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문학석사 학위논문

A Morphological Processing of Determiner-noun Agreement by Korean Learners of English: An ERP Study

영어 명사구 수 일치의 형태 처리-

한국인 영어 학습자 대상 **ERP** 연구

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이 논문을 문학석사 학위논문으로 제출함
2018 년 8 월

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Abstract

A Morphological Processing of Determiner-noun agreement by Korean Learners of English: An ERP Study

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The current study attempted to investigate number agreement processing by advanced Korean learners of English, with distance and working memory capacity as modulating factors. Studies have reported that agreement is acquired at a late stage of second language acquisition, and that L2 learners are insensitive to agreement violations in real-time language processing even at an advanced level. English number agreement is not an exception, especially for L2 learners whose L1 does not

have the same agreement system (Chen et al., 2007; Jiang, 2004; Tanner et al., 2012). Nonetheless, previous studies have focused on subject-verb agreement and how L2 learners process number agreement between English determiner and noun is yet to be investigated. A related question is whether L2 learners with higher working memory capacity show better sensitivity to agreement violations as a function of distance between agreeing constituents. While working memory capacity is argued to be an important element of language aptitude, its role for high proficiency L2 learners is controversial. Granted, the current study examines the online processing of number agreement between English determiner and noun with ERP (event-related potentials) methodology for advanced Korean learners of English with high, middle, and low working memory capacity.

Twelve English native speakers and eighteen Korean learners of English with different levels of working memory capacity (high, middle, low) read English sentences, half of which contained agreement violations. While they were working on the sentences, their EEG data were recorded. The sentences also varied in terms of the distance between determiner and noun (i.e. short distance and long distance). While no LAN effect was observed in both groups in the time window of 300-450 ms, the native group showed a P600 effect (500-600 ms) in response to agreement violations. LAN is an early indicator of morphological violations while the P600 signals repair or reanalysis of syntactic violations. The P600 was not elicited in the learner group in the same time window, for both short distance and long distance conditions. While the short distance conditions overall elicited more positive

waveforms than the long distance conditions for both groups, the distance did not affect the size of P600. Finally, L2 learners with high working memory capacity showed a small P600 effect for short distance conditions at a later time window (700-800 ms).

The result demonstrates that L2 learners do not process number agreement in a native-like way when the equivalent grammatical feature is absent in their mother language. The ERP response of the native group and the learner group to varying distance conditions highlights their difference even more. The native group showed a consistent P600 effect even for long distance conditions, whereas the learner group did not show sensitivity to agreement violations even when the distance was short and therefore the cognitive load was less taxing. Nonetheless, working memory capacity was found to be an influential factor in processing agreement for L2 learners.

The current study has the following implications in regard to second language acquisition. First, L1 effect is crucial in L2 processing. Second, high working memory capacity can in part compensate for L1 effect.

Keywords: ERP, second language acquisition, number agreement, distance, working memory

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1. Introduction

1.1 Research Background

Online processing of agreement is known to be difficult for second language learners to acquire. Both behavioral studies (Coughlin and Tremblay, 2013; Jiang, 2004, 2007; Jiang et al., 2011; Keating, 2009, 2010; Lardiere, 1998; Lew-Williams & Fernald, 2010) and electrophysiological studies using an ERP (event-related potential) method (Chen et al., 2007; Meulman et al., 2014; Osterhaut et al., 2004; Sabourin & Stowe, 2008; Tanner et al., 2012; Tokowicz and MacWhinney, 2005) show that L2 learners are less sensitive to agreement violations than native speakers.

Distance between constituents makes morphosyntactic processing even more challenging (Gibson, 1998; Just & Carpenter, 1992). Even in the cases where L2 learners successfully compute inflectional morphemes, Clahsen and Felser (2006) claim that it will be limited to local domains. According to Gibson (1998), a longer distance between constituents causes processing difficulty mainly due to increased demands on cognitive resources, i.e. working memory. As distance enlarges, a parser has to keep in his memory the syntactic information of the former constituent for a longer time as well as integrate new input into the already built structures.

One possible explanation for L2 learners' morphological difficulties is that second language processing generally requires more attentional control and therefore more computational resources, such as working memory (Linck et al., 2013; Erçetin & Alpketin, 2013). Given the current emphasis on the role of working memory

capacity in the SLA literature, one can question whether L2 learners benefit from larger working memory in acquiring and processing agreement features. It is also possible that the benefit becomes even more salient for more complex structures, such as a long distance between constituents.

The primary goal of the current study is to examine the online processing of number agreement in an English determiner phrase (DP) by advanced L2 learners in comparison to English native speakers, using event-related potentials (ERPs). The second goal is to investigate the extent to which advanced L2 learners are affected by the distance in the DP. This is done by manipulating the distance between the agreeing constituents. In addition, the role of L2 learners' working memory capacity in morphological processing is examined in relation to distance.

1.2 Research Questions

The current study aims to explore the real time processing of English number agreement in a determiner phrase by advanced English learners as a function of distance and learners' working memory capacity. Consequently, the following research questions are addressed:

1) Research Question 1: Do advanced learners of English show sensitivity to number agreement violations in a DP in the same way as English native participants?

2) Research Question 2: Is sensitivity shown by advanced learners of English to agreement violations in a DP affected by the distance between constituents?

3) Research Question 3: Do learners with higher working memory capacity show better sensitivity to number agreement violations as the distance increases?

1.3 Organization of the Thesis

The organization of the present thesis is as follows. Chapter 2 reviews theoretical background and experimental studies on L2 learners' acquisition and processing of agreement features and issues of distance and working memory capacity in regard to language processing. Chapter 3 provides a description of the methods and design used for the ERP experiment. Chapter 4 presents the results of statistical analyses. Chapter 5 discusses the findings from the experiment in relation to the research questions addressed in the study. Finally, Chapter 6 summarizes the findings, addresses the implications of the present study and provides suggestions for future research.

2. Review of Literature

2.1 Theories on L2 Morphological Processing

Different theories have attempted to account for acquisition and processing of morphological components in a second language. A long-lasting controversy lies on (1) whether L2 learners can acquire morphemes nonexistent in their L1, and (2) whether their variable use of inflectional morphemes is a result of representational or processing deficit.

At one end of the spectrum is the Failed Functional Features Hypothesis (Hawkins & Chan, 1997; Smith & Tsimpli, 1995), which argues for a selective availability of Universal Grammar (UG) for late L2 learners. While some principles of UG such as Subjacency and the Binding Principles are available for adult learners, functional features including C (complementizer), Agr (agreement) and D (determiner) are impossible to acquire unless they overlap with L2 learners' mother language. At an early stage of second language learning, learners use L1 features to map L2 morpho-phonological forms. The functional features that are non-existent in learners' L1 cannot be fully adopted and need alternative routes for processing. Consequently, L2 learners form grammatical representations that are qualitatively different from those of native speakers even at their advanced level of L2 proficiency, because functional features remain inaccessible.

