POS Identification by L2 English Learners: A Study on Brain Activation

Shin'ichiro Ishikawa

***Abstract*—**L2 learners, unlike native speakers, often have problems in efficient and seamless processing of varied facets of the L2 vocabulary. In the current study, we paid attention to how learners identify parts of speech (POS) of words in L2. With an fMRI brain imaging technique, we investigated learners' brain activation during POS type identification. Our study illuminated how brain activation varies in terms of the volume and regions according to the POS types to be identified such as nouns, verbs, adjectives, and adverbs, and also to learners' L2 proficiency levels.

***Keywords*—**brain activation, fMRI, L2 vocabulary processing, parts of speech, proficiency

I. Introduction

VOCABULARY knowledge can be compositional and multi-dimensional (Nation, 2001 [1]; Qian,2002 [2] etc.). Native speakers usually process varied facets of vocabulary in a unified and automatized way. However, L2 learners, unlike L1 speakers, often have problems in such a seamless processing of the target vocabulary.

The author has conducted a series of brain imaging studies to explore how L2 English learners process varied facets of English vocabulary such as phonology (e.g., rhyme identification), semantics (e.g., antonym identification), and lexical networks (e.g., collocation identification) (Ishikawa & Ishikawa, 2008 [3]; Ishikawa & Wei, 2009 [4]; Ishikawa, 2010 [5]). Previous experiments showed that learners' brain activation could vary a lot according to the type of the lexical processing and their L2 proficiency levels.

In the current study, the focus of our research is on parts of speech (POS) as a syntactic facet of vocabulary knowledge. As mentioned in Liddicoat & Curnow (2004), the "basis of syntax is the fact that the words of a language come in different classes or parts of speech" [6]. When a learner identifies the POS type of a given set of L2 words, they need to process the syntactic information included in the vocabulary.

Concerning L2 learners' POS identification, two things need to be reconsidered. One is how POS identification differs from other types of L2 lexical processing. In an experiment by Kadota (1998), twenty one Japanese learners of English judged whether (i) two words presented are synonyms or not (semantic judgment), (ii) they are phonetically similar or not (phonological judgment), and (iii) they belong to the same POS type or not (syntactic or word categorical judgment). The results showed that POS identification takes the longest reaction time compared with other two kinds of lexical processing [7]. This seems to suggest that a relatively higher level of processing is required in POS identification.

The other is how different types of POS, especially the four major POS of nouns, verbs, adjectives, and adverbs, are processed in different ways. Syntactically, verbs function as a core of predicate argument structure and nouns function as their internal/ external arguments, while adjectives and adverbs, which are called adjuncts, cannot be arguments by themselves and are not requisite elements in the syntactic structure.

Many previous studies have mentioned the unique status of verbs in lexical perception and processing. According to Imai (2004), for instance, grasping the concept of verbs is much more difficult for children than grasping that of nouns, for the notion of action expressed by verbs is likely to be confused with that of agents expressed by nouns [8].

Recent studies have examined bran activation of people when they process L1 and L2 vocabulary. It is generally said that the regions such as the primary auditory cortex, Wernicke's area, and Broca's area are related to lexical processing. Yokoyama et al. (2006), who compare brain activations of Japanese L1 speakers when they judge nouns and verbs of active and passive forms, reveal that verbs cause greater activation in the left middle temporal gyrus, although verbs and nouns are processed in the same cortical networks [9]. According to Davies et al. (2004), who compare verb identification with noun and adjective identification, the former causes a stronger action-related association and leads to an increased activation in a posterior left middle temporal gyrus [10]. Perani et al. (1999) analyze Italian speakers and report that verb stimuli cause greater activation in the left inferior frontal gyrus than noun stimuli [11].

Meanwhile, such a POS-related difference in the volume and regions of brain activation is not clearly observed in the experiment by Tyler et al. (2001), who analyze English speakers [12]. Based on these findings, Yokoyama (2007) proposes that verbs and nouns may cause different levels of brain activation only when morphologically different as in Japanese and Italian [13].

However, as summarized in Imai (2004), findings and observations in a series of brain studies are often inconsistent. The relationship between a particular POS type and a particular type of brain activation, especially when it is processed by L2 learners has not yet been wholly clarified.

