Scientific Research Publishing

Open Journal of Social Sciences, 2025, 13(5), 32-40
https://www.scirp.org/journal/jss
ISSN Online: 2327-5960
ISSN Print: 2327-5952

Review of Second Language Syntax Processing Research Based on ERP Experiments

Rou Huang

School of International Studies, Hangzhou Normal University, Hangzhou, China
Email: huangrouhznu@163.com

How to cite this paper: Huang, R. (2025). Review of Second Language Syntax Processing Research Based on ERP Experiments. *Open Journal of Social Sciences, 13,* 32-40.
https://doi.org/10.4236/jss.2025.135003

Received: February 18, 2025
Accepted: May 11, 2025
Published: May 14, 2025

Abstract

Over the past decades, research on second language acquisition based on ERP has gained traction among scholars. This review summarizes recent research on second language acquisition using ERP, with a special emphasis on the preferences of Indo-European native speakers and Chinese learners in syntactic studies. Key factors include language proficiency, syntactic structure similarity, tense and voice, and the age of initial learning. The violation paradigm is commonly used, followed by the priming paradigm. The N400 and P600 ERP components are the main focus in this field.

Keywords

ERP Experiment, Second Language Acquisition, Second Language Syntax Processing, Language Proficiency

1. Introduction

Since the establishment of second language acquisition as an independent discipline, nearly half a century has passed. With the advancement of time and technology, an increasing number of cutting-edge techniques have been employed to explore the brain, the "black box" that harbors countless linguistic mysteries. In 1980, Kutas and Hillyard published a report on language research related to event-related potentials (ERP) in Science, marking the first discovery of the N400 component. Since then, ERP technology has gradually gained popularity in linguistic research. Although ERP has been used in language research for a relatively short period, it significantly differs from traditional research methods based on behavior and has gradually become an essential tool for linguistic studies.

Behavioral studies investigating second language (L2) syntactic violations have frequently reported increased processing time. ERP-based research has identified several brain components associated with syntactic processing, such as the Early

Left Anterior Negativity (ELAN), the Left Anterior Negativity (LAN) (Rossi et al., 2006), and a late centro-parietal positivity (P600) (Foucart & Frenck-Mestre, 2012; Rossi et al., 2006). ELAN reflects the early stages of syntactic processing and the automatic construction of syntactic structures, only observed in native speakers or highly proficient L2 learners. LAN is associated with morphosyntactic processing. And P600 reflects non-automatic syntactic reanalysis and repair (Kaan et al., 2000). Various types of syntactic violations—such as violation of agreement, verb inflection, case inflection, pronoun inflection, phrase structure, case marking, and verb argument structure violations—have all been shown to elicit the P600 effect. P600 peaks around 600ms after stimulus presentation and is generally considered sensitive to syntactic morphology. When a sentence has a syntactic error, P600 appears, suggesting it reflects a reanalysis of incorrect syntax.

In studies employing functional Magnetic Resonance Imaging (fMRI), some researchers argue that first language (L1) and L2 comprehension share the same neural substrate, while others suggest that even highly proficient late L2 learners recruit the left inferior frontal gyrus more frequently and occasionally engage the basal ganglia during syntactic processing. In contrast, early and highly proficient L2 learners tend to activate the superior temporal gyrus more often (Hernandez et al., 2007; Luke et al., 2002).

It is worth noting that most L2 studies using syntactic violation paradigms have involved participants whose L1 and L2 both belong to Indo-European languages. Only a few studies have examined the syntactic processing of L2 learners whose native languages are non-Indo-European, such as Chinese, Korean, or Japanese. The following sections will discuss the research findings in these two language background groups separately.

2. Empirical Research on Second Language Syntax Processing

2.1. Experimental Research of Indo-European Language Learners

Factors such as proficiency in a second language, and the syntactic structural similarity between the first and second languages, are focal points of scholarly investigation. Scholars are particularly interested in whether these factors constrain the development of syntactic ability in a second language and whether, with adjustments to these factors, second language speakers can achieve the syntactic processing level of native speakers.