The Shallow Structure Hypothesis (Clahsen and Felser, 2006a, 2006b) claims L2 learners cannot build deep syntactic structure during language processing,

because their grammatical knowledge is less robust. This results in relying more on non-grammatical information such as semantic, pragmatic or surface-level information. In addition, they propose that even if L2 learners show a native-like level of processing, it will be limited to local contexts. In a more recent paper, they propose that such shallow parsing is due to the different weighting of constraints in L2 grammar (Clahsen & Felser, 2017); that is, L2 learners put less weight on morphological constraints compared to native speakers.

At the other end of the spectrum, others posit no difference in grammatical representations between L1 speakers and L2 learners. Instead, they attribute L2 learners' morphological variability to their processing deficits resulting from nonlinguistic differences. One possibility is that L2 learners have limited computational resources (Mcdonald, 2006). He proposed three possible sources for processing difficulty: (1) low L2 memory capacity (2) poor L2 decoding ability, and (3) slow L2 processing speed. Then he tested how these factors influence L2 learners' performance on grammatical tasks. In an experiment that investigated the relationship between these sources and L2 learners' scores on a grammaticality judgment task, their memory capacity and decoding ability were revealed as significant factors. Moreover, when native speakers were put under stress by adding noise or high memory load, their performance in the grammaticality judgment task significantly dropped in its accuracy. The ordering of constructions they experienced difficulty with was also parallel to that of L2 learners. This study clearly demonstrates that even performance of native speakers can be affected by cognitive

load. The author uses this result to argue that grammatical knowledge of L2 learners is not necessarily inferior to that of native speakers; L2 learners show more variability in language processing because they are under "difficult conditions (397)" comparable to the stress imposed on native participants in the study.

While the theoretical accounts remain variant, examining how Korean learners of English process English number agreement may give a clue to the debate on L2 morphological acquisition and processing, especially on whether L2 learner can acquire features that do not exist in their L1. In addition, comparing the extent to which native speakers and learners are affected by cognitive resources, such as distance and working memory capacity, can help understand the two groups' similarities and differences in their language processing.

2.2 Number Agreement in English

English requires certain determiners and nouns, or subjects and verbs agree in number. For example, only when the subject and the verb ((1a) in contrast with (1b)) or the demonstrative adjective and the noun ((1c) in contrast with (1d)) encode the same number value, which is singular in these two cases, is the sentence grammatical.

(1) a. An apple is on the table.

b. *An apple are on the table.

c. This boy

d. *This boys

Studies that investigated acquisition and processing of agreement by English learners have focused on across-phrase structure, i.e. subject-verb agreement (Chen et al., 2007; Jiang, 2004; Tanner et al., 2012). The results show L2 learners are less sensitive to agreement violations compared to native speakers. The same structure was used in the three studies as test materials where intervening materials were inserted between subject and verb (e.g. The key to the cabinet(s) was/*were rusty from many years of disuse). Jiang (2004) conducted a self-paced reading task to test Chinese learners' sensitivity to ungrammatical sentences. Unlike English native speakers who delayed in reading time for the ungrammatical condition, the learner group did not show any reading time difference between the two conditions. Chen et al. (2007) and Tanner et al. (2012) are ERP studies, which have an advantage over behavioral methods in that they provide real-time information on brain activities (Molinaro et al., 2011; Meulman et al., 2014). Two ERP components, the left anterior negativity (LAN) and the P600, are reported to be associated with syntactic violations among native speakers (Barber and Carreiras, 2005; Dowens et al., 2010; Kutas and Hillyard, 1983; Molinaro et al., 2008a, 2008b; Molinaro et al., 2011; Silva-Pereyra & Carreiras, 2007). LAN, a negative-going wave observed in the 300-450ms time window, is associated with an early detection of morphological violations (Friederici, 2002; Munte et al., 1997). P600, a positive deflection which appears 500ms after stimulus onset, is interpreted as a stage of repair or reanalysis

for syntactic violations (Hagoort et al., 1999; Meulman et al., 2014).[1] In Chen et al. (2007), the English native participants exhibited a LAN-P600 pattern to agreement violations whereas the Chinese participants did not. In Tanner et al. (2012), a P600 effect was observed in the Spanish learners of English, but it was smaller and was observed within a later time window compared to the native group.

On the other hand, the agreement between English determiner and noun as in (1c) has received little, if any, attention not only in L2 literature but also in L1 literature. Only Jiang (2007) and Jiang et al. (2011) looked at L2 processing of plural morpheme *–s* within a noun phrase (e.g. The child was watching some of the *rabbit/rabbits in the room.) in a series of self-paced reading experiments. Participants whose L1 was Russian exhibited sensitivity to violations for both the plural morpheme and verb subcategorization but Chinese and Japanese were sensitive only to the latter type of violation. As in Jiang (2004), this result is interpreted as indicating selective automatization of L2 grammar.

Syntactic theories and empirical evidence suggest a possible difference in processing agreement between a subject and a verb (across phrase) and a determiner and a noun (within phrase). According to Wechsler and Zlatic (2000) and King and Dlarymple (2004), agreement in these two structures are controlled by distinct features in constituents' functional structure (f-structure). Agreement between a noun and its determiners is controlled by CONCORD features whereas agreement

[1] Refer to section 2.5 for more details about ERP methodology and components.

between a noun phrase and a verb is controlled by INDEX features. For example, in a noun phrase such as *this boy*, the determiner *this* has the value *singular* in its CONCORD feature. The noun, *boy*, also has the value *singular* for its CONCORD feature. Then, according to the phrase structure rule in (2), which requires the f-structure of the daughter nodes to be the same as that of the mother node, the CONCORD feature of the NP *this boy* becomes *singular*. If the CONCORD features of the determiner and the noun conflict, as in **this boys*, the f-structure of the mother node NP results in having no solution since the values *singular* and *plural* are incompatible.

(2) $NP \rightarrow (Det \uparrow{=}\downarrow) N \uparrow{=}\downarrow$

(King and Dalrymple, 2004, p. 71)

On the other hand, the agreement between a noun phrase and a verb is governed by the INDEX feature, another feature that belongs to the f-structure. In the sentence *An apple is on the table*, both the noun phrase *an apple* and the verb *is* have the value *singular* in their INDEX features. Hence, the sentence is grammatical. Positing distinct agreement features for the phrase-internal structure and the across-phrase structure makes it possible to explain sentences such as in (3) where the determiner and the verb have different number values.

(3) This boy and girl are eating pizza.