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II. Research design

2.1 RQs

Previous studies have suggested that POS identification, which concerns syntactic processing of L2 vocabulary, is essentially different from phonological or semantic processing, and that verbs among the major POS types tend to be processed in a somewhat unique way. However, there still remains much to be clarified.

In the current study, we will conduct brain imaging experiments and analyze how Japanese learners identify POS of English words so as to explore learner's syntactic processing of L2 vocabulary.

The research questions to be considered are as follows:

RQ1 Which of syntactic (POS), semantic (antonym), and phonological (rhyme) processing causes greater brain activation?

RQ2 Which of the major POS types (nouns, verbs, adjectives, and adverbs) causes greater brain activation in processing?

RQ3 Which proficiency level of learners shows greater brain activation in POS type identification?

RQ4 Which brain regions are activated when learners at different proficiency levels identify the four kinds of POS types?

Our hypotheses to RQ 1 to 4 are H1: POS identification causes greater activation than the other two kinds of POS identification as suggested in Kadota (1998); H2: brain activation level does not vary significantly according to POS types as mentioned in Tyler et al. (2001); H3: lower-level learners who do not get accustomed to L2 lexical processing show greater activation than upper-level learners who process L2 vocabulary in a more efficiently automatized way (Ishikawa & Wei, 2012 [14]); and H4: brain activation is observed in Wernicke's area, which concerns speech perception, and also in Broca's area, which is said to concern syntactic processing of vocabulary in addition to speech production, mainly when lower-level learners identify each POS type. We will pay attention to the volume of brain activation (VBA) for RQs 1-3, and the activated brain regions (ABR) for RQ4.

2.2 Experiments

We will conduct two kinds of experiments using a 3T MRI machine. In order to analyze how learners' brains are activated during their POS identification, we will adopt a technique called fMRI (functional magnetic resonance imaging), which enables us to obtain a highly precise brain activation image. Human neural activity usually leads to an increase in oxygen in blood in the brain, which results in a change of magnetic susceptibility. This change is precisely identified by fMRI (Field, 2004) [15].

In the first experiment (Exp 1), subjects are given noun (N) identification tasks and verb (V) identification tasks, while in the second experiment (Exp 2), they are given adjective (J) identification tasks and adverb (A) identification tasks. In both cases, subjects are also given control tasks. Brain activation caused by control stimuli is finally subtracted from the activation caused by each of the four POS identification tasks.

In POS identification tasks, subjects are orally given a pair of words and told to judge whether they belong to the same POS type or not by pressing one of two buttons, while in control tasks, they are given a pair of artificially synthesized noises and told to press one of the two buttons at random.

One experiment lasts for approximately fifty minutes. After having several preparatory practices for the task, subjects enter the MRI machine and a three-dimensional whole brain image is taken. Then, after having a short trial session, which is for calibration or checking the appropriateness of experimental conditions, they have two task sessions in succession. Next, they have a short break, during which the T1 image is taken, and finally have the last task session. One task session consists of six modules. A single module comprises the sequence of (1) Instruction (a task type shown on the screen), (2) Task 1 (noun or adjective identification tasks, six pairs of words presented), (3) Control Task (four pairs of artificially synthesized noises presented), (4) Rest, (5) Instruction, (6) Task 2 (verb or adverb identification tasks, six pairs), (7) Control Task (four pairs), and (8) Rest. In one session, subjects have 72 word pairs and 48 noise pairs to be processed in total, meaning that they have 360 stimulus pairs, 216 lexical pairs and 144 noise pairs, in total during an experiment.

The design of the current experiments is essentially the same as that adopted in the author's previous experiments focusing on L2 learners' semantic and phonological processing of words, enabling us to compare the results of the current experiment with those of the previous experiments.

2.3 Subjects

Twenty four healthy subjects participate in the experiments: twelve subjects for Exp 1 and the other twelve for Exp 2. All the subjects are right-handed, and all excluding two are college students. No subjects have an experience of living in English speaking countries for two months or longer. Their academic majors vary from humanities and social sciences to sciences and engineering.

