Separation or Combination of Chinese Structural Particles *De*[1] and *De*[2]: Evidence from an ERP Experiment

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Abstract: The Chinese structural particles *de*[1] (的) and *de*[2] (地) are the products of modern language planning. The functions of both are the core components of connecting modifier-head structures, but there are subtle differences in semantic and grammatical collocation. Theoretically speaking, this kind of differentiation helps to make up for the lack of morphological marks in Chinese, facilitates the grammatical understanding of written language, and is also widely adopted in basic education in China. However, people often do not deliberately distinguish between them in oral communication and written expression, so the issue of the separation and combination of *de*[1] and *de*[2] has always been controversial. This paper holds that finding an objective cognitive basis from the perspective of neurolinguistics can help overcome the limitations of introspection. Therefore, by conducting ERP (event-related potential) experiments, we studied whether there are differences between *de*[1] and *de*[2] in cognitive mechanisms, and further discussed whether it's necessary to differentiate them, to provide an exploratory breakthrough for solving this problem.

Keywords: structural particle, ERP, N400, P600, Chinese.

1 Introduction

The structural particles *de*[1] (的) and *de*[2] (地) are both important components in forming Chinese modifier-head structures, serving to mark the grammatical relationship between the modifiers and heads. Generally speaking, when using *de*[1] and *de*[2], we follow the word order of "adjective/adverb + structural particle + head", where the head connected by *de*[1] is a nominal element while that connected by *de*[2] is a verbal one. However, this prescribed division has not been explicitly standardized in ancient Chinese, but is artificially demarcated in modern times, leading to problems such as:

(1) Since the pronunciations of the two are identical, it's of great difficulty to distinguish their grammatical properties and meanings without written contexts. In practice, people often mix them up unless emphasized. Especially, using *de*[1] instead of *de*[2] in some cases requiring *de*[2] to appear has become a common phenomenon nowadays.

(2) Chinese, as an isolating language, lacks strict morphological means as marking tools, so there is no absolute boundary between nouns and verbs. Moreover, there are many class-ambiguous words that can function as both nouns and verbs (depending on context), making the debate an ongoing topic in Chinese studies without a clear consensus.

1.1 Brief History of the Controversy Between *De*[1] (的) and *De*[2] (地)

There has always been a fierce debate in the history of Chinese language research about whether they should keep differentiated or merge into the same form as a single structural particle (see Jiang & Cao, 2005). The first major discussion on the topic occurred during the May Fourth Movement, and ended with the trichotomy of structural particles (see Ling & Jia, 1991; Li, 2008):

(1) "底" (for convenience, hereinafter referred to as *de*⁰) was assumed to be a "preposition" that indicates a meaning of relationship (not the preposition as currently understood, but rather a particle that includes possessive pronouns). e.g., 玛丽底孩子 (ma-li *de*⁰ hai-zi, "Mary's child"); 他底书 (ta *de*⁰ shu, "his book").

(2) "的" (*de*¹) was a suffix indicating some attributes for adjectives and pronouns deriving from adjectives. e.g., 红的花 (hong *de*¹ hua; "red flower"); 老的 (lao *de*¹, "the old").

(3) "地" (*de*²) was defined as a suffix for adverbials to describe status, degree, scope, means, etc. e.g., 努力地学习 (nu-li *de*² xue-xi, "work hard").

This kind of artificially interfered classification, however, has gradually arisen more and more disagreements over time. As a consequence, the dichotomy of *de*¹ and *de*² became widely accepted, while *de*⁰ was excluded, and eventually retired from history (its function was absorbed by *de*¹) in the 1950s. This shows that there must be some rationality and motivation to separating *de*¹ and *de*², for it can compensate for morphological deficiencies of the Chinese language and accordingly distinguish different kinds of modifier-head structures (attributive or adverbial) effectively. This binary approach is also widely adopted in basic education system in China.

Whereas, we should also notice that there was still internal divergence with regard to the binary classification of Chinese structural particles. In fact, since the 1980s, discussions about whether this artificial intervention between *de*¹ and *de*² was necessary have never stopped. On the one hand, Scholars supporting the "combination" view based on a practical perspective, advocated that there was no need to distinguish between the two as they are not deliberately differentiated in spoken language and did not cause comprehension barriers. And now that their main function was the same (i.e., to connect attributive structures), emerging them into a united form could be more succinct and more efficient. (e.g., Lyu, 1981; Xu, 1981; Ni, 1983; Wu, 1984; Li, 1988; Xu, 2004). On the other hand, many scholars insisted the "separation" view, emphasizing that separation between the two would bring lots of benefits for language standardization, legibility and comprehensibility of Chinese, language teaching, etc. (e.g., Niu, 1983; Gan, 1986; Zhang, 1986; Tao, 1995; Qu, 2002).

It's obvious that both factions have found their foothold from the perspectives of either historical origin or practical usage. But the controversy has long been unresolved.

To better understand the nature of this issue, some scholars adjusted their research methods through field investigations (e.g., Wang, 1995; Cheng, 2015). They conducted surveys on the use of de^1 and de^2 in textbooks as well as among middle school students. Results showed that most participants preferred distinguishing the two structural particles, but due to differences in age, language proficiency, learning environment, and personal habits among Chinese speakers, there were inevitably some situations where the both were used interchangeably. Zhang (2018) pointed out that this separation is essentially a matter of language planning, and conducted investigations from multiple angles such as questionnaires about written language, input method "cloud-association ranking order" test, and dictation test. He stressed that quantitative research should be carried out based on sufficient social investigations to comprehensively grasp the actual situation of daily communication and provide a piece of scientific evidence for language planning.

It can be seen from the above, that existing linguistic theories and sociological survey results are more or less influenced by the subjectivity and real-life experience of their authors, which means it's nearly impossible to escape the limitations of introspection, and therefore difficult to observe this phenomenon through an objective perspective.

1.2 Overview of Relevant Experimental Research

Some scholars overseas have decided to study the physiological and psychological mechanisms of language use employing more scientific methods. In recent years, disciplines such as experimental linguistics and cognitive science have been rapidly developing, with remarkable research achievements. One of them is called event-related potential (hereinafter, referred to as ERP). It's the scalp-recorded voltage fluctuation that's time-locked to an event, which scientists praise as a "window to observe brain function". Neurolinguistics based on ERP technology has opened up a new path for ontological research in linguistics. This technique on the basis of cognitive science not only explores human language mechanisms in a more neutral way, but also provides solid experimental data for testing the individual sense of language and grammar theories, to overcome the shortcomings of introspection prone to personal bias.