(King and Dalrymple, 2004, p. 75)

Here, the nouns *boy* and *girl* share the same *singular* value with the determiner *this*. The noun phrase *this boy and girl* thus acquires the value *singular* for its CONCORD feature. Its INDEX feature, however, has the value *plural*, which is the same as the INDEX feature of the copular verb *are*. There is no way of accounting for (3) if the within-phrase agreement and the across-phrase agreement function within the same feature.

Bañón et al. (2012) and Dowens et al. (2010) provide an empirical evidence that the two structures elicit different ERP responses. They compared agreement processing of Spanish gender and number in within-phrase structures verses across-phrase structures. Bañón et al. (2012) investigated ERP responses by native Spanish speakers for sentences as given in (4).

(4) a. [within-phrase] El banco es un DP[edificio muy seguro/*seguros/*segura] y el juzgado también.
the bank is a building-MASC-SG very safe-MASC-SG/*MASC-PL/*FEM SG and the courthouse too

b. [across-phrase] El cuento VP[es anónimo/*anónimos/*anónima] y el manuscrito también.

the story-MASC-SG is anonymous-MASC-SG/*MASC-PL/*FEM-SG and the manuscript too

While agreement violations in both structures elicited P600 effects, within-phrase agreement violations yielded more positive waveforms than across-phrase agreement violations.

Dowens et al. (2010) found reduced sensitivity by nonnative speakers for across-phrase agreement violations compared to within-phrase agreement violations; participants elicited a LAN-P600 pattern for (5a) but only P600 for (5b).

(5) a. [within-phrase] El/*La/*Los suelo está plano y bien acabado.
The-MASC-SG/*FEM-SG/*MASC-PL floor-MASC-SG is flat and well Finished.

b. [across-phrase] El suelo está plano/*plana/*planos y bien acabado.
The floor-MASC-SG is flat-MASC-PL/*FEM-SG/*MASC-PL and well Finished.

These results suggest readers are generally more sensitive to the establishment of agreement for phrase-internal relations than across-phrase dependencies. Given this difference, it is worth investigating how L2 learners process within-phrase agreement in English.

2.3 Distance Effect in Language Processing

Distance, manipulated by increasing the number of intervening words between syntactically dependent constituents, hinders dependency resolution (Gibson, 1998; Just and Carpenter, 1992; Nicenboim et al., 2015). A considerable amount of studies have demonstrated that morphological processing is affected as the distance is enlarged with intervening words (Gunter et al., 1997; Kaan, 2002; Keating, 2009, 2010; Münte et al., 1997; O'Rourke & Van Petten, 2011; Rispens & De Amesti, 2017). Among the L1 literature, most studies report the impact of distance on P600 but not on LAN (except for Kaan, 2002 where no effect of linear distance was found in ERP response). For instance, O'Rourke and Van Petten (2011) looked at the distance effect on Spanish gender agreement processing with the following materials:

(6) a. Supongo que es normal que el baño privado/*privada tenga jabón y champú.
I suppose that it is normal that the bathroom-MASC private-MASC/*FEM has soap and shampoo.

b. Es importante que el queso esté rallado/*rollada para que no haya pedazos grandes.
It is important for the cheese-MASC to be grated-MASC/*FEM so that there are no big pieces.

c. El documento que es tan importante está firmado/*firmada y listo para el juicio.

The document-MASC that is so important is signed-MASC/*FEM and ready for the judge.

Note the distance between the noun and the adjective becomes larger from (6a) to (6c) with zero word in (6a), one word in (6b) and five words in (6c). The Spanish participants showed a consistent LAN effect for the three conditions but a decreased P600 effect in (6c) compared to (6b). They explain this result by distinguishing syntactic processes represented by LAN and P600. A LAN effect indicates a syntactic error was detected whereas a P600 effect means readers' attempt to repair or reanalyze the detected error. Hence, the consistency of LAN and reduced P600 for longer distance can be interpreted as readers' detection of the agreement violations but unwillingness to put an extra effort to repair.

It seems reasonable to suspect that distance would affect L2 learners more, given their limited cognitive resources in processing second language (Mcdonald, 2006). Their ability to process inflectional morphemes, in particular, is expected to deteriorate with increased distance because they tend to process content words before grammatical forms (VanPatten, 2004). This may result in ignorance or partial processing of inflections on nouns and verbs, which contribute little to the meaning of a sentence. When additional lexical items are inserted between agreeing constituents, then, it is more likely that these morphemes will be "dumped from

working memory as the processing resources in working memory are exhausted by efforts required to process lexical items (p.8)."

Empirical evidence so far has not reached consensus, perhaps due to different methods employed in each study. In Keating (2009), advanced learners of Spanish read sentences half of which contained gender agreement violations between noun and adjective (e.g. La tienda está abierta/*abierto *The store-FEM is open-FEM/*MASC*) while their eye movements were recorded by an eye-tracker. The distance between the noun and the adjective was both structurally and linearly manipulated. The detection of agreement violations by L2 learners was limited to short distance conditions compared to native speakers. In a follow-up study (Keating, 2010) where conditions differed only in their linear distance, a similar result was found, L2 learners showing more vulnerability to distance effect. On the contrary, Foote (2011) and Coughlin and Tremblay (2013), which used self-paced reading tasks, did not find such distance effect for L2 learners.

Theoretical work relates distance effect in language processing with working memory demands. Gibson (1998) emphasizes the role of locality in language comprehension in his syntactic prediction locality theory (SPLT). This theory posits two components: a memory cost component and an integration cost component. The former decides how much computational resources are needed to store input and the latter decides how much computational resources to put in integrating new input to the already built structure. As additional words consume both the memory cost and integration cost, longer distances are considered more expensive in both aspects. Just

and Carpenter (1992) also predict distance effects in language comprehension in that a longer distance causes working memory to hold prior information for a longer time while simultaneously processing additional input.

Although the connection between distance and working memory has been studied mostly in wh-constructions (King and Kutas, 1995; Johnson et al., 2016; Dussias and Piñar, 2010), the same account is possible in agreement processing, which involves two constituents that match in person, number or gender. As the distance between the constituents increases, it will require more working memory resources (Hartsuiker & Barkhuysen, 2006; Tanner, 2011). For example, consider the two sentences below:

(7) a. This smart student took the test that turned out to be too easy.

b. This smart and young university student took the test that turned out to be too easy.

In both cases, readers should hold the number property of *this* until they encounter the noun *student* in order to decide whether the sentence is grammatically correct. Compared to (7a), however, (7b) imposes more cognitive load in that there are three more words between *this* and *student*, i.e. *and*, *young*, and *university*. This means that readers should use their memory resources to process additional information (that the student is young and attends university) while storing the feature *singular* in memory at the same time.