TABLE I
SUBJECTS PARTICIPATING IN THE EXPERIMENTS

Exp 1		Exp 2	
Subject	Score	Subject	Score
Sbj_1_01	410	Sbj_2_01	410
Sbj_1_02	430	Sbj_2_02	430
Sbj_1_03	515	Sbj_2_03	515
Sbj_1_04	540	Sbj_2_04	575
Sbj_1_05	580	Sbj_2_05	580
Sbj_1_06	640	Sbj_2_06	630
Sbj_1_07	640	Sbj_2_07	630
Sbj_1_08	715	Sbj_2_08	705
Sbj_1_09	735	Sbj_2_09	720
Sbj_1_10	740	Sbj_2_10	740
Sbj_1_11	805	Sbj_2_11	800
Sbj_1_12	945	Sbj_2_12	945

The subjects' L2 proficiency levels are strictly controlled. The average TOEIC(R) Test scores of the twelve subjects participating in Exp 1 and Exp 2 are 641.0 and 640.0 respectively. The difference between the average scores of the two groups is not significant (p=.98).

The subjects in each group are subdivided into three proficiency levels, lower (-595; N=5), middle (600-695; N=2), and upper (700-; N=5). The respective average scores of the subjects at lower and upper levels are 495.0 and 788.0 in Exp 1, and 502.0 and 782.0 in Exp 2. The differences between the two proficiency levels are significant in both groups (p<.001 in Exp 1; p<.01 in Exp 2).

2.4 Stimuli

In order to elicit appropriate reaction from subjects, stimuli should not be too unfamiliar or complicated, which is why all the stimuli are chosen from the top three thousand words of the JACET 8000 Basic Word List, which is based mainly on the British National Corpus.

Fifty percent of the lexical pairs belong to the same POS type and they are expected to induce yes responses, while the remaining fifty percent belong to different POS types and are expected to induce no responses.

The table below is a sample of the Yes and No stimuli used in the experiments. The figures attached to words represent the frequency rank in the JACET List.

TABLE 2
WORD STIMULI USED IN THE EXPERIMENTS (EXAMPLES)

POS	Y/N	Stim 1	Rank	Stim 2	Rank
V	Yes	say	47	surround	1463
V	Yes	know	56	communicate	1464
V	No	arrive	481	new	111
V	No	spend	483	old	114
N	Yes	people	46	knife	1465
N	Yes	year	68	birthday	1470
N	No	piece	482	new	111
N	No	art	484	old	114
J	Yes	old	114	silent	1280
J	Yes	different	158	friendly	1291
J	No	traditional	857	arrive	481
J	No	safe	872	spend	483
A	Yes	really	154	afterward	2215
A	Yes	always	155	sadly	2240
A	No	huge	885	include	494
A	No	normal	895	join	505

The lexical difficulties are roughly controlled between two kinds of POS identification tasks, between yes and no tasks, and between the two kinds of experiments. The order of presenting each stimulus is automatically randomized.

2.5 Data Analysis

SPM2 is used for analysis of the data obtained from fMRI experiments. The volume of brain activation (VBA) is estimated by multiplying the volume of a single voxel (3^3 mm^3) by the number of voxels in the kE regions whose activation level is statistically significant (p<.05).

Group analysis is then conducted to extract a general activation pattern from individual activations. The p value for significance judgment is set at .01.

III. FINDINGS AND DISCUSSIONS

3.1 RQ1 Types of lexical processing

First, we will compare the VBAs (mm^3) in the three types of lexical processing (Fig. 1). The VBA in POS identification is based on the data taken from the twenty four subjects participating in Exp 1 and Exp 2, while VBAs in antonym and rhyme identifications are based on the data taken from a different group of twenty four subjects participating in the author's previous experiments (Ishikawa & Ishikawa, 2008).

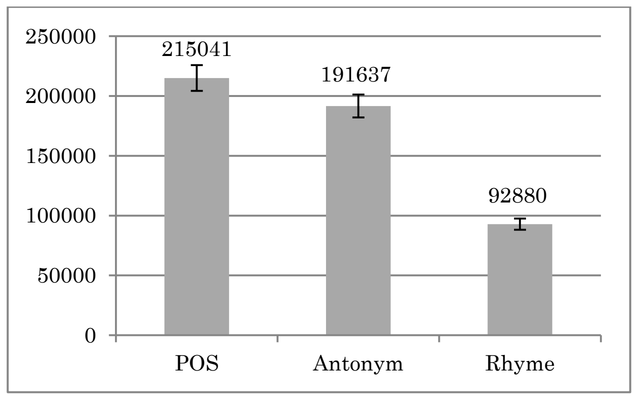


Fig. 1 VBAs in the three kinds of lexical processing

Our analysis showed that POS identification causes much greater activation than rhyme identification, which partially supports the finding reported in Kadota (1988) and suggests a relatively higher processing load of syntactic processing of L2 vocabulary.