Although there are numerous ERP components, when it comes to language processing and comprehension, two of them have attracted the great attention of neurolinguists: the N400 and the P600. They are considered language-sensitive and significant indicators to reflect the difficulty degree of the lexical semantics or grammatical collocations. Generally speaking, the N400 is usually associated with semantic processing, and there were two mainstreams of accounts, namely the "access/retrieval" account and the "integration" account, while the P600 has a lot more to do with the syntactic reanalysis and repairing (Hahne & Friederici, 1999; Brouwer et al., 2012; Kutas & Federmeier, 2000, 2011). The N400 is a negative deflection peaking around 400 ms, with a relatively broad distribution of the scalp (often the most prominent in the centro-parietal region). It's usually elicited by semantically anomaly words compared with semantically congruent words, also related to the expectation of the word to appear after the preceding context (e.g., Kutas & Hillyard, 1980; Kutas & Hillyard, 1984; Federmeier & Kutas, 1999; Kutas & Federmeier, 2011). In terms of the access/retrieval account, the N400 reflects the "lexical retrieval" (i.e., mapping the activated word form into a representation of word meaning while concerning the context where it occurs) from long-term memory. The harder the lexical retrieval, the greater the N400's amplitude. While the integration account regards the N400 as an index of post-lexical processing, for it plays a crucial role in integrating the word meaning of the activated word form with the preceding context. The P600 is a positive deflection with a latency of about 600 ms and lasting several hundred milliseconds in the centro-parietal or frontal areas (Hagoort et al., 1993; Delogu et al., 2019). Its amplitudes increase in response to various syntactic factors, including syntactic violations, unexpected words, complex sentences, etc. (e.g., Hagoort et al., 1993; Hahne & Friederici, 1999; Kaan et al., 2003; Hoeks et al., 2004).

In recent years, some viewpoints have challenged the traditional functional division between the two. Just like how Chinese lacks morphological markers so that the boundaries between lexis and grammar are sometimes vague, there are also situations where it's very difficult to separate the processing of both the ERP components. This is consistent with the phenomenon of "semantic P600" which is highly related to implausible thematic role assignments (Kuperberg et al., 2003; Kolk et al., 2003; Kim & Osterhout, 2005; Brouwer et al., 2012), and the rethinking of N400 with a "hybrid" account which combines both the "access/retrieval" account and the "integration" account, believing the N400 amplitude reflects both the effort involved in retrieving word meaning from word form ("pre-activation") and integrating it into the utterance interpretation ("unification") (Baggio & Hagoort, 2011; Delogu et al., 2019). These new theories tried to explain how the syntactic and semantic information is processed from a new viewpoint. For instance, the P600 is considered a family of late positivities (varying in aspects like latency, amplitude, duration, and distribution) corresponding to the word-by-word construction, reorganization, or updating of a mental representation of what is being communicated. That is to say, when it needs extra effort to achieve a coherent mental representation, the P600 will serve as an electrophysiological signal bound to it for researchers to observe and analyze.

There were not many studies that used experimental methods to investigate the particles in languages, though, new discoveries based on previous achievements have been made. For example, Nakagome et al. (2001) studied the neural recognition mechanism of how sentence-final particles and interrogative phrases matched in Japanese. They found that when there is a semantic or syntactic violation in the collocation, N400 and P600 will be elicited respectively, and the right temporal cortex plays an important role in facilitating the integration of contextual information. Mueller et al. (2009) used ERP technique to explore the collocation recognition between the auxiliary *può* ("to be able to", first person singular) / *sta* ("to be", first person singular) and the suffix of main verb *-re* (infinite form) / *-ndo* (gerund form) in Italian by native speakers and non-native speakers. They concluded that when these auxiliaries did not match with the correct verb suffixes, N400 and P600 could be observed in Italian native speakers while non-native speakers would elicit a negative component similar to N400 and a positivity in their brains' anterior regions, indicating that native speakers might process sentences based on abstract grammatical rules while non-native speakers were likely to rely more on lexical forms. By recruiting Chinese postgraduates whose majors were related to linguistics, Liao et al. (2020) designed a relevant ERP experiment to analyze Chinese structural particles, which was a preceding experimental study of

Chinese structural particles. Their main concern was to observe the differences in ERP waveforms between the correct (congruent) and incorrect (incongruent) collocations of three structural particles “的” (i.e., “de^1 mentioned in this article”), “地” (“de^2 mentioned in this article”), and “得” (hereinafter, referred to as de^3, a third structural particle widely used in modern Chinese, whose function is to connect the predicate and the following complement). However, there were deficiencies in the selection of experimental subjects, materials, paradigm, and the allocation of the experimental procedure in this experiment. And for the reason that de^3 is different from the other two in terms of pronunciation and grammatical function, people will not confuse it with other particles in either spoken or written contexts. Thereby, its guidance for the in-depth study of structural particles was limited. In general, although some scholars in the field of Chinese language studies have taken the first step in using the ERP technique to research structural particles, the overall experimental results and conclusions still need further verification and enhancement.

1.3 Research Goals and Hypotheses

With the help of highly precise time resolution provided by ERP, we can effectively record people’s immediate reactions to relevant stimuli under controlled conditions, providing objective, analyzable, and interpretable evidence. Based on summarizing previous experimental experience, this article aimed to go beyond simple theoretical research or paired experiments, design a more comprehensive experimental method and process, to explore whether there are electrophysiological differences in the neural cognition of de^1 and de^2, thus providing a scientific empirical conclusion for the issue of the “separation or combination” controversy.

The present study took students who have received higher education as participants, to explore whether there was a significant difference in people’s intuition regarding the correct and incorrect use of the two structural particles de^1 and de^2. As it was presented for a short time, participants could not utilize their indirect empirical knowledge to analyze and repair errors in time when discovering incongruent collocations. As a consequence, the results could demonstrate whether they deeply acknowledge this differentiation of the two structural particles, even though they had already received relevant knowledge and experience about the “necessity” to distinguish them.

According to this, we set four conditions with those particles: (1) congruent use of de^1 (which was thought to be grammatical in the eyes of the support of “combination”); (2) incongruent use of de^1 (which means the context required de^1 to be the correct particle, but de^2 was used instead); (3) congruent use of de^2; and (4) incorrect use of de^2 (using the unexpected structural particle de^1 instead). If there was no significant ERP difference for the usage of de^1 in both congruent and incongruent conditions, it indicated that de^1 had the universality of connecting either the nominal structure or the verbal structure. The same applied to de^2. Furthermore, if there was no significant difference in the ERP waveforms of the two particles under different circumstances, it showed that their functions were completely equivalent and people have already regarded them as the same from the bottom of hearts, so there was no need for the separation, and merge them into a single form would be a better choice. On the contrary, if significant differences are observed between them under various conditions, it demonstrated that there was still a need for differentiation between them.