2.1.1. Proficiency in a Second Language

Several studies have shown that proficiency in a second language affects second language syntactic processing (Sagarra & Herschensohn, 2013; Foucart & Frenck-Mestre, 2012; Hahne et al., 2006). The differences in syntactic processing between a second language and a native language are primarily due to lower proficiency in the second language, where speakers have not fully grasped the syntactic features of the second language. Experimental research involving participants whose first and second languages both belong to the Indo-European language family has

shown that highly proficient second language speakers can exhibit syntactic processing patterns similar to native speakers, while those with lower proficiency cannot. Sagarra and Herschensohn (2013) used self-paced reading techniques and syntactic judgment tasks to explore the impact of second language proficiency on syntactic processing. The results showed that both late-stage high-proficiency and low-proficiency Spanish second language speakers (with English as their first language) had high accuracy rates in syntactic judgment tasks. However, in the self-paced reading task, only intermediate and high-proficiency speakers exhibited processing patterns similar to native speakers.

Some experimental results have shown that low proficiency in second language speakers can induce a P600 effect during syntactic processing (Osterhout et al., 2006), but other studies have found otherwise (Foucart & Frenck-Mestre, 2012). Osterhout et al. (2006) found that French speakers, after one month of learning English, induced an N400 effect when processing English subject-verb agreement violations. N400 is a negative component that appears around 400ms after the presentation of a violating word. It is believed to be related to semantic expectancy. The greater the semantic deviation, the larger its amplitude, indicating more cognitive effort is required. Not only can text elicit N400 but inconsistent content or scene images can also trigger it. After four months of learning English, English learners induced a significant P600 effect. The P600 is generally linked to syntactic reanalysis or repair processes, indicating that as learners' proficiency increases, they become more sensitive to syntactic anomalies and start engaging syntactic parsing mechanisms similar to native speakers. Foucart and Frenck-Mestre (2012) investigated intermediate and low-proficiency French second language speakers (with English as their first language) processing violations of noun and post-nominal adjective relations. The results showed that native French speakers induced a P600 effect, while intermediate and low-proficiency French second language speakers induced an N400 effect without inducing a P600 effect. This suggests that lower proficiency learners may not yet fully engage syntactic processing mechanisms, and instead process such violations more as semantic incongruities.

Scholars have often examined the syntactic processing of highly proficient second language speakers. Hahne (2001) used an auditory channel to find that late-stage high proficiency German second language speakers (with Russian as their first language) induced a P600 component when processing phrase structure violations, without inducing an Early Left Anterior Negativity (ELAN) component. The ELAN typically reflects early automatic syntactic structure building and is usually observed in native speakers when encountering phrase structure violations. The absence of ELAN in second language speakers suggests that even highly proficient late learners may not engage fully automatic syntactic processes in the earliest stages of syntactic parsing. In subsequent research, Hahne et al. (2006) examined late-stage high proficiency German second language speakers (with Russian as their first language) processing German inflected words. The results showed that German second language speakers induced an Anterior Negativity

(AN) and P600 component when processing regular inflected words, but induced an N400 component when processing irregular inflected words. The AN reflects morphosyntactic processing and is often associated with the application of rule-based grammatical knowledge. The elicitation of both AN and P600 for regular inflections indicates that learners had acquired rule-based processing strategies for predictable morphological patterns. However, the presence of the N400 for irregular inflected words suggests that irregular forms may still be processed more lexically or semantically, as they are not governed by clear morphological rules. These findings imply that while advanced second language learners may develop native-like syntactic processing mechanisms for rule-governed forms, their processing of irregular structures still relies on lexical memory rather than syntactic prediction.