Meanwhile, the difference between POS identification and antonym identification is slight. This may suggest that POS identification and antonym identification, which concern syntactic and semantic perception of L2 vocabulary, exist at similar levels of processing for learners.

3.2 RQ2 Types of POS to be processed

Next, we will analyze the VBAs (mm^3) in the four kinds of POS processing, namely, identification of verbs, nouns, adjectives, and adverbs (Fig. 2).

The figure below illustrates that the volumes of the regions activated during the four kinds of POS identification vary considerably. Adjectives and adverbs, which are additional elements in the predicate argument structure, seem to cause greater activation than verbs and nouns, which are requisite elements. Learners may have greater difficulty in processing peripheral POS types than in processing more syntactically central POS types.

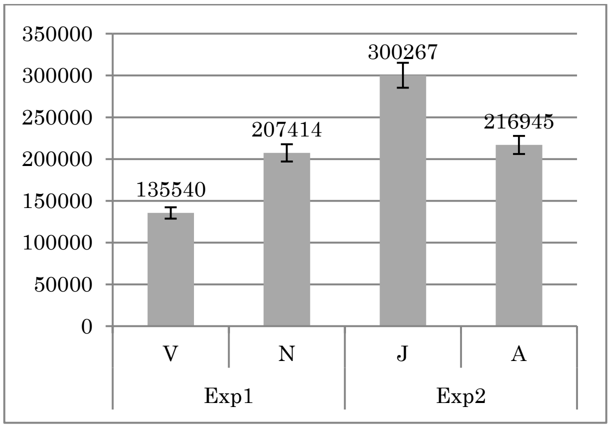


Fig. 2 VBAs in the four kinds of POS identification (V, N, J, A represent verbs, nouns, adjectives, and adverbs respectively.)

Also, nouns cause greater activation than verbs, and adjectives cause greater activation than adverbs, which might suggest that the load for processing the vocabulary relating to the dynamic status of things is smaller than that for processing the vocabulary relating to static attributes of them.

Unlike the findings reported in the previous studies, verbs do not necessarily lead to the greatest activation among the four types of POS. It seems that learners perceive verbs more intuitively and easily, while they make greater efforts to process the other types of POS.

3.3 RQ3 Proficiency levels of learners

Next, we will compare the VBAs (mm^3) of learners at different L2 proficiency levels (Fig. 3).

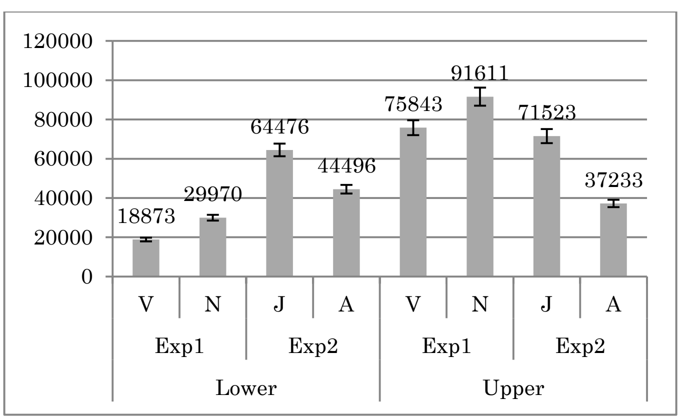


Fig. 3 VBAs of learners at different L2 proficiency levels (NB: Lower refers to learners whose scores in the TOEIC$^{(R)}$ Test are below 495, while Upper refers to learners whose scores are over 700.)

The volume of brain regions found significantly activated is much smaller here in comparison to the previous analyses, as the number of subjects used for group analysis decreases from twenty four in total to five in each proficiency level.

However, the figure above shows several noteworthy facts about POS identification by learners at different L2 proficiency levels. First, POS identification generally causes greater activation for upper-level learners than for lower-level learners. Second, lower-level learners activate their brains more intensely when processing adjectives and adverbs as additional elements in predicate argument structures. Meanwhile, upper-level learners tend to activate their brains more intensely when processing verbs and nouns as requisite elements, suggesting that upper-level learners can be more sensitive to syntactically core POS types.