Meanwhile, considering that participants whose majors were language-related might pay more attention to the legality and acceptability of lexical semantics and grammatical structures, we would categorize them into “Professional” and “Nonprofessional” (hereinafter, the “P” and “NonP”) groups. Through between-subjects analysis, we examine whether majors would have an impact on the experimental results. To be more specific, if there was a main effect of major on ERP waveforms, it suggested that professional knowledge about linguistics significantly influenced participants’ judgment. This further implied the importance of teaching, language standardization, and personal language awareness in language planning and policy. Conversely, if the opposite was true, it showed that different majors do not affect participants’ sense of language when judging the usage of structural particles. In other words, this differentiation cannot be acquired and improved by training and was an artificial intervention that contradicted people’s linguistic intuition. The separation policy of the two particles was unnecessary and needed further refinement.

2 Methods

2.1 Participants

48 native Chinese readers (27 males and 21 females; mean age = 23.6 years; SD = 1.2 years) participated in the experiment, and 8 of them were excluded from data analysis due to not meeting the criteria for enough valid trials. All participants were postgraduate students with no reading disabilities or neurological disorders, and they were all right-handed and had normal or corrected-to-normal vision according to the test standards by Snyder & Harris (1993). Informed consent forms were filled out before the experiment, and each participant would receive appropriate compensation after the experiment. The experimental procedure of the present study was approved by the Ethics Committee of Sichuan University.

In order to further observe whether there is an impact caused by proficiency and sensibility of language, we also paid attention to and controlled the majors when recruiting participants. In terms of whether their majors are related to language studies (e.g., linguistics, philology, translation, TCSOL, etc.), they were divided into the “P” group (relevant to language studies) and the “NonP” group (irrelevant to language studies) in half (see Table 1).

Table 1. Distribution of the participants for data analysis. After excluding 8 unqualified participants, we ensured that the number of participants is balanced between both majors and genders.

	P	**NonP**
Male	10 persons	10 persons
Female	10 persons	10 persons

2.2 Stimuli

We selected common words from the *Modern Chinese Dictionary* (现代汉语词典), *Standard Dictionary of Modern Chinese* (现代汉语规范词典), and *Dictionary of Commonly Used Words in Modern Chinese* (现代汉语常用词词典) to prevent comprehension barriers caused by unfamiliar words. At the same time, to create typical contexts suitable for *de*¹ and *de*², and avoid confusion between nouns and verbs, words that have more than one part of speech, such as "研究" (yan-jiu, "research") and "通知" (tong-zhi, "notice") were dismissed to ensure that the nouns and verbs had enough typicality of their respective parts of speech. Subsequently, we launched a questionnaire survey to test the legitimacy and familiarity of the experimental materials. Those that passed two pre-tests (the average score of legitimacy and familiarity were both ≥ 4.5, with a full score of 5) were accepted into the official experiment, which consisted of 300 phrases containing *de*¹ and 300 phrases containing *de*², a total of 600 phrases. The selected phrases have eliminated the interference of novel usages such as buzzwords, memes, metaphors, and metonymies, to ensure the experimental materials conformed to standard Chinese expression. Under the guidance of related experiment design, those stimuli were divided into two parts:

(1) **Critical items.** The particle *de*¹ was required to be used in attributive phrases, while *de*² was in adverbial phrases by contrast. Thereby, this division allowed for two subcategories of critical items: the first comprised "adjective + *de*¹ + noun", with a total of 200 items, and the second consisted of "adjective + *de*² + verb"[1], also with a total of 200 items. There were 400 critical items in total. To examine the differences in grammatical processing between congruent and incongruent collocations, half of the critical items in each category were replaced by "ungrammatical" expressions. Accordingly, the critical items were eventually categorized into four types of conditions as shown in Table 2. The distinction lay in whether the grammatical environment was consistent with the structural particles required to appear.

Table 2. Critical items. we can apply schemata for better understanding. In the square-bracket schema [X→Y] below, the left side of the arrow indicates what is required in the grammatical environment (X), while the right side indicates what actually appears (Y).

	Schema	Explanation
Condition 1	[1→1]	*de*¹ (的) was used in the "*adjective + structural particle + noun*" structure, which required *de*¹ (的) to appear. So this condition is congruent.
Condition 2	[1→2]	*de*² (地) was used in the "*adjective + structural particle + noun*" structure, which required *de*¹ (的) to appear. So this condition is incongruent.

[1] Chinese is a non-inflected language, and cannot be classified based on the external form of words. Unlike Indo-European languages, there is no one-to-one correspondence between word classes and syntactic constituents in Chinese (Lu, 2022). As a result, in Chinese, it's a common phenomenon for adjectives to modify verbs. Generally speaking, what we consider adverbs in English, such as "rapidly", are regarded to be the result of combining the adjective "rapid" with the structural particle "*de*²" in Chinese. The same applies to other word classes.

Condition 3	[2→2]	*de*² (地) was used in the "*adjective + structural particle + verb*" structure, which required *de*² (地) to appear. So this condition is congruent.
Condition 4	[2→1]	*de*¹ (的) was used in the "*adjective + structural particle + verb*" structure, which required *de*² (地) to appear. So this condition is incongruent.

(2) **Filler items.** Since the distinction between the two structural particles was very dependent on the part-of-speech restrictions of the context, to prevent participants from relying solely on the preceding words to predict whether the following would be a noun or a verb, 200 filler items complying with Chinese standard grammar (see Zhu, 1961b) were added as interference, and divided into two categories. The first was made of "noun + *de*¹ + verb" (100 trials), while the second consisted of "adverb/adjective + *de*² + adjective" (100 trials).

2.3 Procedure

The experiment was carried out in a soundproof electromagnetic shielding room. Participants were expected to stay as still as possible, with their eyes fixed on the center of the computer screen at a distance of approximately 80 cm and their hands placed naturally on the keyboard. E-Prime 3.0 was used to present the stimuli and record the behavioral data. The background color of the screen was white, the font color was black, and the font size was 60 pounds.

As shown in Fig. 1, the experiment followed this procedure: Each modifier-head structure was presented as a single trial. In each trial, an initial fixation (+) appeared in the center of the screen for 800 ms to concentrate the participant's attention. Then, the *modifier* (consisting of an adjective and a structural particle) was diaplayed for 1000 ms, following an 800 ms blank screen before presenting the *head* (either a noun or a verb) for 2000 ms. After that, participants were asked to make a judgement by pressing a key ("yes" or "no") with their right index or middle finger as quickly as possible when they see the instruction to determine whether or not the modifier and the head collocated with each other grammatically. The next trial began immediately after the participant made a response, and trials with response time over 2 seconds would be excluded from the subsequent analysis.