Rossi et al. (2006) also used an auditory channel to examine the impact of second language proficiency on syntactic processing. The experiment compared late-stage German and Italian second language speakers (German second language speakers with Italian as their first language and Italian second language speakers with German as their first language) processing word category violations, morphosyntactic agreement violations, and simple active sentences with both violations. The results showed that for the three violation conditions, highly proficient second language speakers exhibited the same processing patterns as native speakers, with ELAN, LAN, and P600 components present. Low proficiency second language speakers only exhibited a P600 component, with a delayed latency and reduced amplitude. The authors emphasized that highly proficient late-stage second language speakers can achieve the syntactic processing level of native speakers, thus not supporting the view that there are essential differences in syntactic processing between native and second language speakers.

In addition to ERP technology, scholars have also used fMRI technology to explore second language syntactic processing. fMRI research mainly focuses on whether there is the same neural substrate for first and second language processing. Hernandez et al. (2007) found that both early and late-stage Spanish second language speakers, when processing irregular words compared to regular words, showed enhanced activation in the left hemisphere BA 44 area. Within-group comparisons found that late-stage Spanish second language speakers when processing irregular words compared to regular words, had neural activity extending to the left hemisphere BA 47 area, while early-stage Spanish second language speakers extended to the left hemisphere BA 6 area. Comparisons between groups found that compared to early-stage second language speakers, late-stage second language speakers had enhanced activation in the left hemisphere BA 44/45 area when processing irregular words. This shows that late-stage second language speakers require more extensive syntactic processing. Rüschemeyer et al. (2005) pointed out that compared to native German speakers, late-stage high proficiency German second language speakers (with Russian as their first language) listening to sentences with syntactic violations had greater activation in the left inferior

frontal gyrus (BA 44/6), left intraparietal sulcus, right angular gyrus, and bilateral caudate nuclei. Golestani et al. (2006) used a production experimental paradigm to find that compared to native speakers, second language speakers had enhanced activation in the left anterior cortex during syntactic processing. Additionally, second language speakers had additional activation in the basal ganglia, supplementary motor cortex, and cerebellum.

2.1.2. Syntactic Structural Similarity between Languages

In the process of second language syntactic processing, the syntactic structural similarity between the first and second languages is also a crucial factor. Syntactic structures that are similar between languages, second language speakers have a processing pattern similar to native speakers. Kotz (2009) pointed out that the syntactic transfer phenomenon between the first and second languages is a dynamic process. As second language proficiency improves, the syntactic transfer phenomenon between languages will change.

MacWhinney (2007) found that in the early stages of learning a second language, structural cues in the first language might erroneously dominate the acquisition of second language syntax, resulting in a negative transfer effect. Over time, the influence of first language cues on specific structural cues in the second language, such as case inflection forms in German or Dutch, may weaken. McDonald (1987) found through research that as second language proficiency improves, Dutch second language speakers (with English as their first language) suppress the use of English word order cues. This shows that second language proficiency can constrain the impact of syntactic structural similarity between languages.

However, some scholars believe that in the interaction between second language proficiency and syntactic structural similarity between languages, syntactic structural similarity plays a more significant role (Tolentino & Tokowicz, 2014; Dowens et al., 2010; Tokowicz & MacWhinney, 2005). Some studies have shown that the syntactic structural similarity between languages is a significant factor constraining second language syntactic processing. Tokowicz & MacWhinney (2005) used ERP technology to examine the situation of late-stage low proficiency Spanish second language speakers (with English as their first language) processing syntactic violation sentences. The results showed that only syntactic structures similar between English and Spanish and syntactic structures unique to Spanish could induce a P600 component.

It should be noted that the above studies selected low proficiency second language speakers as subjects. Which factor plays a more significant role when highly proficient second language speakers process syntactic structures similar and dissimilar between the first and second languages? Some scholars have also studied this question. Dowens et al. (2010) examined late-stage high proficiency Spanish second language speakers (with English as their first language) processing grammatical gender agreement violations (unique to the second language) and number agreement violations (similar between the first and second languages). The experiment also examined the impact of violation location, with one being within

phrases and the other being across phrases. The results showed that for within-phrase grammatical gender and number agreement violations, Spanish second language speakers and native Spanish speakers both induced an early negativity and P600 component. For across-phrase grammatical gender and number agreement violations, Spanish second language speakers only induced a P600 component without inducing an early negativity.