It is of note that learners' proficiency seems to be characterized by greater activation in processing core POS types of verbs and nouns. This implies the possibility that advanced learners internalize the L2 syntactic structures more deeply than novice learners.

3.4 RQ4 Activated brain regions

Finally, we will analyze the activated brain regions (ABRs) in each experimental condition.

It is generally said that language is processed mainly in the left hemisphere.

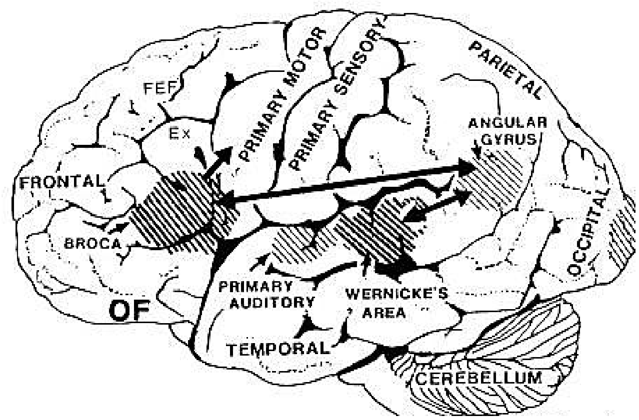


Fig. 4 Speech-related areas in the left hemisphere (Joseph, 1982 [16])

The primary auditory cortex concerns the perception of auditory sounds. Wernicke's area and Broca's area are traditionally thought to concern speech perception and speech production respectively.

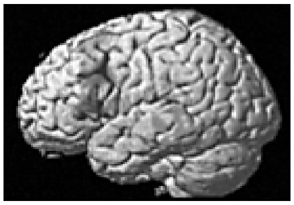
In addition, some researchers propose that the angular gyrus is related to storing or processing of phonological inputs, and the supramarginal gyrus, spreading at its left, is related to processing letters and/or metaphors. Also, some recent studies have proposed a module hypothesis. Sakai (2002), for instance, insists that Broca's area, Wernicke's area, and the angular/ supramarginal gyrus concern syntactic, phonological, and semantic processing respectively [17].

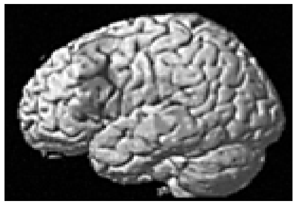
3.4.1 Types of POS to be processed

The figures below show regions significantly activated when learners process verbs, nouns, adjectives, and adverbs. ABRs are shaded in black (Fig. 5-8).

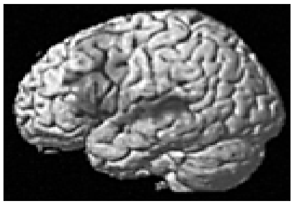
Broca's areas are activated in all of the four experimental conditions, but Wernicke's areas, which concern the perception of vocabulary, are activated only when learners try to identify the POS types of adjectives and adverbs.

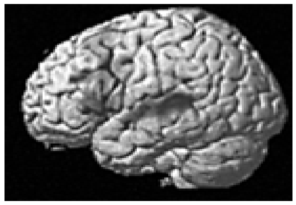
This suggests that L2 learners take in verbs and nouns more easily, while they need to pay more attention to processing less central POS types of adjectives and adverbs.





V N





J A

Fig. 5 ABRs in verb identification (upper, left), Fig. 6 ABRs in noun identification (upper, right), Fig. 7 ABRs in adjective identification (lower, left), Fig. 8 ABRs in adverb identification (lower, right)

3.4.2 Proficiency levels of learners

Finally, we will see how ABRs change according to POS types and learners' L2 proficiency levels (Fig. 9-16).

