Neural Mechanism of Simple Sentence Processing in L2 Learners of English with Different Proficiency

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ABSTRACT

To analyze and explore the neural mechanism of simple sentence processing in L2 learners of English with different proficiency. The paper uses event-related potentials technology to comprehensively examine the processing advantages of relative clauses in L2 learner of English under a variety of life conditions and compares the processing differences of L2 learners with high and low proficiency. There is a LAN-P600 effect in Chinese-English bilinguals with high proficiency when processing similar syntax violations. There is only a P600 effect in the central apex area in bilinguals with low proficiency. For dissimilar syntactic structure violations, there is no significant difference in the neural mechanism for bilinguals with both high and low proficiency. The transfer of syntactic knowledge of mother tongue will exert continuous impact on the processing of L2 simple sentences and the effect of mother tongue transfer on L2 syntactic processing is greater than that of proficiency.

Key Words: Chinese-English Bilinguals, Syntactic Processing, Event-related Potentials

DOI Number: 10.14704/nq.2018.16.6.1600 **NeuroQuantology 2018; 16(6):405-409**

Introduction

A lot of evidence proves that event-related potentials technology (ERP) is very sensitive to sentence processing and can detect the sentence processing process of high-speed integration and even that in an unconscious state. Compared with the reaction-time paradigm, ERP can provide the reaction time and cortical activity data of the language analysis process without adding interference tasks and the conscious judgment of subjects, which enables us to perform real-time monitoring with high lock-time of the sentence processing process (Tang *et al.*, 2002). Nowadays, the study on sentence processing using ERP as technical support has provided much inspiration for the cognitive neural mechanism of sentence processing.

With the popularity of second language (referred to as "L2") education in China, the study of second language learning is also of great significance. In recent decades, the research on L2 learning has progressed by leaps and bounds, but a unified theory has not yet been formed. In the 125th anniversary of its inaugural publication, Science Magazine put forward 125 issues that call for detailed study in the next 25 years, including the study of neural mechanism in L2 learning (Parry, 2005). Therefore, it is of great significance to study L2 syntactic processing from the perspective of neurocognition.

The initial study was mainly based on the critical period hypothesis, which explained that children were more likely to acquire a language than adults.

This hypothesis suggests that there will be a critical period due to the physiological factors of brain development, in which the language acquisition is the easiest; after the critical period,

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 4 March 2018; **Accepted:** 27 April 2018

language acquisition will be limited to a certain extent. Early behavioral experimental studies on L2 acquisition confirmed the existence of the critical period, suggesting that L2 learners can only gain similar levels of native language processing in early childhood. However, with the advance of research methods, more and more studies have provided evidence against the effect of critical periods (Brownell *et al.*, 1990). Therefore, whether the effect of critical periods is a determinant of the ultimate achievement of L2 learning requires more evidence to clarify relevant differences. In particular, it is necessary to explore whether late-stage L2 learners can obtain similar neural mechanism as native speakers.

It is a common belief in the research field of L2 learning that the L2 syntactic learning is more difficult than lexical semantic learning (Bowden *et al.*, 2013) and this problem has attracted a large number of researchers to explore what are the influencing factors of L2 syntactic processing. At present, the view that has been accepted by most researchers is that proficiency and the learners' mother tongue all have significant impact on L2 syntactic processing. However, the opposite view holds that the L1 of learners does not have significant impact on the L2 syntactic processing. There is already evidence suggesting that the L2 learning of late-stage bilinguals is affected by the L1 processing neural network. However, the question that is still unclear and has received a lot of discussion is: to what extent the impact of L1 will be influenced by different proficiency levels of learners. (Kaplan *et al.*, 1990).

Although L2 education has been widely implemented in our country, for most learners, it is a very difficult task to learn a foreign language during adolescence or adulthood and it is also very difficult to achieve complete success. Especially in the actual teaching process, it is generally found that L2 grammar learning of learners is often more difficult than lexical semantic learning. Therefore, researches on the neural mechanism of syntactic processing in late-stage L2 learners has a significant guiding role for learners. The research results of this study have important theoretical significance and practical value.