In summary, the experimental studies listed above on the syntactic violation processing of Indo-European native speakers mostly examine the two factors of second language proficiency and syntactic structural similarity between languages separately, with few considering the interaction between the two factors. It is necessary and essential to examine the roles of the two factors in the same experiment.

2.2. Experimental Research of Chinese EFL Learners

Event-Related Potential studies on bilingual syntactic processing have garnered significant attention in the domestic field. Traditional research, which paid much attention to behavioral experiments, relied on reaction times and accuracy rates to infer the brain's understanding of syntax. Such methods were often susceptible to external interference. Due to the high sensitivity of ERP, it can capture minute psychological changes, offering a direct insight into the mechanisms of syntactic processing.

Guo and Chen (2011) found that highly proficient English L2 learners (with Mandarin as their first language) only elicited a positive ERP component when processing the violations of English syntactic structures that are similar to Mandarin. In contrast, lower proficient language learners only elicited the N400 component. Regardless of proficiency level, no corresponding ERP components were elicited when processing English syntactic structures that differ from Mandarin. This underscores the pivotal role of syntactic similarity between languages.

However, Chang and Wang (2013) reported inconsistent findings. They found that the proficiency of Mandarin native speakers in English reflects their real-time processing level of English syntax. Still, the impact of syntactic similarity between Mandarin and English was only evident in behavioral data. A study by Chang et al. (2014) found that high-proficiency native Chinese speakers did not display a processing pattern similar to native speakers when processing English reduced relative clauses (which differ between Chinese and English), supporting the Shallow Structure Hypothesis. However, in contrast to Chang's study, Zhang et al. (2017b) focused on the interaction effects of syntactic structure similarity and second language proficiency. They found that low-level learners are more sensitive to syntactic structure similarity. In contrast, high-level learners could elicit P600 for both similar and distinct syntactic violations, indicating that high-level learners can exclude interference from their native language when processing a second language. This finding is consistent with the Unified Competition Model (UCM) proposed by MacWhinney (2007).

In syntactic processing, studies on tense and voice are also numerous. Chang

and Gao (2009) investigated the neural processing mechanisms of passive sentences in Chinese English learners by setting up different types of violation sentences. They found that syntactic and semantic processing interact and exhibit a clear asymmetry, with sentence processing being primarily semantic. Similarly, Ji and Li et al., (2018) also used a violation paradigm to study the processing mechanism of present participles in English. Unlike previous studies, participants did not exhibit typical ELAN, N400, or P600 components in response to syntactic or semantic violations. Instead, a P2 and a broadly sustained negativity were observed, with no essential neural mechanism differences between high and low proficiency participants. The findings align with the Shallow Structure Hypothesis (SSH), suggesting a fundamental difference between second language learners and native speakers.

Zhang et al. (2017a) found that high-level participants elicited an AN+P600 response when processing regular verb past tenses, while low-level participants only elicited a P600-like waveform with a widespread scalp distribution. This indicates that high-level participants can automatically process regular verb past tenses, while low-level participants need to allocate more cognitive resources for conscious processing. When processing irregular verb past tenses, high-level participants elicited a P600 response, while no electrophysiological response was observed in low-level participants, suggesting that low-level participants struggle to differentiate the past tense of irregular verbs. Ma and Hu (2014) also studied the mental representation of verb past tenses, proposing that regular and irregular verb past tenses correspond to two separate systems: mental grammar and mental lexicon, respectively. From the above review, it's evident that N400 and P600 are indispensable components in ERP research on L2 syntactic acquisition, especially N400, which is involved in various aspects of language processing.

3. Conclusion

This article reviews and summarizes domestic research on second language acquisition based on ERP in recent years. The conclusions are as follows.