All the stimuli were divided into four blocks with 150 trials in each. To minimize the influence of other irrelevant factors, the order of blocks was pseudorandomly arranged in a Latin square based on the participants' genders and majors. The differences between pressing keys have also been balanced. The two keys registered for "yes" and "no" were switched after half of the participants finished the experiment. Participants were instructed to take a brief practice session to become familiar with the procedure before the official experiment. (the stimuli in the practice session would not appear in the official experiment). A short break was set after each block, and the entire experiment lasted for around 1 hour for each participant.

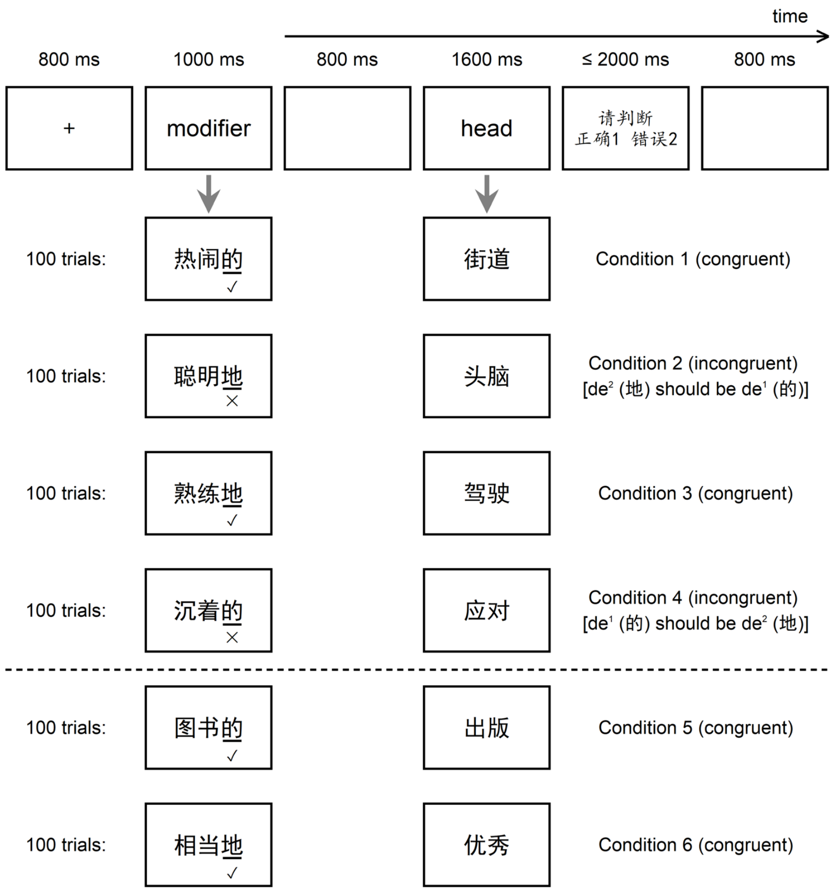

Fig. 1. Illustration of the experimental procedure. Adjectives and structural particles combined to form modifiers. Participants would see the modifier and the head in sequence, and then judge whether the collocation was grammatically correct.

2.4 EEG Recording

The EEGs were recorded in a secured elastic cap with 64 Ag/AgCl electrodes and SynAmps 2 amplifier (NeuroScan, Charlotte, NC, USA). According to the extended international 10/20 system, the electrodes were placed on the scalp at locations.). The right and left mastoids were set to record electrical activities and the vertical electrooculogram (VEOG) was recorded by bipolar channels placed above and below the left eye. The ground electrode was connected to AFz. All the electrodes were referenced to the tip of the nose. Electrode impedances were kept below 5 kΩ. Continuous EEG data (0.03–100 Hz) were recorded and digitized with a resolution of 24 bits and a sampling rate of 500 Hz.

2.5 Data Analysis

Continuous recording of EEG experiments was conducted, followed by offline analysis and processing of the collected EEG using Neuroscan 4.3. The steps were as follows:

(1) The EEG data were amplified using a finite pulse response filter with a bandpass of 0.1–25 Hz..

(2) The blink artifacts were corrected by means of a regression-based procedure (Semlitsch et al., 1986).

(3) The continuous EEG data were cut into epochs, which were set to 1100 ms in length, including the 100 ms prior to the stimulus presentation.

(4) All the epochs were corrected by using the pre-stimulus 100-ms baseline.

(5) To eliminate artifacts such as blinking and incorrect responses made by the participants, any channel other than VEOG with an amplitude exceeding ±75 μV would be rejected.

(6) The remaining EEG epochs were classified and averaged according to four experimental conditions, resulting in four types of ERPs mentioned above. The number of EEG epochs for each type used for grand averaging was not less than 70%.

(7) The ERPs were re-referenced offline to the average of two mastoids.

In accordance with the grand average ERP waveform characteristics, the differences under four conditions are mainly concentrated on two ERP components: N400 (with a latency of approximately 478 ms) and P600 (with a latency of approximately 746 ms). A four-way ANOVA was used for analysis. The Benjamini-Hochberg procedure (Benhamini & Hochberg, 1995) was applied to control the false discovery rate (hereinafter, the "FDR", i.e., the mean proportion of significant test results that are false discoveries) to estimate the significance of each test by an FDR level of 5%. The Mass Univariate ERP Toolbox was used for the t-test with FDR controls (Groppe et al., 2011). During the massive univariate analysis, the EEG data included two factors: Condition and Major. The former consisted of the aforementioned four types of grammatical environments, while the latter contains two levels (Professional and Non-Professional, hereinafter referred to as "P" and "NonP").

3 Results and Discussion

3.1 Behavioral Data

The mean accuracy rates based on the percentage of correct response times in each condition are summarized in Table 3. Paired-samples t-test revealed that there was no significant difference in accuracy between majors [Condition 1: $t(19) = 2.010$, $P = .059$, 2-tailed; Condition 2: $t(19) = 1.213$, $P = .240$, 2-tailed; Condition 3: $t(19) = 1.252$, $P = .226$, 2-tailed; Condition 4: $t(19) = -.027$, $P = .979$, 2-tailed]. One-way ANOVA showed that there were significant differences in accuracy between Condition 4 and other Conditions (Ps < .001), the results were the same for both the P and NonP groups. According to the standard deviation of the two groups, it can be seen that the overall performance of the P group was more stable and consistent, indicating a more attentive state or a better sense of language.

Table 3. Behavioral results. Accuracy rate refers to the percentage of correctness when judging whether the collocation meets the grammatical requirement. SD means standard diviation.