Methods

This experiment recruits 30 healthy college students whose native language is Chinese and whose second language is English. Their age ranges from 20 to 26 years old. The requirement for the Chinese-English bilinguals recruited is that they begin English learning at around 12 or later. According to the predecessors' point of view, the learners who started L2 learning at this time are all late-stage learners. The initial selection of subjects is based on their grades in the Public English Test System. One group of recruited subjects are Chinese-English bilinguals who fail to pass the CET-4 or their CET-4 scores are below 450. The other group of respondents were Chinese-English bilinguals who passed the Professional English Band 8 examination. The other group of subjects are Chinese-English bilinguals who have passed the TEM-8 examination. They are required to do self-evaluation of their proficiency based on the English reading proficiency scale and then they are required to complete the English proficiency evaluation test. According to the proficiency classification criteria of the test and the scores of self-evaluation, 15 subjects in high and low proficiency group are selected respectively. All the L2 learning of subjects occurs in the classroom environment and does not have long-term living experience in the target language English environment. Meanwhile, all subjects are right-handed with normal vision or corrected vision and no history of mental or neurological disease. They volunteer to participate in the experiment and the body movement unrelated to the experimental task is avoided in the experimental process.

In order to examine the impact of the L1 of late-stage Chinese-English bilinguals on L2 syntactic processing and whether learners can learn the syntactic phenomenon missing in L1 but existing in L2, this paper examines four types of syntactic phenomena in the L2 English based on the degree of syntactic similarity between Chinese and English to L2 English, which are similar and dissimilar syntactic phenomena in Chinese and English and formal syntax and morphological syntax peculiar to English (Nakagawa, 1991). The experiment contains a total of 240 experimental sentences and 60 sentences for each experimental condition. Half of these 60 sentences contain incorrect syntax while the other are correct sentences. Different types of sentences complement each other. In order to allow bilinguals with low proficiency to achieve the maximum comprehension degree of sentences and to reduce any effect of unfamiliar

Table 1. The statistical table of behavioral data

Type	Average reaction time (ms)		Correct rate (%)	
	Mean	Standard deviation	Mean	Standard deviation
Highly skilled group similar structure	678.09	206.19	91.77	4.32
Highly skilled group dissimilar structure	781.19	275.75	72.96	7.97
Highly skilled and unique form structure	782.10	263.76	62.38	8.73
Highly skilled and unique morphological structure	768.62	257.69	86.31	7.16
Low-skilled group similar structure	592.65	189.88	87.27	7.07
Low-proficiency group dissimilar structure	727.09	247.82	59.05	9.04
Low-famous peculiar form structure	704.24	252.89	53.69	9.67
Low-famous morphological structure	791.95	380.74	69.57	8.65

vocabulary, the experimental corpus selected in this paper is the active sentence of statement. Each sentence contains 5 to 10 high-frequency words and bilinguals are very familiar with these words.

Results and discussion

Analysis of behavioral data results

This experiment requires all subjects to judge whether the sentence is grammatically correct after reading each sentence, and the average accuracy and average response time of high and low proficiency groups are recorded, as is shown in Table 1.

The statistical analysis of the response time and accuracy of the four syntactic structures of high and low proficiency Chinese-English bilinguals is conducted and the results show that the average accuracy of sentence comprehension tasks for high proficiency bilinguals is 78.63% and the average response time is 752.50ms. The average accuracy of low proficiency bilinguals under the same task is 67.4% and the average response time is 703.98ms. The variance analysis of the accuracy and response time of these two groups of subjects is conducted and the results show that there is a significant difference in the response of similar syntactic structures and dissimilar structures in the high proficiency group $F(1,13)=22.283$, $p=0.000$. The difference between the accuracy is also significant $F(1,13)=36.977$, $p=0.000$. The results show that the response time of similar syntactic grammar judgment is shorter and the accuracy is higher than that of dissimilar structure.

Results of ERP analysis data

The ERP waveforms induced in the keyword location of similar structure of correct sentences and violation sentences in low-proficiency group are shown in Figure 1 and 2. It can be seen from the Figure that the P600 component is induced in the keyword location in these two types of sentences. By observing the brain electrical activity mapping, it can be found that a P600 component with more positive amplitude is induced in the central apex area during the 500-700ms time window when low-proficiency bilinguals are processing the violation sentences compared with correct sentences.