Overall, among all empirical studies, syntactic research has been favored by scholars both domestically and internationally. Experimental studies on the processing of syntactic violations by Indo-European native speakers often focus on two factors: second language proficiency and the similarity of syntactic structures between languages. Domestic scholars tend to concentrate on the similarity of syntactic structures, tense and voice. Notably, the violation paradigm is the most common in domestic second language syntactic processing research, followed by the priming paradigm. The N400 and P600 are the two most focused-on ERP components in the field of second language processing.

ERP technology offers advantages in the field of second language acquisition that traditional behavioral experiments do not. It provides real-time monitoring of cognitive activity in the brain with data across four dimensions (time, intensity, polarity, and brain region), pinpointing processing down to the millisecond.

However, ERP also has its drawbacks. It has a relatively low spatial resolution and requires the combination of other methods like fMRI or PET for precise brain region localization. The experimental process is easily disturbed; even blinking or speaking can cause voltage fluctuations. Over the past decade, few domestic scholars have combined ERP with fMRI or PET for deeper observations, and few have focused on research related to child second language acquisition.

Therefore, future research should pay more attention to syntactic teaching in second language acquisition. By leveraging neuroscience and cognitive neuroscience, we can enhance the efficiency of second language learning, truly harnessing the linguistic value of ERP technology for natural language teaching and learning.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Chang, X., & Gao, S. (2009). Psychological Mechanisms of Sentence Processing in Chinese College Students: A Study of Passive Sentences. *Psychological Science, 27,* 1363-1367.

Chang, X., & Wang, P. (2013). Influence of Second Language Proficiency and Cross-Linguistic Syntactic Similarity on English Passive Sentence Processing in Chinese Learners. *Foreign Language Teaching and Research, 45,* 241-252.

Chang, X., Zhu, H. H., & Wang, P. (2014). The Influence of Cross-Linguistic Syntactic Similarity on Second Language Syntactic Processing. *Foreign Language Teaching and Research, 46,* 560-571.

Dowens, M. G., Vergara, M., Barber, H. A., & Carreiras, M. (2010). Morphosyntactic Processing in Late Second-Language Learners. *Journal of Cognitive neuroscience, 22*, 1870-1887. https://doi.org/10.1162/jocn.2009.21304

Foucart, A., & Frenck-Mestre, C. (2012). Can Late L2 Learners Acquire New Grammatical Features? Evidence from ERPs and Eye-tracking. *Journal of Memory and Language, 66,* 226-248. https://doi.org/10.1016/j.jml.2011.07.007

Golestani, N., Alario, F., Meriaux, S., Le Bihan, D., Dehaene, S., & Pallier, C. (2006). Syntax Production in Bilinguals. *Neuropsychologia, 44,* 1029-1040. https://doi.org/10.1016/j.neuropsychologia.2005.11.009

Guo, J., & Chen, B. (2011). Effects of Syntactic Similarity between Chinese and English and Second Language Proficiency on L2 Syntactic Processing. *Psychological Science, 34,* 571-575.

Hahne, A. (2001). What's Different in Second-Language Processing? Evidence from Event-related Brain Potentials. *Journal of Psycholinguistic Research, 30*, 251-266. https://doi.org/10.1023/A:1010490917575

Hahne, A., Mueller, J. L., & Clahsen, H. (2006). Morphological Processing in a Second Language: Behavioral and Event-Related Brain Potential Evidence for Storage and Decomposition. *Journal of Cognitive Neuroscience, 18,* 121-134. https://doi.org/10.1162/089892906775250067

Hernandez, A. E., Hofmann, J., & Kotz, S. A. (2007). Age of Acquisition Modulates Neural Activity for Both Regular and Irregular Syntactic Functions. *NeuroImage, 36,* 912-923. https://doi.org/10.1016/j.neuroimage.2007.02.055

