Both verbs and prepositions elicited a negativity at the frontal site in 230-330 ms and 350-500 ms window. No difference was seen in 230-330 ms and 350-500 ms window; In difference waves, a negativity was elicited in the left and right hemisphere at about 270-400 ms and 470-600 ms window for both open and closed-class words. **Conclusion** These may demonstrate that prepositions in modern Chinese are probably not a separate class from verbs and that N280 may be not a specific component for only prepositions (or closed-class words).

Keywords: Chinese; prepositions; verbs; event-related potentials; difference waves

1 Introduction

There is still disagreement on what category of the so-called “prepositions” should be, because very few of these words are fully grammaticalized in modern Chinese, most of which are in the process of grammaticalization and have the properties of both verbs and prepositions^[1-3]. Therefore, event-related potentials (ERPs) is adopted to probe into the neural mechanisms of verbs and prepositions in modern Chinese in order to provide some neuroscience evidence for the solution of this debate^[4]. This experiment has been done to explore whether these words (prepositions), separated from verbs in modern Chinese, can be supported by the neural-mechanism in human brain with psychological reality^[5,6].

2 Materials and methods

2.1 Participants Sixteen undergraduate students (8 females and 8 males) participated in this experiment (for a nominal fee). Participants ranged in age from 19 to 23 years and were right-handed native speakers of Chinese, with normal or corrected-to-normal vision^[7]. All subjects were willing to participate in the experiment without any mental or neuropathic record^[8,9].

2.2 Materials Stimuli for the experiment used 15 verbs (V) and prepositions (Vp) respectively. Two different phrase frames, namely, the right and wrong collocations, were constructed from each verb and preposition^[10]. Each verb and preposition was made to produce 4 right phrase collocations and 4 wrong ones. Thus there were 240 items for each participant^[11]. All the stimuli in the experiment were investigated in order to assure their familiarities (beyond 80%). Take “让” as an example (Tab. 1).

2.3 Procedure Each participant sat in a comfortable chair in a sound-attenuated room at an appropriate distance from the computer screen with a microphone attached^[12,13]. The instructions for the task were given orally^[14]. A practice trial

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Tab. 1 Take “让” as an example

V		Vp	
A (right collocation)	B (wrong collocation)	C (right collocation)	D (wrong collocation)
()路	()草	()他们干完	()礼堂开会
()座	()灯	()墨水染黑	()手套戴上
()价	()事	()大雨淋湿	()房间搞乱
()位	()鸟	()大风吹坏	()水里游过

was given at the beginning of the first block of stimuli^[15]. Participants were tested in two sessions lasting about 1 h (excluding about 30 min of experimental preparation). Each trial consisted of the following events: “+” appeared in the center of the computer for 100 ms, followed by a blank screen for 1 000 ms; an incomplete phrase, “()位”, appeared in the center of the computer for 1 000 ms followed by a blank screen for 1 000 ms; then the target, “让”, appeared in the center of the computer for 1 000 ms followed by a blank screen for 1 500 ms (the response window was 1 300 ms), after which participants were asked to decide if the preceding phrase was a normal phrase of Chinese^[16]. Participants were instructed to press the button marked 1 if the phrase was grammatically right, otherwise, pressed the button marked 4. Participants responded by pressing one of the two buttons, which were counter-balanced (right and left) across participants.

Continuous EEG was recorded using tin electrodes attached to an elastic cap (Electro-cap International) in accordance with the extended 10–20 system^[17]. Off-line recordings collected were analyzed by using Neuroscan 4.3 software. Repeated-measures analysis of variance was applied to the waveforms of the two time windows by SPSS 13.0 software.

2.4 Criteria ERPs waves were inspected in the processing of verbs and prepositions.

3 Results

ERPs waves show the cognitive processing of brain’s dealing with the external stimuli^[18]. The study analyzed the ERPs waveforms combined with difference waves^[19]. Referring to earlier studies done by other people, the investigators identified two time windows ranged from 230 to 330 ms and from 350 to 500 ms after stimulus presentation for the ERPs; and from 270 to 400 ms and from 470 to 600 ms for the difference waves respectively.

3.1 The grand average ERPs of verbs and prepositions

The grand average waveforms for all verbs and prepositions are given in Fig. 1. The ERPs are characterized by an initial negativity peaking at about 280 ms followed by a N400, earlier than N400-N700 found by former researchers^[20]. Repeated-measures analysis of variance was applied to the waveforms of the two time windows by SPSS 13.0 software in which the within-subject factors were word class (verbs versus prepositions) and electrodes. Reported *P* values were corrected.