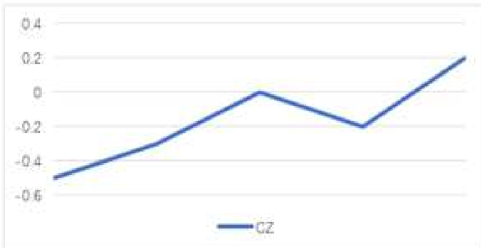

Figure 1. Grand average reference ERP and topography maps of similar syntactical structures in low proficiency group

Figure 2. Grand average reference ERP

The ERP waveforms of dissimilar structural control sentences and violating sentences are shown in Figures 3 and 4. It can be see from the figure that the N400 and LNC component is induced respectively by bilinguals when they are processing the correct sentences and the violation sentences. During the 300-500ms time window, the two-factors analysis of variance of component (correct, violation) × electrode (6 levels: C1, CZ, C2, CP1, CPZ, CP2) is performed on the N400 component and the results show that there is no significant difference between the types $F(1,13)=4.305, p = 0.058$ and that there is no interaction effect between types and electrodes, $F(5,65) = 0.533$, $p = 0.595$. During the time window of 800-900ms, the two-factors analysis of variance of component (correct, violation) × electrode (6 levels: C1, CZ, C2, CP1, CPZ, CP2) is performed on the LNC component and it is found that there is no type main effect between correct sentences and violation sentences, $F(1,13)=2.421$, $p=0.144$ and that there is no interaction effect between types and electrodes, $F(5,65)=0.930$, $p=0.425$. Through the observation of brain electrical activity mapping, we did not find a significant change in the current density between violation sentences and correct sentences.

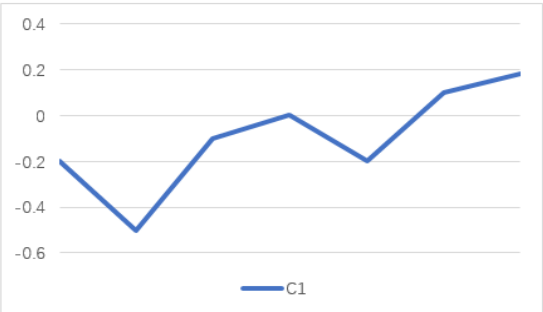

Figure 3. Grand average reference ERP and topography maps of dissimilar syntactical structures in low proficiency group

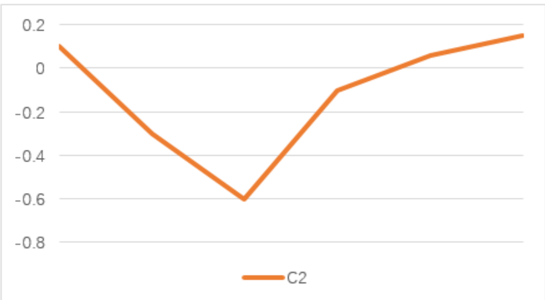

Figure 4. Grand average reference ERP

The ERP waveforms induced by the keyword location of similar structural violating sentences and control sentences in high-proficiency group are shown in Figures 4, 5 and 6. It can be seen from the Figure that the LAN and P600 are both induced by the keyword position in both types of sentences. The analysis windows of the LAN are 300-420ms and 420-500ms. During the 300-420ms time window, the multiple-factor repetitive measurement and analysis of variance of types (2 levels: correct, violation)×hemispheres (2 levels: left, right) × brain region (2 levels: anterior, posterior) × electrode (5 levels: AF3, F1, F3, FC3, FC1; C1, C3, C5, CP1, CP3; AF4, F2, F4, FC2, FC4; C2, C4, C6, CP2, CP4) is performed on the LAN component and the results show that there is no type main effect, $F(1,13) = 2.374$, $p = 0.147$ and that there is no significant difference between the left and right hemisphere, $F(1, 13) = 2.271$, $p=0.156$. There is a significant difference between the anterior brain area and the posterior brain area, $F(1,13)=26.191$, $p=0.000$. There is no interaction effect between types and the left and right hemisphere, $F(1,13)=1.341$, $p=0.268$ and there is no interaction effect between types and the anterior and posterior brain area, $F(1,13)=0.129$, $p=0.725$.