	Mean accuracy rate ± SD (%)			
	Condition 1	**Condition 2**	**Condition 3**	**Condition 4**
P	98.8 ± 2.2	95.7 ± 5.8	95.9 ± 5.4	84.8 ± 10.0
NonP	97.2 ± 2.4	91.8 ± 12.5	92.6 ± 9.3	84.9 ± 13.4
Total	98.0 ± 2.4	93.8 ± 9.8	94.3 ± 7.7	84.9 ± 11.7

3.2 ERPs

The grand-averaged ERPs on different conditions are illustrated in Fig. 2 (for the NonP group) and Fig. 3 (for the P group). As shown in those figures below, both Condition and Major affected the results of ERP responses. Two time windows were selected on based on previous relevant studies (see Tsai et al., 2009; Zhang et al., 2013; Xia et al., 2014): 300–500 ms for the N400 effect and 600–800 ms for the P600 effect, in which N400 was likely reflected in the centro-parietal scalp region while P600 was obviously presented in the posterior scalp region. Compared with the congruent collocations, both kinds of incongruent collocations elicited larger negativity in the 350–500 ms time window between the P group and the NonP group, in which the response of the *de[1]* type of stimulus was more significant. At the same time, during 600–800 ms post stimuli, the mismatch of *de[1]* collocation in the P group elicited a stronger centro-parietal positivity, while the NonP group's response was not so obvious. This showed that Major had a significant main effect in the case of congruent and incongruent grammatical collocations. For *de*[2], there was no significant difference between the two major groups. These observations were statistically verified in Fig. 4.

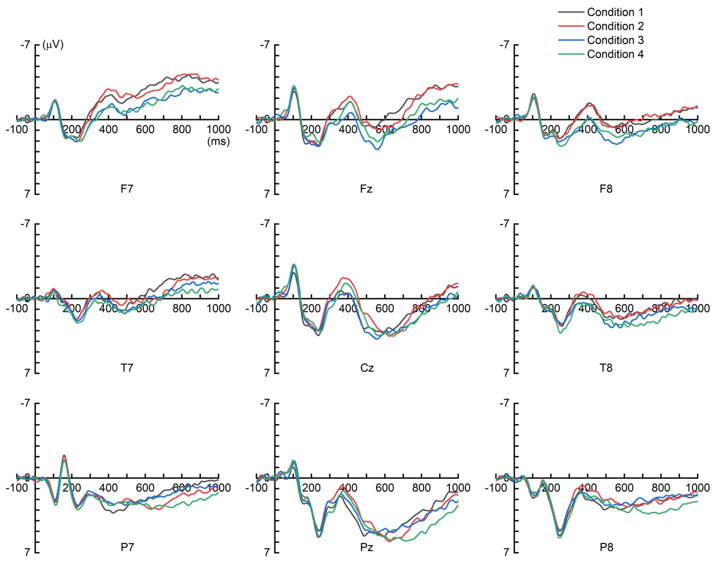

Fig. 2. Grand-averaged ERPs elicited by different conditions in the NonP group.

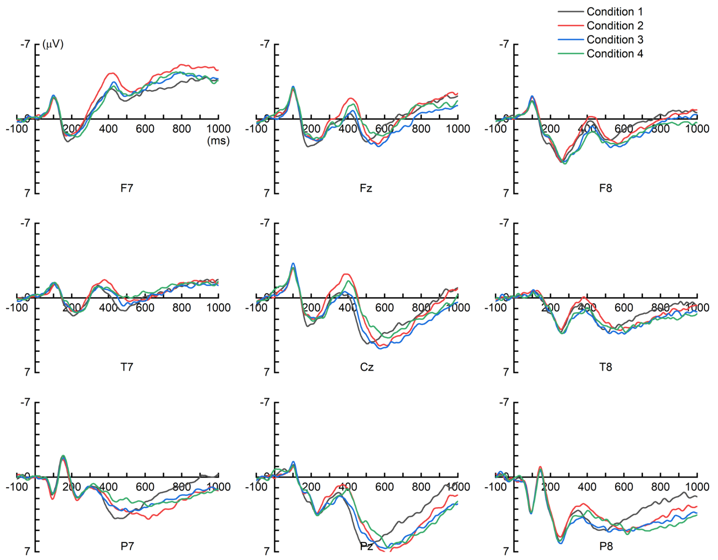

Fig. 3. Grand-averaged ERPs elicited by different conditions in the P (professional) group.

Significant differences between the ERPs to congruent conditions and the ERPs to incongruent conditions were consistently observed at approximately 350–500 ms and 600–800 ms in the P group (highlighted by red dotted lines in Fig. 4). In the subsequent analysis of lateralization, we have separated six regions of interests, namely: (1) left anterior (F3, F5, F7, FC3, FC5, FT7); (2) right anterior (F4, F6, F8, FC4, FC6, FT8); (3) left central (C3, C5, T7, CP3, CP5, TP7); (4) right central (C4, C6, T8, CP4, CP6, TP8); (5) left posterior (P3, P5, P7, PO3, PO7, O1); and (6) right posterior (P4, P6, P8, PO4, PO8, O2).

3.1 350–500 ms Time Window: N400 Results

To further examine the features revealed by the results above, and confirm whether there was a distribution difference in lateralization in the 350–500 ms time window, we performed a repeated measurement ANOVA. The mean N400 amplitudes were analyzed by using "word" (*de*[1] and *de*[2], based on the contextual requirement), "congruency" (congruent and incongruent), and "hemisphere" (left hemisphere and right hemisphere) as within-subjects factors, and "major" (P and NonP) as a between-subjects factor. The results showed a main effect of "hemisphere" [$F(1, 36) = 57.626$, $P < .001$], which indicated that there was a significant difference between the left and right hemisphere. There were also some significant interactions: (1) "word" and "congruency" [$F(1, 36) = 5.714$, $P = .022$], indicating that the amplitudes of N400 differed between the congruent conditions and incongruent conditions; (2) "congruency" and "major" [$F(1, 36) = 20.958$, $P < .001$].

3.2 600–800 ms Time Window: P600 Results

When observing the time window of 600–800 ms, we analyzed the relationship between these three within-subjects factors and one between-subjects factor using the same steps mentioned above. The results indicated main effects of "word" [$F(1, 36) = 5.835$, $P = .021$], "congruency" [$F(1, 36) = 18.399$, $P < .001$] and "hemisphere" [$F(1, 36) = 4.659$, $P = .037$], respectively. This can also be reflected in Fig. 2–3, where larger positivity was elicited in the right parietal region. There were also significant interactions among "word", "congruency" and "major" [$F(1, 36) = 14.432$, $P = .014$], among "word", "hemisphere" and "major" [$F(1, 36) = 10.886$, $P = .002$], as well as among "word", "congruency" and "hemisphere" [$F(1, 36) = 9.583$, $P = .004$], in accordance with a larger positivity in condition 4 of the NonP group shown in Fig. 2.