Considering all L2 studies listed above used behavioral methods, a neurophysiological study is needed to better detect distance effect for L2 learners. It will also allow one to compare ERP responses with existing L1 ERP studies. In addition, it remains an open question how the distance will play a role in within-phrase constructions. Hence, the current study focuses on distance effects on number agreement processing between English demonstrative determiner and noun, a structure that has not been studied in previous literature. Finally, following Gibson (1998)'s SPLT or Just and Carpenter (1992), the current study examines whether agreement processing within long distance requires more working memory capacity is examined in this study. Working memory is gaining much attention in regard to language comprehension in L2 literature as well as L1. The definition, measurement, and the role of working memory capacity in SLA is discussed in the next section.

2.4 Working Memory

2.4.1 Definition and Measurement of Working Memory Capacity

Working memory is a brain system involved in storage and manipulation of temporary information necessary in complex cognitive processes (Baddeley, 1992, p.556). Baddeley and Hitch (1974)'s tripartite model explains working memory in terms of three subcomponents (Figure 1): (1) phonological loop which is responsible for holding verbal and acoustic information, (2) visuospatial sketch pad that stores

visual and spatial information and (3) central executive which controls the amount of attention the working memory uses for different information. The fourth component, episodic buffer, which integrates the three components of working memory and long-term memory, was added in Baddeley (2000).

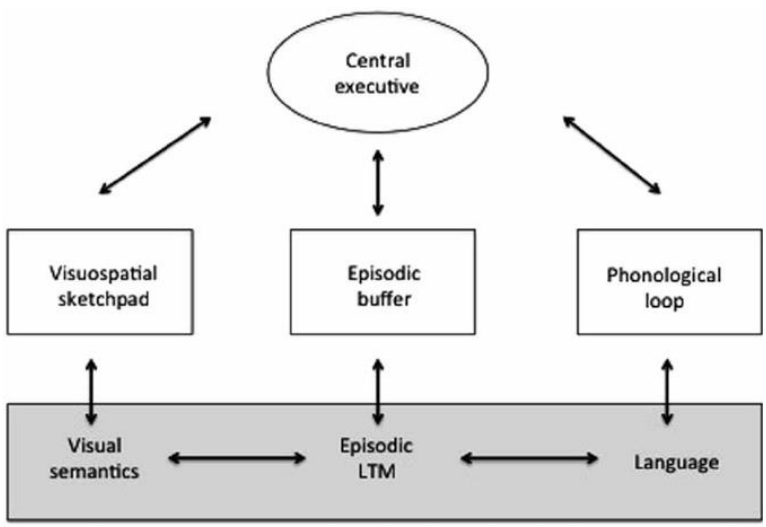

Figure 1 Baddeley's working memory model

(Baddeley, 2000, p.147)

Baddeley and Hitch's (1974) work triggered emergence of different working memory models, up to dozen (Wen, 2016), such as the Embedded Processes model by Cowan (1999) and the Controlled Attentional model by Engle (2002), which put more emphasis on the functional aspect of working memory. Although the models are divergent in explaining specific structures and mechanisms of working memory, six commonalities can be pointed out, according to the Unified Approach proposed

by Miyake and Shah (1999) and Wen (2016). First, working memory is not purely structural. Instead of positing working memory as a static "memory container", all models take a functional or control-oriented view. That is, working memory is a dynamic system that not only holds but manages information currently available. Second, the storage function of working memory is an active process that is related to complex cognitive activities. Third, the integral part of working memory lies on the central executive system that controls and regulates cognitive activities. Fourth, working memory has a limited capacity in the amount and duration of information it can hold. Fifth, working memory has both characteristics of domain-specificity (storage) and domain-generality (central executive). Lastly, working memory is closely connected to long term memory. Most working memory models accept the view that working memory functions as an activated portion of long term memory.

Tasks that are designed to measure working memory capacity are categorized as simple and complex (Juffs & Harrington, 2011; Linck et al., 2013; Wen, 2012) based on what component of working memory they measure. Simple memory span tasks are understood as measuring the capacity of phonological loop (Gilabert and Muñoz, 2010; Linck et al, 2013). They include digit span, word span or non-word span tasks, which test the amount of information individuals can store and rehearse after a short period of time. In such tasks, a string of letters or digits are presented to participants. Then the participants are asked to recall as many items as they remember. Complex memory span tasks, on the other hand, measure not only storage but also the processing function of working memory by incorporating a secondary

task to word/digit recall tasks. Therefore, they rely more on the function of central executive, or executive working memory (EWM; Wen, 2016). The reading span task, introduced in Daneman and Carpenter (1980), requires participants to read aloud a serial of sentences and recall the last word of each sentence. The number of sentences in each set increases over time. The reading span task has been used as a measure of working memory in a considerable number of L2 studies (Harrington, 1992; Harrington and Sawyer, 1992; Daneman and Merikle, 1996). However, it has a disadvantage of involving linguistic ability. Especially when the reading span task is performed in L2, it is possible that the measured working memory capacity correlates with participants' L2 proficiency. A more domain-general method is operation span task (OSPAN; Turner & Engle, 1989) where participants perform simple mathematical operations while holding words or letters in their memory for later recall. Despite limiting involvement of linguistic knowledge, a significant correlation is found between OSPAN task scores and reading comprehension (Bergsleithner 2010; Daneman & Merikle, 1996).

2.4.2 The Role of Working Memory in SLA

One of the main characteristics of working memory is that it has a limited capacity (Just & Carpenter, 1992). It has been argued that individuals' working memory capacity is responsible for their abilities to comprehend language and learn new languages (Harrington, 1992; Miyake & Freedman, 1998).

Working memory has gained a great attention in recent SLA studies, in particular, and has been suggested to be incorporated into one of the components of language aptitude. Skehan (2015)'s Information Processing (IP) model includes working memory as a central component in learning a second language. According to the IP model, working memory is a central construct that affects most of the L2 cognitive processes within all three stages in SLA: input processing, central processing, and output. Especially during earlier stages of SLA, the slower speed of L2 lexical and parsing requires larger working memory capacity to memorize more vocabulary, notice feedback and efficiently analyze language input and extract patterns.

Working memory capacity is also a possible predictor of successful language learning for highly advanced learners. High proficiency Language Aptitude Battery (Hi-LAB; Doughty et al., 2010; Linck et al., 2013), which is a language aptitude test designed to predict a high-level L2 proficiency, includes working memory span, namely phonological short term memory and central executive system, as one of its components. While higher phonological memory is hypothesized to facilitate vocabulary learning, the central executive system is relevant to broader aspects of language learning. L2 learners that exhibit better performance in the central executive system are more likely to: (1) update the contents of working memory with more relevant information (*updating*), (2) inhibit dominant responses when required (*inhibition*), (3) shift between their L1 and L2 (*task-switching*); and (4) hold more

information in their focus of attention (*attentional capacity*). Table 1 presents a summary of Hi-LAB constructs.