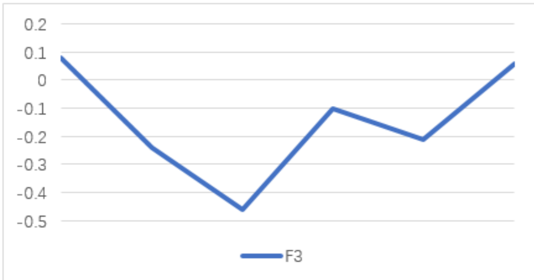

Figure 5. Grand average reference ERP and topography maps of similar syntactical structures in high proficiency group

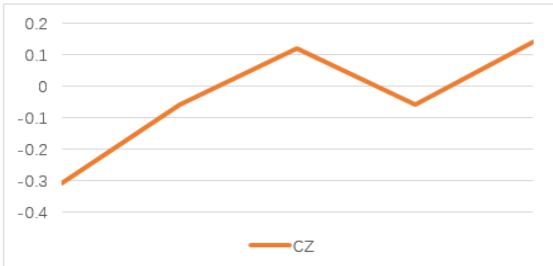

Figure 6. Grand average reference ERP

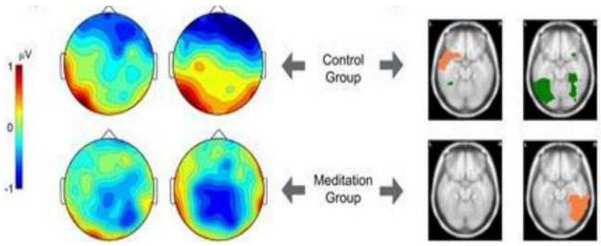

Figure 7. 500-560ms EEG

eISSN 1303-5150

During the 420-500ms time window, the same repetitive measurement and analysis of variance is performed on the induced LAN component and the results show a very significant type main effect F(1,13)=18.576, p=0.001. There is no significant difference between the right and left hemisphere, F(1,13)=0.110, p=0.745. There is no significant difference between the anterior and posterior brain area, F(1,13)=3.191, p=0.097. There is no interaction effect between types and hemisphere F(1,13)=0.416, p=0.530 and there is also no interaction effect between types and the anterior and posterior brain region, F(1,13)=0.632, p=0.441 (Abdullaev *et al.*, 2010).

There is also no significant difference between types and electrodes, F(5,65)=0.273, p=0.788. During the 550-630ms time window, the same variance analysis is performed on the mean amplitude of the P600 component and the results show that there is a significant difference between correct sentences and violation sentences, F(1,13)=4.994, p=0.044. Through the observation of the brain electrical activity mapping, it is found that during the 300-500ms time window, the voltage value of violation sentences induced in the left anterior brain is more negative than correct sentences. After 500ms, as figure 7, the voltage value of violation sentences in the middle posterior brain is more positive compared with correct sentences and the current density in the left hemisphere is greater than that in the right hemisphere, which is consistent with the statistical analysis results of ERP waveforms (Yang *et al.*, 1989).

Conclusion and outlook

Proficiency has a profound impact on the processing of L2 simple sentences. In this study, late-stage Chinese and English bilinguals can obtain similar neural processing mechanisms as target language speakers when they reach a higher level of proficiency. For the dissimilar syntactic structure violation, both high and low proficient bilinguals do not realize the syntactic violation (Glucksberg *et al.*, 1990). As a result, it is believed that even if bilinguals have reached a higher level of proficiency, the transfer of syntactic knowledge in the mother tongue will exert continuous impact on the processing of L2 simple sentences and the impact of mother tongue transfer on L2 syntactic processing is greater than that of proficiency.

References

Abdullaev YG, Posner MI. Time Course of Activating Brain Areas in Generating Verbal Associations. Psychological Science 2010; 8(1): 56-59.

Brownell HH, Simpson TL, Bihrle AM, Potter HH, Gardner H. Appreciation of metaphoric alternative word meanings by left and right brain-damaged patients. Neuropsychologia 1990; 28(4): 375- 83.

Glucksberg S, Keysar B. Understanding metaphorical comparisons: Beyond similarity. Psychological Review 1990; 97(1): 3-18.

Kaplan JA, Brownell HH, Jacobs JR, Gardner H. The effects of right hemisphere damage on the pragmatic interpretation of conversational remarks. Brain & Language 1990; 38(2): 315-33.

Nakagawa A. Role of Anterior and Posterior Attention Networks in Hemispheric Asymmetries during Lexical Decisions. Journal of Cognitive Neuroscience 1991; 3(4): 313-21.

Parry C. Typhoid fever and cholera. Medicine 2005; 3(7): 34-36.

Tang Y, Zhang W, Ma L, Weng X, Li D. Journal of Chinese Psychology Acta Psychologic 2002; 34(4): 333-37.

Yang B, Xu ST. the functional characteristic of the hemispheres for recognizing Chinese characters and English words in subjects with different native language. Acta Psychologica Sinica 1989; 21(2): 70-74.