3.3 Mass Univariate Analysis Results

To discover the spatiotemporal distribution of significant differences between the ERPs to congruent conditions and incongruent conditions in each group, we adopted repeated measures, two-tailed t-tests at all time points for each of the 64 scalp electrodes. And the bottom panels in Fig.4 illustrated the resultant significant spatiotemporal distributions, with FDR correction for multiple comparisons. To clarify the differences, we subtracted the ERPs to incongruent conditions from the ERPs to congruent conditions, and the resulting difference ERPs (grand-averaged) from all 64 recording electrodes (excluding the VEOG channel) were displayed in the top panels of Fig. 4. Additionally, we calculated the global field power (GFP) of the difference ERPs for each condition and displayed them in the middle panels of Figure 4. The topographic maps at the peaks of GFP were depicted in Fig. 4, which showed the topographic distribution of the difference in ERPs between congruent conditions and incongruent conditions.

An early difference between the ERPs to the P group and the ERPs to the NonP group was consistently monitored in *de*[1] conditions, visualized by the GFP peaks around 484 ms. The GFP peaks of the topographic maps were shown in Fig. 4. And there was an obvious late positivity between the ERPs to the P group and the NonP group, marked by the GFP peaks about 786 ms when the contexts required structural particle *de*[1] to appear, but what actually occurred was *de*[2]. Although both the groups did not show statistical significance between either 350–500 ms or 600–800 ms on the right side of Fig. 4, combined with the analysis results of SPSS mentioned above, and the waveform differences in Fig. 4, we can see that the P group still had a tendency to evoke a larger N400 when the structural particles that did not conform to standardization.

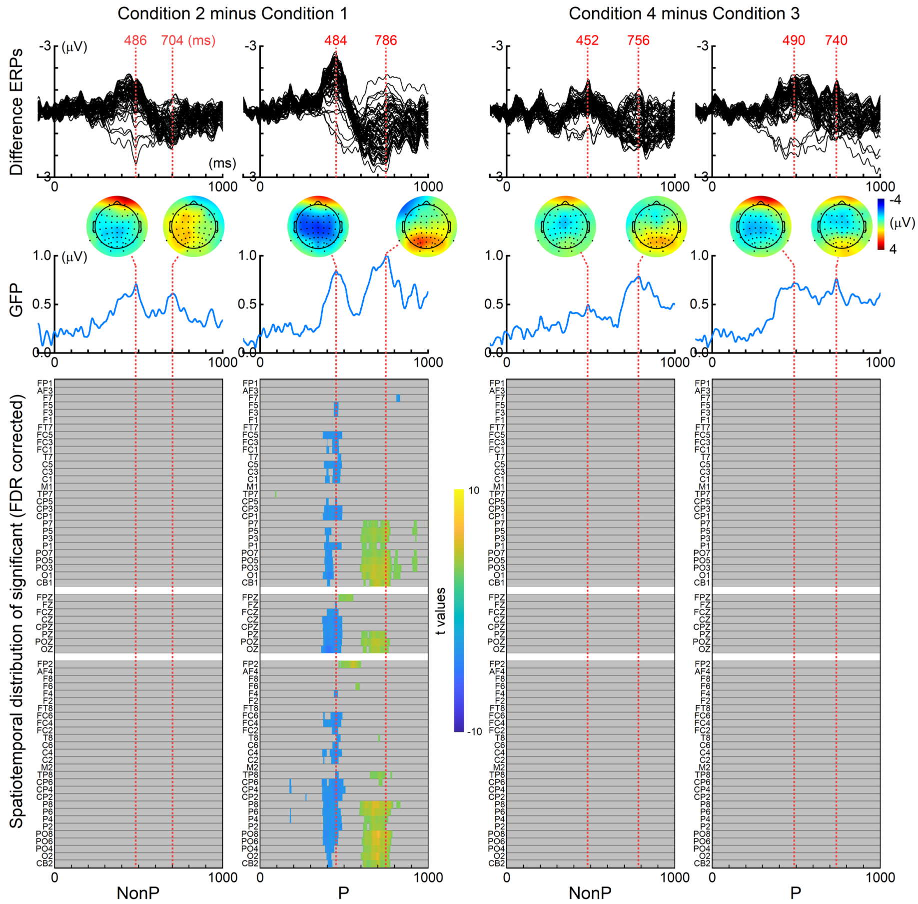

Fig. 4. ERP differences between congruent and incongruent conditions. The ERPs to incongruent conditions were subtracted from those to congruent conditions for both groups. The difference ERPs from the 64 recording electrodes (i.e., butterfly plot) were illustrated in the top panels. The global field power (GFP) of the difference ERPs for each task was calculated and illustrated in the middle panels.

4 Discussion

As mentioned above, the incongruent conditions elicited a larger N400 than that of the congruent conditions, in which Condition 2 and 4 emerged more significant negativities shown in Fig. 2–3. More interestingly, *de*[1] conditions (Condition 1 and 2) presented more negative ERP responses compared with *de*[2] conditions (Condition 3 and 4). Based on previous studies about N400, when encountering difficulties in lexical retrieval or semantic integration, there would be a larger N400 observed in the incongruent conditions. Besides, the N400 of *de*[1] conditions can be explained from three aspects. First, as Liao et al. (2020) have argued, the structural particle *de*^{1} may possess more functions such as modification, ownership, restrictive relationship, etc., indicating that it can match more meanings or contribute to predicting more lexical collocations, so the chances that the head after *de*^{1} deviating from the participants' semantic expectations would be more likely to occur. Second, according to the *Green Paper on Language Situation in China* (GPLSC, 2008), *de*^{1} was the most frequently used particle in modern Chinese, which determines that it was more familiar to the participants than *de*^{2} regardless of the majors, so this would lead to broad semantic predication instead of constraining a concrete one. Furthermore, the popularity of *de*^{1} suggested that participants eliminated or ignored the boundaries between nouns and verbs, tending to cross the meaning of word classes to integrate these *de*^{1} phrases while it may be limited to some semantic association linking with verb category in *de*^{2} condition. Meanwhile, this also reflects that in "*de*^{1} + verb" structures, and there is no need to argue the "verb" after the structural particle is the nominalized result or the verb itself, because the definition of word category is an artificial product, while the meaning of the natural world is often continuous. How to classify categories is nothing but a different way of human cognition of the world (see Shen, 2016).