Table 1 Hi-LAB constructs

Constructs		
Memory	Working Memory	Phonological Short-Term Memory Central Executive
	Long-term Memory	Rote Memory
Acuity	Perceptual Acuity	
Speed	Processing Speed	
Primability	Priming	
Induction	Implicit Induction Explicit Induction	
Pragmatic sensitivity	In research and development	
Fluency	In research and development	

(Doughty et al., 2010, p.12)

In fact, a considerable amount of studies have demonstrated that L2 learners' working memory capacity can play an important role in acquiring general comprehension abilities (Harrington &Sawyer, 1992; Leeser, 2007), phonological features (Martin and Ellis, 2012), and writing skills (Bergleithner, 2010) as well as morphological forms (Coughlin & Tremblay, 2013; Hopp, 2014; Keating, 2010; Sagarra, 2008; Sagarra & Herschensohn, 2010; Wen, 2012). For example, Sagarra

(2008) tested whether English learners of Spanish with higher working memory capacity show more sensitivity to adverb-verb tense disagreement (e.g. Ayer el estudiante miró/*mira una pelicula de terror en el cine. *Yesterday, the student watched/*watches a horror film at the cinema*). A significant interaction effect between working memory capacity and agreement ($F(1)=196.051$, $p < .01$) was found. Sagarra and Herschensohn (2010) also report a positive correlation between L2 learners' working memory capacity and their sensitivity to adjective-noun gender agreement in Spanish in both online ($r = .334$, $p < .01$) and offline ($r = .290$, $p < .05$) tasks.

Nonetheless, it is not always the case that working memory capacity is found to be an influential factor in L2 processing. Sagarra (2017) points out working memory effects tend to be found for low proficiency learners (Leeser, 2007; Walter, 2004) but not for high proficiency learners (Chun & Payne, 2004; Gilabert & Muñoz, 2010). While this may indicate lack of working memory effects among high proficiency learners, another explanation is also possible that the structure tested was not complex enough to impose any difficulties on high proficiency learners. For working memory effects to be detected, the task should require cognitive resources (Linck et al., 2013; Sagarra, 2017). For instance, Akamutsu (2008) failed to find any relationship between learners' working memory capacity and a word recognition test. He claims that when a given task is so simple for participants, such as a word recognition task, it is likely that low span and high span learners perform at a similar level, leading to a lack of working memory effects. On the other hand, a significant

correlation between working memory capacity and agreement processing was found in Keating (2010) and Coughlin and Tremblay (2013) when task demands increased due to the enlarged distance between agreeing constituents.

If even learners at a high level of proficiency fail to compute inflectional morphemes, a domain-general resource, such as working memory, can be considered a possible factor. Yet, previous studies predict a varying effect of working memory capacity according to different task demands. Following this assumption, the current study tests whether working memory capacity can explain individual differences in showing sensitivity to agreement violations as a function of distance among high proficiency learners.

2.5 ERPs and Language Processing

Compared to behavioral methods (e.g. grammaticality judgment task, self-paced reading task, eye-tracking), neurological methods can provide a more direct indicator of human language processing, by measuring brain activities in real-time. Such methods include computerized axial tomography (CAT or CT), magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and eletroencephalography (EEG). CAT and MRI assess brain structure and anatomy, whereas fMRI, PET and EEG measures brain function. PET uses positrons (positively charged particles) to track brain regions that were activated by certain stimuli; fMRI makes use of blood flow; lastly, EEG is an

electric recording method that measures electrical activity of the brain. When EEG data, which provides continuous brain activity, is time-locked to a specific event, it is called event-related potentials (ERPs). Although EEG and ERPs have poorer spatial resolution compared to other methods such as fMRI, they have the advantage of non-invasiveness and more importantly, they offer a very high temporal resolution. In other words, they are able to detect the exact time certain brain activity occurred.

EEG is recorded by electrodes placed on the brain scalp. The most commonly used system to position electrodes is the international 10-20 system (Figure 2). Electrodes are positioned at 10% points from the midline, drawn from the nasion (the depressed area between the eyes) to the inion (the bump at the back of the head). Electrode names are comprised of two parts: one or two letters that indicate the general brain region (F = frontal, C = central, O = occipital, T= temporal) and a number that indicates distance from the midline. The electrodes placed in the left hemisphere are given an odd number and those in the right hemisphere are given an even number. Electrodes along the midline are labeled with a "z" (zero). For example, the electrode named C1 is positioned at the 10% point left from the midline electrode Cz.

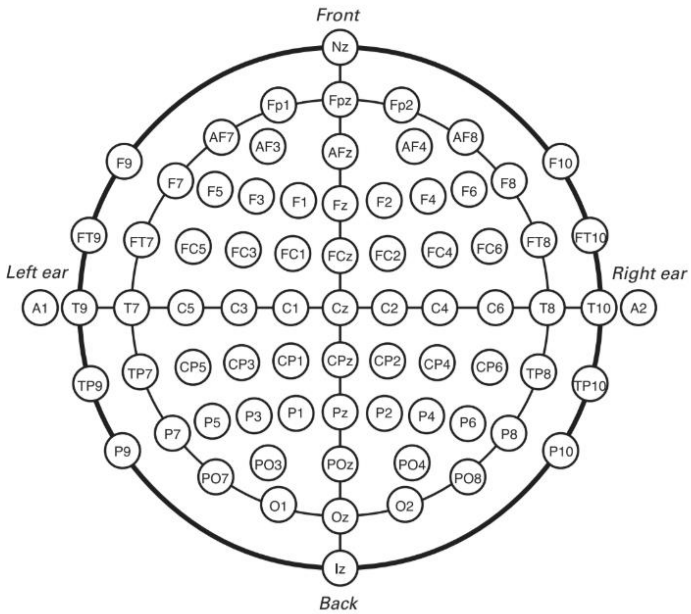

Figure 2 International 10-20 system

(Luck, 2014, p.167)

Figure 3 illustrates the procedure ERPs are obtained. Once the electrical activity of the brain is recorded, it is amplified and averaged over trials within the same condition. The obtained ERP is then compared with the ERP obtained from a different condition, to see how the task manipulation brings change in the waveform. Some waveforms are distinguished by their amplitude, latency (timing), and distribution over the brain regions as indicating certain cognitive processes underlying them. For instance, N400, which is a negative waveform that peaks around 400ms after the onset of a critical word, is known to appear when participants read sentences with semantic anomaly (e.g. *I take coffee with cream and* ***dog***) (Kutas and Hillyard, 1983). These waveforms are called ERP components (Kaan, 2007).