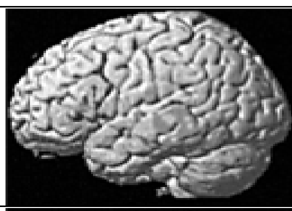
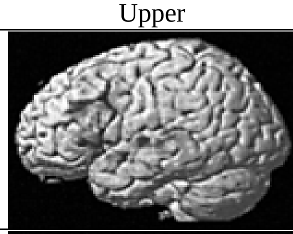
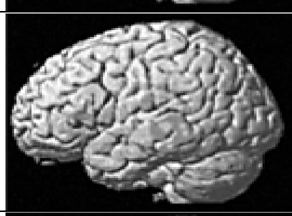
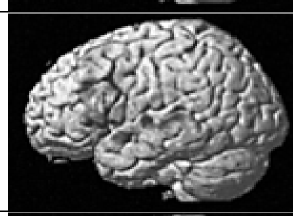
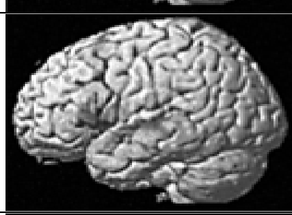
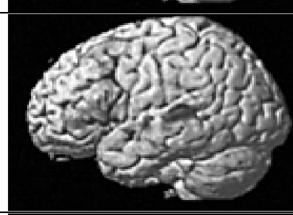
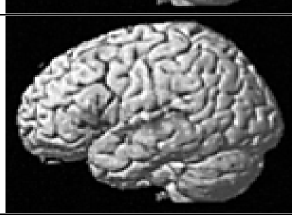
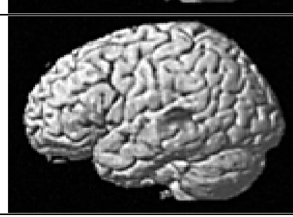
	Lower	Upper
V		
N		
J		
A		

Fig. 9 ABRs in lower-level learners' verb identification (upper, left), Fig. 10 ABRs in upper-level learners' verb identification (upper, right), Fig. 11 ABRs in lower-level learners' noun identification (second upper, left), Fig. 12 ABRs in upper-level learners' noun identification (second upper, right), Fig. 13 ABRs in lower-level learners' adjective identification (third upper, left), Fig. 14 ABRs in upper-level learners' adjective identification (third upper, right), Fig. 15 ABRs in lower-level learners' adverb identification (lower, left), Fig. 16 ABRs in upper-level learners' adverb identification (lower, right)

In case of lower-level learners, significant activations are hardly observed, meaning that individual subjects use different regions and commonly activated areas cannot be identified. Meanwhile, in case of upper-level learners, activated areas are much clearer, mainly covering Broca's areas in processing verbs and nouns, and Wernicke's areas in processing adjectives and adverbs.

Unlike novice learners, advanced learners seem to process syntactically requisite elements in predicate argument structures more efficiently by selectively activating Broca's area in charge of syntactic processing of lexical inputs.

IV. Conclusion

In the current study, we examined brain activation when L2 learners identify POS types of English words, utilizing an fMRI brain imaging technique.

First, concerning RQ1 (types of lexical processing), it was shown that POS identification generally causes greater activation than rhyme identification, while the difference between POS identification and antonym identification is not necessarily clear. The results, which partially support our hypothesis, might suggest that syntactic and semantic facets impose a greater processing load on learners.

Second, concerning RQ2 (types of POS to be processed), unlike the hypothesis, it was revealed that identifying the POS types of adjectives and adverbs causes greater activation than identifying those of verbs and nouns. Learners in general seem to tend to pay greater attention in identification of peripheral POS types in syntactic structures.

Third, concerning RQ3 (proficiency levels of learners), it was shown that the volume of brain activation in POS identification tends to be larger for upper-level learners than for lower-level learners, which is contrary to our hypothesis. This implies that POS identification is not automatized even for upper-level learners, who are more sensitive to the difference in syntactic status of each word in L2 vocabulary. Also, the analysis proved that advanced learners tend to pay greater attention to verbs and nouns requisite in syntactic structures, while novice learners instead pay attention to adjectives and adverbs as syntactically peripheral elements.

Finally, concerning RQ4 (activated brain regions), unlike our hypothesis that Broca's area and Wernicke's area are always activated simultaneously, it was revealed that Wernicke's area, which concerns speech perception, is activated mainly when learners process adjectives and adverbs, though Broca's area is activated in any type of POS identification. Also, comparison of learners at upper and lower L2 proficiency levels showed that the former tend to efficiently process verbs and nouns, two key elements in the sentence structures by activating Broca's areas.

Although the current study revealed many interesting facts about the mental mechanism of L2 learners' syntactic processing of L2 vocabulary, we also need to be aware of its limitations. In particular, the number of subjects in the current experiments is not necessarily sufficient and this might influence the results. In the following studies, we therefore need to reconsider the findings obtained here by increasing the number of subjects.

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