Similarly, as an indicator of difficulties in syntactic processing, P600 was prominent in *de*^{1} conditions in the P group, according to the aforesaid description, *de*^{1} can match with nouns and verbs while *de*^{2} can only be paired with verbs, therefore it would take possibly more efforts in *de*^{1} conditions to distinguish the categories of the critical items. From this perspective, the P groups are well-trained to recognize the lexical categories (i.e., word classes, or parts of speech), so they might be more engaged in the prediction and processing stage of the structures containing *de*^{1}, and response to structures with the particle *de*^{2} more quickly than the Non P group. Additionally, it remains to be explained why the *de*^{2} incongruent condition (Condition 4) in the NonP group elicited a larger P600 than the P group shown in Fig. 3. And it's worth mentioning that with the sample size expanded, the two ERP components may be found significant under Condition 4 minus Condition 3. If it is confirmed, accordingly, it shall be unnecessary to classify the two particles and prove that Chinese is a more meaning-concentrated language. Thus, this is not only a new discovery for structural particles, but also provides new insights into the understanding of research on Chinese ontology.

In other words, the experimental results showed that the differentiation of *de*^{1} and *de*^{2} needed to be discussed separately in conjunction with specific grammatical environments.

(1) For the particle *de*^{1} in congruent and incongruent conditions, there was a significant main effect observed in Major, i.e., the P group elicited significantly larger amplitudes of both N400 and P600 when *de*^{1} should appear but was replaced by *de*^{2}; while the NonP group did not show significant differences in both conditions. However, it should be noted that the N400 evoked by Condition 2 (incongruent use of *de*^{1}, i.e., "adjective + *de*^{2} + noun") was still slightly larger than that by Condition 1 (congruent use of *de*^{1}, i.e., "adjective + *de*^{1} + noun"). These findings indicate that such a separation of Chinese structural particles had a grammatical basis, as *de*^{2} was regarded as absolutely incompatible with nouns, and the differences between the two groups further demonstrate that the differentiation can be reinforced through language teaching and training, providing convenience for rapid recognition and confirmation of grammatical collocations.

(2) For the particle *de*², there were no significant differences observed in both groups under the congruent and incongruent uses of *de*², which was consistent with the results discovered by Liao et al. (2020). It confirms that *de*² did not have a higher priority in necessity in contrast to *de*¹. Whether through professional training or conscious correction, people were always inclined to hold a subconsciousness that *de*¹ could connect both nominal structures and verbal structures, and view the collocation of "adjective + *de*¹ + verb" as fairly acceptable. Thus, this suggests that the connective function of *de*¹ has a generality that conforms to the linguistic intuition of most people. These findings basically coincide with the "combination" point of view.

In summary, the issue of Chinese structural particles is a complex linguistic phenomenon that needs to take into account not only the typicality of lexical semantics and parts of speech but also various social variables. Moreover, the ultimate goal of this issue is not to draw the conclusion of absolute separation or combination, so we need to classify and discuss it according to different situations. Based on the ERP experiment, this study found that *de*¹ seems to possess a more versatile generality than *de*². Although the normative usage of *de*¹ in written textbooks is to connect nominal structures, it can still be commonly accepted to connect verbal structures in actual use. By contrast, *de*² is a particle with higher specialization, exclusive of connecting nominal modifier-head structures. If people haven't undergone special training and emphasis on the separation, they often tend to choose the more versatile structural particle *de*¹ to simplify expressions based on the economic principles of language. After all, the important use of language is for communication rather than rigid grammatical rules. This study provides a new perspective and evidence for understanding the structural particles and their neural mechanisms in Chinese, and inspires us to reconsider the issue of separation and combination of them in future language planning. And language planning should follow the natural development trajectory of language itself. Adopting the widely accepted grammatical feature of *de*¹ to connect verbal modifier-head structures may be also a feasible suggestion in the future.

Acknowledgments. This work was sponsored by a grant from the College of Literature and Journalism, Sichuan University awarded to Yufeng Li.

References

1. Baggio, G., Hagoort, P.: The balance between memory and unification in semantics: A dynamic account of the N400. *Language and Cognitive Processes*. 26 (2011) 1338–1367.
2. Benjamini, Y., Hochberg, Y.: Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society: Series B (Methodological)*. 57 (1995) 289–300.
3. Brouwer, H., Fitz, H., Hoeks, J.C.J.: Getting real about semantic illusions: Rethinking the functional role of the P600 in language comprehension. *Brain Research*. 1446 (2012) 127–143.
4. Cheng, S.: Jie-gou zhu-ci "de (的), de (地), de (得)" de fen-he shi-yong [The use of the structural particles *de*¹, *de*² and *de*³ in combination and separation]. *Bulletin of Chinese Language Teaching*. (8) (2015) 52–54.

5. Delogu, F., Brouwer, H., Crocker, M.W.: Event-related potentials index lexical retrieval (N400) and integration (P600) during language comprehension. *Brain and Cognition*. 135 (2019) 103569.
6. Federmeier, K.D., Kutas, M.: A rose by any other name: Long-term memory structure and sentence processing. *Journal of Memory and Language*. 41 (1999) 469–495.
7. Gan, Y.: Ye-tan "de (的), de (地)" de fen-he wen-ti [On the issue of the separation and combination of *de*[1] and *de*[2]]. *Journal of Jiangsu Normal University (Philosophy and Social Sciences Edition)*. (1) (1986) 144–147.
8. Groppe, D.M., Urbach, T.P., Kutas, M.: Mass univariate analysis of event-related brain potentials/fields I: A critical tutorial review. *Psychophysiology*. 48 (2011) 1711–1725.
9. Hagoort, P., Brown, C., Groothusen, J.: The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes*. 8 (1993) 439–483.
10. Hahne, A., Friederici, A.D.: Electrophysiological evidence for two steps in syntactic analysis: Early automatic and late controlled processes. *Journal of Cognitive Neuroscience*. 11 (1999) 194–205.
11. Hoeks, J.C.J., Stowe, L.A., Doedens, G.: Seeing words in context: The interaction of lexical and sentence level information during reading. *Cognitive Brain Research*. 19 (2004) 59–73.
12. Jiang, S., Cao, G.: *Jin-Dai Han-Yu Yu-Fa-Shi Yan-Jiu Zong-Shu* [*An Overview of the Modern Chinese Grammar*]. Beijing: The Commercial Press. (2005).
13. Kaan, E., Harris, A., Gibson, E., Holcomb, P.: The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes*. 15 (2000) 159–201.
14. Kim, A., Osterhout, L.: The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language*. 52 (2005) 205–225.
15. Kolk, H.H.J., Chwilla, D.J., van Herten, M., Oor, P.J.W.: Structure and limited capacity in verbal working memory: A study with event-related potentials. *Brain and Language*. 85 (2003) 1–36.
16. Kuperberg, G.R., Sitnikova, T., Caplan, D., Holcomb, P.J.: Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research*. 17 (2003) 117–129.
17. Kutas, M., Federmeier, K.D.: Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences*. 4 (2000) 463–470.
18. Kutas, M., Federmeier, K.D.: Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology*. 62 (2011) 621–647.
19. Kutas, M., Hillyard, S.A.: Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*. 207 (1980) 203–205.
20. Kutas, M., Hillyard, S.A.: Brain potentials during reading reflect word expectancy and semantic association. *Nature*. 307 (1984) 161–163.
21. Li, F.: Cong bu-yong "de (底)" kan "de (的), de (地)" he-bing de ke-neng-xing [The possibility of not using *de*[0] to combine *de*[1] and *de*[2]]. *Wuhan University Journal (Philosophy & Social Science)*. (2) (1988) 89–93.
22. Li, Z.: The study on the division and combination of Chinese constructive adverb *de*[1]. *Journal of Shanxi Normal University (Social Science Edition)*. (5) (2008) 123–127.
23. Liao, Q., Zheng, J., Zhao, L.: Neural correlates of processing Chinese structural particles: An ERP study. *Neuroscience Letters*. 735 (2020) 135132.
24. Ling, Y., Jia, M.: "De (的)" zi de fen-hua [The separation of *de*[1]]. *Language Teaching and Linguistic Studies*. (3) (1991) 103–114.
25. Lu, J.: Again on the issue of Chinese word classes—From Mr. Shen Jiaxuan's viewpoint of "mutual inclusion of Chinese verb and noun". *Journal of Northeast Normal University (Philosophy and Social Sciences)*. 318 (2022) 1–15.
26. Lyu, S.: Guan-yu "de (的), de (地), de (得)", he "zuo (做), zuo (作)" [Regarding *de*[1], *de*[2], *de*[3], and *zuo*[1], *zuo*[2]]. *Chinese Language Learning* [*Yu-Wen Xue-Xi*]. (3) (1981) 52–53.