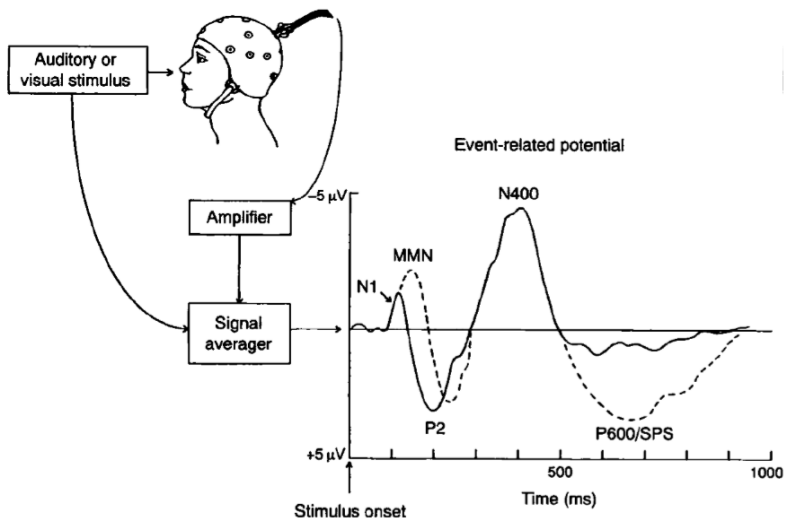

Figure 3 Illustration of how ERPs are obtained

(Kaan, 2007, p.572)

Two ERP components are of interest in the current study: left anterior negativity (LAN) and P600, which are related to syntactic anomaly or difficulty. LAN, as the name indicates, is a negative-going waveform whose distribution usually spans in the left anterior region of the scalp. It is observed from 300ms to 450ms after the onset. Although its latency is similar to N400, which also appears in the 300-500ms time window, the two components are differentiated according to their distribution: LAN is frontally distributed in the left hemisphere while N400 is distributed over broader areas. LAN is elicited by grammatical errors, including agreement violations. For instance, Gunter et al. (2000) conducted an ERP study with German sentences where the gender agreement between article and noun was

manipulated (e.g. Sie bereist das/*den land auf einem kräftigen Kamel. *She travels the-NEUTER/*MASC land-NEUTER on a strong Camel.).* Gender agreement violations elicited a negative waveform, identified as LAN, between 350ms and 450ms after the onset of the critical word (*land* in the example sentence).

P600 is a positive waveform that appears between 500ms and 900ms. Conditions that elicit P600 are not necessarily constrained to grammatical anomaly; it is also reported when participants read more complicated sentences. In Kaan et al. (2000), waveforms were more positive in the corresponding time window for a sentence *Emily wondered* ***who*** *the performer in the court had imitated for the audience's amusement* compared to *Emily wondered* ***whether*** *the performer in the court had imitated for the audience's amusement* because the former contains a long distance dependency and therefore is more difficult to establish the syntactic structure. Nonetheless, the fact P600 is consistently observed in studies investigating gender and number agreement makes this component an important indicator of detecting agreement violations (Kaan, 2007).

Although the biphasic LAN-P600 effect is common in response to agreement violations, some studies report only P600 effect without LAN (Frenck-Mestre et al., 2008; Kaan et al., 2003; Nevins et al., 2007; Wicha et al., 2004). LAN and P600 may reflect different stages of language processing, as suggested by Münte et al. (1997). For the purpose of examining the discrete role of the two components, sentences with pseudo-words were compared with those with real words. Both

conditions contained manipulation of number match/mismatch between subject and verb. Examples are given in (8).

(8) a. Der Kruke plötzt den Schruck. [pseudo-word, match]

A flurk nerches the minch.

b. *Das Klenck funen den Wech. [pseudo-word, mismatch]

A mizzel quench the plurr.

c. Der Junge schlägt den Hund. [real word, match]

The kid beats the dog.

d. *Der Mann trinken das Bier. [real word, mismatch]

The man drink the beer

LAN was observed only in pseudo-word conditions, in contrast to P600 which was found only in real word conditions. The authors interpret this result as indicating LAN to represent detection of morphosyntactic errors irrespective of semantic elements. P600, on the other hand, is elicited when reprocessing or reanalysis of a sentence is necessary. Absence of P600 for pseudo-word conditions implies that this component requires semantic context. Another possible difference between LAN and P600 is whether the process occurs consciously or not. When participants were asked to remember whether the sentence was presented or not (and

therefore their attention was not driven to the syntactic error) in one experiment and were asked to judge acceptability of each sentence (and hence, there was higher probability of participants attending to the syntactic error) in another experiment, LAN was elicited in both experiments whereas P600 was elicited only in the latter. This indicates P600 represents more controlled and conscious processing than LAN (Münte et al., 1997),.

ERPs can provide information on how language users process language with a high temporal resolution. Moreover, it can detect cognitive processes that take place subconsciously, in opposition to behavioral methods. Hence, the ERP technique is suitable to measure performance of L2 learners—their implicit knowledge of second language, in particular, while they process language in real time.

3. Methodology

3.1 Participants

A total of thirty participants took part in this study. Of thirty, twelve were native speakers of English (six males, six females) and eighteen were Korean learners of English (nine males, nine females). All participants were right-handed, had normal, or corrected to normal vision and had no history of neurological disabilities. Before the experiment, they were informed that the study was about English sentence processing. The original purpose of the study, which is to investigate their processing of number agreement, was debriefed at the end of the experiment. This was to prevent any prior knowledge of the original purpose from biasing the result. The participants were given 20,000 won as compensation for their participation.

The Korean participants were at an advanced level of English proficiency with TOEFL iBT scores of 110 or higher or TEPS (Test of English Proficiency developed by Seoul National University) scores higher than 850. TOEFL, which is administered by Educational Testing Service (ETS), assesses test takers' ability to understand and use English in four different skills: Reading, Listening, Speaking and Writing. On the other hand, TEPS, consisting of four sections of Listening, Grammar, Vocabulary and Reading, is more focused on comprehension skills of test takers. A TEPS score of 850 can be understood as equivalent to a TOEFL score of 111, according to the TEPS council. Nevertheless, each of the two tests comprises of two

sections the other test does not have; TOEFL measures test takers' production skills that TEPS does not, while TEPS assesses test takers' grammar and vocabulary knowledge that TOEFL does not. In order to compensate for this difference, an additional measure of English proficiency was used on the date of the experiment. Participants were given a short version of ECPE (The Examination for the Certificate of Proficiency in English), which is a standardized English examination developed by University of Michigan targeted at advanced EFL learners. The short version consisted of 60 items selected from a total of 120 items in the GCVR (Grammar, Cloze Test, Vocabulary, Reading) section. Among the 60 items, 20 were from the grammar section, 10 from the cloze test, 20 from the vocabulary and 10 from the reading section. Participants had 30 minutes to solve the problems. Each item was counted as one point. All the participants scored above 40 out of 60 items (66.6%) with a mean score of 47. Finally, they self-rated their English proficiency on a five-point scale (1: very low, 5: very high). A summary of background measure of the participants is presented in Table 2.