Ji, Y., & Li, X. (2018). An ERP Study on Complex Syntactic Processing in a Second Lan-

guage: The Case of English Present Participles. *Foreign Language Teaching, 39,* 52-58.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an Index of Syntactic Integration Difficulty. *Language and Cognitive Processes, 15,* 159-201. https://doi.org/10.1080/016909600386084

Kotz, S. A. (2009). A Critical Review of ERP and fMRI Evidence on L2 Syntactic Processing. *Brain and Language, 109*, 68-74. https://doi.org/10.1016/j.bandl.2008.06.002

Li, X., Huang, Y., & Ji, Y. (2018). An ERP Study on the Processing of English Subjunctive Mood by Chinese Learners: The Case of "It" Clause Subjects. *Foreign Language Teaching and Research, 50,* 556-568.

Luke, K., Liu, H., Wai, Y., Wan, Y., & Tan, L. H. (2002). Functional Anatomy of Syntactic and Semantic Processing in Language Comprehension. *Human Brain Mapping, 16,* 133-145. https://doi.org/10.1002/hbm.10029

Ma, H., & Hu, J. (2014). An ERP Study on the "Dual-System" Cognitive Model of Past Tense Verbs. *Foreign Language Journal, 27,* 33-38.

MacWhinney, B. (2007). A Unified Model. In N. Ellis, & P. Robinson (Eds.), *Handbook of Cognitive Linguistics and Second Language Acquisition* (pp. 287-312). Lawrence Erlbaum Press. https://doi.org/10.1075/tilar.22.15mac

Mcdonald, J. L. (1987). Sentence Interpretation in Bilingual Speakers of English and Dutch. *Applied Psycholinguistics, 8,* 379-413. https://doi.org/10.1017/s0142716400000382

Osterhout, L., McLaughlin, J., Pitkänen, I., Frenck-Mestre, C., & Molinaro, N. (2006). Novice Learners, Longitudinal Designs, and Event-related Potentials: A Means for Exploring the Neurocognition of Second Language Processing. *Language Learning, 56,* 199-230. https://doi.org/10.1111/j.1467-9922.2006.00361.x

Rossi, S., Gugler, M. F., Friederici, A. D., & Hahne, A. (2006). The Impact of Proficiency on Syntactic Second-Language Processing of German and Italian: Evidence from Event-Related Potentials. *Journal of Cognitive Neuroscience, 18,* 2030-2048. https://doi.org/10.1162/jocn.2006.18.12.2030

Rüschemeyer, S. A., Fiebach, C. J., Kempe, V., & Friederici, A. D. (2005). Processing Lexical Semantic and Syntactic Information in First and Second Language: fMRI Evidence from German and Russian. *Human Brain Mapping, 25*, 266-286. https://doi.org/10.1002/hbm.20098

Sagarra, N., & Herschensohn, J. (2013). Processing of Gender and Number Agreement in Late Spanish Bilinguals. *International Journal of Bilingualism, 17,* 607-627. https://doi.org/10.1177/1367006912453810

Tokowicz, N., & MacWhinney, B. (2005). Implicit and Explicit Measures of Sensitivity to Violations in Second Language Grammar: An Event-Related Potential Investigation. *Studies in Second Language Acquisition, 27,* 173-204. https://doi.org/10.1017/s0272263105050102

Tolentino, L. C., & Tokowicz, N. (2014). Cross-language Similarity Modulates Effectiveness of Second Language Grammar Instruction. *Language Learning, 64,* 279-309. https://doi.org/10.1111/lang.12048

Zhang, H., Bian, J., & Wang, Q. (2017a). ERP study on English Past Tense Processing Mechanisms in Chinese Learners with Different Proficiency Levels. *Foreign Language Teaching, 38,* 12-19.

Zhang, H., Yu, F., & Bian, J. (2017b). Cross-Linguistic Syntactic Similarity and L2 Syntactic Processing: Evidence from ERP in Chinese English Learners. *Foreign Language Teaching and Research, 49,* 803-817.