27. Mueller, J.L., Oberecker, R., Friederici, A.D.: Syntactic learning by mere exposure—An ERP study in adult learners. *BMC Neuroscince*. 10 (2009) 89.
28. Nakagome, K., Takazawa, S., Kanno, O., Hagiwara, H., Nakajima, H., Itoh, K., Koshida, I.: A topographical study of ERP correlates of semantic and syntactic violations in the Japanese language using the multichannel EEG system. *Psychophysiology*. 38 (2001) 304–315.
29. Ni, B.: Ye-tan "de (的), de (地), de (得)" de fen-he [On the use of *de*[1], *de*[2], and *de*[3]]. *Chinese Language Learning* [*Han-Yu Xue-Xi*]. (6) (1983) 17–22.
30. Niu, C.: "de (的), de (地)" fen-kai hao ji qi-ta [Separating *de*[1] and *de*[2] is better]. *Journal of Ningxia University (Humanities & Social Sciences Edition)*. (3) (1983) 33–37.
31. Qu, F.: The development of the written form of the Chinese structural auxiliary *de*[1] and the issue of its combination and division. *The Northern Literary Studies*. (5) (2002) 67–70.
32. Semlitsch, H.V., Anderer, P., Schuster, P., Presslich, O.: A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology*. 23 (1986) 695–703.
33. Shen, J.: *Ming-Ci He Dong-Ci* [*Nouns and Verbs*]. Beijing: The Commercial Press. (2016).
34. Snyder, P.J., Harris, L.J.: Sex and familiar sinistrality effects on spatial tasks. *Cortex*. 29 (1993) 115–134.
35. Sun, R. Jie-gou zhu-ci "de (的), de (地)" de fen-he wen-ti [Issue of the separation and combination of *de*[1] and *de*[2]]. *Journal of Yangzhou University (Humanities & Social Sciences)*. (4) (1995) 80–82.
36. Tao, K.: Jie-gou zhu-ci "de (的), de (地)" ying-gai yan-ge qu-fen shi-yong [The structural particles *de*[1] and *de*[2] should be strictly distinguished in their usage]. *Journal of North Minzu University (Philosophy and Social Science)*. (4) (1995) 59–62.
37. Tsai, P, Yu, B.H., Lee, C., Tzeng, O.J., Hung, D.L., & Wu, D.H.: An event-related potential study of the concreteness effect between Chinese nouns and verbs. *Brain Research*. 1253 (2009) 149–160.
38. Wang, H.: Yu-wen jiao-cai zhong "de (的), de (地)" de fen-he wen-ti [Issue of the separation and combination of *de*[1] and *de*[2] in Chinese language textbooks]. *Language Planning*. (4) (1995) 27–28.
39. Wu, Z.: Jie-gou zhu-ci "de (的), de (地), de (得)" yi he-bing wei-yi [It is advisable to merge the structural particles *de*[1], *de*[2] and *de*[3]]. *Journal of Ningxia University (Humanities & Social Sciences Edition)*. (3) 72–75.
40. Xia, Q., Peng, G., Shi, F.: Hemispheric lateralization in the semantic processing of nouns, verbs and verb-noun ambiguous words in Chinese: Evidence from an ERP study. *Journal of Psychological Science*. 37 (2014) 1333 – 1340.
41. Xu, C.: Ye-tan "de (的), de (地), de (得)" he "zuo (做), zuo (作)" do uke-yi he-bing [On the rationality of combining *de*[1], *de*[2], *de*[3], and *zuo*[1], *zuo*[2]]. *Journal of Shanxi University (Philosophy and Social Science Edition)*. (3) (1981) 69.
42. Xu, Y.: Structural particle *de*[2] should be replaced by *de*[1]. *Journal of Nanchang University (Humanities and Social Sciences)*. (6) (2004) 151–155.
43. Zhang, G.: The role of variationist study in language planning: A case study of the variation between *de* (的) and *de* (地). *Studies in Language and Linguistics*. 38 (2018) 120–127.
44. Zhang, W.: Tan jie-gou zhu-ci "de (的), de (地)" de fen-he [On the separation and combination of *de*[1] and *de*[2]]. *Journal of Jiangsu Normal University (Philosophy and Social Sciences Edition)*. (1) (1986) 147–151.
45. Zhang, Y., Li, P., Piao, Q., Liu, Y., Huang, Y., Shu, H.: Syntax does not necessarily precede semantics in sentence processing: ERP evidence from Chinese. *Brain and Language*. 126 (2013) 8–19.
46. Zhu, D.: Shuo "de (的)" [On *de*[1]]. *Studies of the Chinese Language*. (12) (1961a) 1–16.
47. Zhu, D.: Zai shen-me qing-kuang xia yong "de (的)" he "de (地)" [When to use *de*[1] and *de*[2]]. *The Press*. (6) (1961b) 36–37.