Table 2 Means and ranges of the background measures of the participants

Measure	**Learners** M (range)	**Natives** M (range)
Age at testing (years)	23.4 (20-27)	27.6 (23-39)
Age of first exposure to English (years)	6.68 (3-12)	

Length of residence (years)	1.8 (0-12)
ECPE score	47 (40-59)
Self-rated proficiency	3.87 (2.75-5)
Reading	4.38 (3-5)
Listening	4.22 (3-5)
Speaking	3.61 (1-5)
Writing	3.27 (2-5)

3.2 Working Memory Measurement

This study used the OSPAN task, one type of complex span tasks, to measure participants' working memory capacity for following reasons. First, it is a complex span task, rather than a simple span task, that better predicts L2 acquisition (Daneman and Merikle, 1996; Linck et al., 2013). Second, the role of the central executive is enlarged especially at a later stage of language acquisition (Skehan, 2016). Considering that the nonnative participants in this study are highly proficient L2 learners, it deemed appropriate to employ the OSPAN task.

The task was performed on a PC placed in the lab, run through Inquisit Lab 4 (Millisecond software). There were three practice sessions before participants began the main task. In the first practice session, participants saw a series of English letters that appeared on the computer screen and had to recall as many letters as possible by selecting alphabets in the same order as presented. They were provided

with feedback about how many letters they recalled correctly for every trial. In the second practice session, the participants were asked to solve math problems (e.g. (8*9)-8=?). When they came up with the answer, they clicked the mouse to move to the next screen with a random number. If the number was the correct answer, they clicked "True"; if not, they clicked "False." The computer automatically calculated the average time each participant spent to solve the math problems. The third practice session combined the two former practice sessions. In this part, letters appeared one each between math problems so that the participants had to recall the letters after solving three to seven math problems. Consequently, the number of letters to be memorized ranged from three to seven. The average response time calculated in the second practice session was used as a time limit for participants to solve math problems. If they spent more than the mean time plus 2.5 SD (standard deviation), the trial was counted as a speed error. The main session was designed in the same way as the third practice session. It consisted of a total of 75 letter recall trials and 75 math problems. Participants were instructed to keep the accuracy rate of math problems above 85%. This was to prompt them to concentrate fully on calculation rather than letter recall when solving the math problems.

The absolute recall score was used as a measure of participants' working memory capacity. The score was computed by summing the number of letters for only those trials that were scored a perfect score. For example, if a participant recalled two letters in a 2-sized set, four letters in a 4-sized set and four letters in a 6-sized set, the absolute score would be 6 (2+4+0). The mean score of the native

group was 55.6 (range: 40-75) and the mean score of the learner group was 54.1 (range: 15-75). A t-test revealed no significant difference in working memory capacity between two groups (t=-0.28, p=0.77).

3.3 Stimuli

A total of 56 sentences were used as experimental materials in each of 4 conditions: correct and incorrect number agreement and short and long distance. Half of them started with a singular demonstrative adjective *this* and the other half started with a plural demonstrative adjective *these*. (See Table 4 for Example Materials.)

All experimental sentences had animate subjects. Moreover, the nouns were all regular nouns whose plurality is marked by -s. Short condition sentences were generated by inserting an adjective or noun between the determiner and the noun (e.g. *This smart student took the exam that turned out to be too easy*). Long condition sentences were created by inserting two adjectives connected with a conjunction word *and* and an additional noun or adjective, including the word used in the short condition sentences (e.g. *This smart and honest university student took the exam that turned out to be too easy*).[2]

2 Such structure was selected for following reasons. First, based on the results of Barber and Carreriras (2005), where even native speakers were hindered in detecting syntactic anomaly when the distance was four words (e.g. El piano que compramos ayer está roto/*rota y no funciona. *The piano-MASC that we bought yesterday is broken-MASC/*FEM and doesn't work*.), the four-word distance between constituents was deemed to be large enough to affect agreement processing in comparison to short distance sentences. Then, the Corpus of Contemporary American English (COCA) revealed that the structure [adjective + and + adjective + noun/adjective] was the most common to be inserted between

To control for frequency of the target nouns and intervening words, the log frequency per million words was calculated using the COCA database (Corpus of Contemporary American English; Davies, 2017). The frequency of intervening words in the short distance conditions and the long distance conditions were matched (t=-0.1, p=0.913). Table 3 presents a summary of log frequencies of the target nouns and intervening words that were used in the short and long distance conditions.

Table 3 Means and ranges of log frequencies of the target nouns and intervening words

Target nouns	Short distance conditions	Long distance conditions
M (range)	M (range)	M (range)
4.11 (2.7-5.42)	4.12 (2.55-5.42)	4.06 (2.88-5.03)

Finally, an acceptability judgment task was administered to ensure the same degree of plausibility between short distance sentences and long distance sentences. Twenty English native speakers rated acceptability of each sentence on a seven-point Likert scale. The task was performed online in Ibex Farm interface. Among the experimental materials, only grammatical sentences were selected. Two separate lists were created with distance as a factor. In other words, for each item set, a short distance condition and a long distance condition were stored in a different list so that participants saw only one version of each item. Participants were presented either of

this/these and a noun, with a frequency of 0.68 per million. (c.f. a possible alternative structure, [adjective + adjective + and + noun/adjective] had a frequency of 0.32 per million.)

the two sets and were asked “How natural is each sentence?”. They rated 1 for “unnatural” and 7 for “very natural. There was no time limit in performing the task. A mixed effects linear regression model with item and subject as random effects revealed no significant difference in acceptability between two conditions ($p > 0.01$).

The materials were counterbalanced across four separate lists using a Latin square design so that each participant saw only one version of each item set and an equal number of each condition. Additional 112 sentences were included as fillers.

Table 4 Example materials

Conditions	Examples	Number of items per list
Short distance	This smart student/*students took the exam that turned out to be too easy.	7/7
	These caring doctors/*doctor treated the patient that used to smoke a lot.	7/7
Long distance	This smart and honest university student/*students took the exam that turned out to be too easy.	7/7
	These caring and respected medical doctors/*doctor treated the patient that used to smoke a lot.	7/7

3.4 Procedure

The experiment took place in Brain and Humanities Lab located at Seoul National University. For EEG recording, participants sat in front of a computer

monitor in an electrically shielded room. They were instructed to answer comprehension questions that appear after the last word of each sentence.[3]

Sentences were presented word by word in the center of the monitor screen after a 1000 ms-long fixation. A word appeared on a grey screen in white fonts for 600 ms followed by a 100 ms-long blank screen. After the last word of each sentence, a comprehension question (e.g. *The exam was too easy*. for a target sentence *This smart student took the exam that turned out to be too easy*.) appeared on the screen. Participants pressed "y" for "yes" and "n" for "no" on keyboard. After a practice of ten sentences, they began the main experiment session which consisted of two blocks of 84 sentences, including 28 target sentences in each block. A block contained an equal number of sentences in each condition (grammatical/ungrammatical and short/long).