Both verbs and prepositions elicited a negativity at the frontal site (with electrodes F3, F4, FZ, FC3, FC4, FCZ, FT7, FT8) in 230-330 ms window. Statistically, no difference was seen in peak [$F(1,15) = 0.372, P = 0.551$] and latency [$F(1,15) = 0.934, P = 0.349$]. A salient possibility is that N280 might not be a specific component for only prepositions (or closed-class words)^[21]. The following negativity occurred at the fronto-temporal and central sites in 350-500 ms window. There was still no significant difference in peak [$F(1,15) = 0.144, P = 0.710$] and latency [$F(1,15) = 0.144, P = 0.710$].

3.2 Difference waves of verbs and prepositions In order to abstract a purer psychological component to further analyze the differences in processing verbs and prepositions, difference waves were obtained by subtracting the waveform elicited by grammatically right phrases from by grammatically wrong phrases, as shown in Fig. 2.

The difference waves were characterized by an initial negativity (with electrodes F3, FZ, F4, FC3, FCZ, FC4, C3, CZ, C4, CP3, CPZ, CP4, P3, PZ, P4, O1, OZ, O2) in the 270-400 ms window followed by a positivity occurred at about 470 ms after stimulus presentation. Repeated-measures analysis of variance was applied to the waveforms of the two time windows by SPSS 13.0 software in which the within-subject factors were word class (verbs versus prepositions) and electrode^[22]. Reported *P* values were corrected.

Both verbs and prepositions elicited a negativity (with electrodes F3, FZ, F4, FC3, FCZ, FC4, C3, CZ, C4, CP3, CPZ,

Fig. 1 The grand average waveforms of verbs and prepositions at the frontal (F3, FZ, F4), fronto-parietal (FC3, FCZ, FC4) and fronto-temporal (FT7, FT8) sites in 230-330 ms window and at the frontal (F3, FZ, F4), fronto-parietal (FC3, FCZ, FC4), fronto-temporal (FT7, FT8) and central (C3, CZ, C4) sites in 350-500 ms window. V, verbs; Vp, prepositions.

Fig. 2 The difference waveforms of verbs and prepositions in 270-400 ms and 470-600ms windows. V, verbs; Vp, prepositions.

CP4, P3, PZ, P4, O1, OZ, O2) at the left and right hemisphere in 270-400 ms window. Statistically, no difference was seen in the average peak [$F(1,15) = 0.184$, $P = 0.674$]. The following positivity occurred at the fronto-temporal and central sites^[23,24]. There was still no significant difference in peak [$F(1,15) = 1.135$, $P = 0.303$]. This shows that there is no significance in the syntactic processing of verbs and prepositions^[25].

4 Discussion

There will be great differences in the semantic and syntactic processing of verbs and prepositions, if they are two separate classes^[26,27]. Both verbs and prepositions elicited a negativity at the frontal site in 230-330 ms window of their ERPs waves. No difference was seen in peak and latency, nor in the following negativity occurred at the fronto-temporal and central sites in 350-500 ms window. There was also no significance in their difference waves^[28]. These may demonstrate that prepositions in modern Chinese are probably not a separate class from verbs for there is no significant difference in the processing of both verbs and prepositions^[29].

Their similarities, in a sense, prove coverb theory: researchers noted children used “coverbs” as verbs when they initially studied them, even though coverb phrases were next to predicative phrases, they would consider them as a combination of two discourses but separate structures.

However, our study is not a proof of the findings that a frontal negativity evoked only by closed-class words over left anterior electrode peaked at about 280 ms after stimulus presentation^[30]. A negativity was elicited by verbs as well as prepositions in the left and right hemisphere at about 230-500 ms window after stimulus presentation (in Fig. 1 and Fig. 2), consistent with the studies. Those authors, working with the Dutch language, found an anterior negativity evoked by content words but not to vary as a function of word length and frequency^[31]. In conclusion, N280 may not be a specific component for prepositions (or closed-class words), that is, N280 could not prove the existence of prepositions in Chinese.

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大脑中汉语“介词”加工的依赖性机制：来自事件相关电位研究的证据

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摘要： **目的** 考察分析汉语中动词与介词在大脑神经加工机制上的异同。**方法** 采用事件相关电位(event-related potentials, ERP)技术, 选择以汉语为母语的正常被试者共 16 人, 观察被试者在加工两类词时脑电的 ERP 波形变化。**结果** 动词与介词的原始波比较结果表明, 动词与介词在 230-330 ms 的时间窗口均诱发一个负波, 在 350-500 ms 也均诱发一个负波, 它们在峰值上均无显著差异; 动词与介词的差异波比较结果表明, 无论是在语义上还是句法上, 发现两个类型的单词在刺激呈现后 270-400 ms 和 470-600 ms 的时间窗口内, 在大脑两侧均诱发一个负波。**结论** 大脑对动词与介词的加工机制没有出现显著差异, 介词难以独立成类, N280 也非虚词的特定性成分。

关键词： 汉语; 介词; 动词; 事件相关电位; 差异波