[3] ERP studies differ as to what task is given to participants while they are presented with stimuli sentences. While some studies asked participants to judge grammaticality or acceptability of the sentences (Bañón et al., 2012; Barber & Carreiras, 2005; Meulman et al., 2014; Rispens & de Amesti, 2017; Weber-Fox & Neville, 1996), others, but not many, gave comprehension questions as a post-task (Davenport & Coulson, 2011; Frank et al., 2015; O'Rourke& Van Petten, 2011). The current study used comprehension questions in order to minimize participants' attention drawn to grammatical elements of the target materials and measure their use of agreement information in real-time. Which part of the sentence participants pay attention to is crucial, especially in L2 studies, given their limited cognitive resources during L2 processing compared to native speakers. It can even change L2 learners' performance. For instance, when L2 learners were asked to translate English sentences to their L1, their sensitivity to agreement violations increased than when they read sentences for comprehension. This is because they were more attentive to grammatical forms in the former (Lim & Christianson, 2015). In this study, asking participants to read for comprehension seemed to be a preferable task to measure their implicit and real-time use of their knowledge on number agreement.

3.5 EEG Recording and Analysis

The EEG was recorded from 29 Ag/AgCl electrodes (ActiCap, Brain products) positioned based on the international 10-20 system (midline: FPz, Fz, FCz, Cz, CPz, Pz, OZ; lateral: FP1/2, F7/8, F3/4, FT7/8, FC3/4, C3/4, TP7/8, CP3/4, T5/6, P3/4, O1/2). FPz was used as the ground electrode and Cz as the reference. Eye blinks and movements were monitored with two electrodes placed on the outer canthi and below the left eye. Two additional electrodes were placed over the right and the left mastoids. The actiCHamp amplifier (Brain Products GmbH, Munchen, Germany) was used with an online filter of 0.1 Hz and 70 Hz and a sampling rate of 500 Hz. Impedances were kept below 10 kΩ.

The EEG data analysis was performed with Brain Vision Analyzer 2.1. The data were re-referenced to the left and right mastoids and filtered with a high-pass filter at 0.1 Hz and a low-pass filter at 30 Hz. Then the data were segmented to epochs from 100 ms before to 900 ms after the onset of a critical word. Trials were averaged and corrected to baseline set at 100 ms before the onset of the critical word. Separate ERPs were created for each condition, each subject and each electrode site.

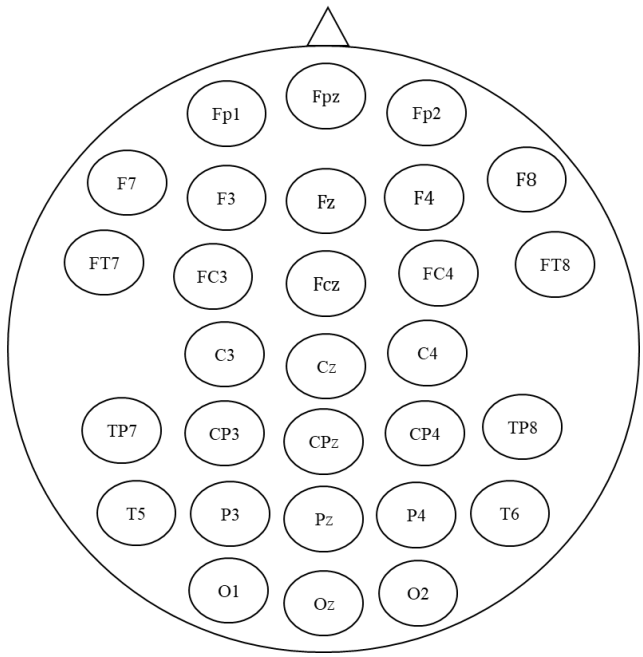

Figure 4 Schematic distribution of channels used in the study

Section 4.2 reports results for the statistical analysis for time windows of 300-450 ms and 500-600 ms each corresponding to where LAN and P600 are expected, according to visual inspection and previous studies (Chang et al., 2015; Friederici, 2002; Lelekov-Boissard et al., 2002; Munte et al., 1997; Wirsich et al., 2017; Zawiszewski et al., 2011). For each time window, repeated measures ANOVAs were conducted in order to examine ERP responses to agreement violations (Research Question 1) and varying distance (Research Question 2) by the native group and the learner group. All analyses were performed in R (version 3.4.3) using the ezANOVA function from the ez package (Lawrence, 2016). Separate

ANOVAs were conducted for midlines (Fz, Cz, Pz) and lateral sites: left anterior (F7, F3, FT7, FC3), right anterior (F8, F4, FT8, FC4), left posterior (CP3, TP7, T5, P3), and right posterior (CP4, TP8, T6, P4) regions. For midlines, four-way ANOVAs were conducted with amplitude of each electrode as a dependent variable. Independent variables were correctness (grammatical vs ungrammatical), distance (short vs long), and electrodes as within-subjects factors and group (native vs learner) as a between-subjects factor. For lateral sites, five-way ANOVAs were conducted. The mean amplitude of the electrodes located in the same region was obtained and used as the dependent variable. For independent variables, correctness, distance, hemisphere (left vs right), and anteriority (anterior vs posterior) were included as within-subjects factors and group as a between-subjects factor. Results related to correctness and distance are reported separately.

In section 4.3, the effect of participants' working memory span was investigated (Research Question 3). To this end, participants were divided into three groups based on their OSPAN scores: high working memory span group, medium working memory span group, and low working memory span group. Then the high working memory span group and the low working memory span group were compared, with working memory (high vs. low) included as a between-subject factor. For all ANOVAs conducted, Greenhouse-Geisser correction was done in the cases where the assumption of sphericity was violated.

4. Results

4.1 Behavioral Results

In order to induce participants to read sentences for meaning, a comprehension question was given as a task for every sentence. The mean percentage of correct answers for the native group was 93.45%. For target sentences, the accuracy rate was slightly higher (97.56%). For the learner group, the mean percentage of correct answers was 91.56% for all sentences and 96.42% for target sentences.

In addition, the native group, but not the learner group seemed to be hindered by agreement violations in comprehending sentences, indicated by the asymmetric error rate for grammatical and ungrammatical sentences. For the native group, among the comprehension errors for target sentences, 63.15% occurred in the ungrammatical sentences and 36.8% occurred in the grammatical sentences. In contrast, the learner group made more errors in the grammatical sentences (56%) than in the ungrammatical sentences (43.9%).

4.2 ERP Results

Grand average ERPs time-locked to the onset of the critical words are presented in Figures 5, 6, 7 and 8.[4] Figures 5 and 6 show ERP responses of the native group and the learner group in short distance conditions respectively. Figures 7 and 8 refer to ERP responses of the two groups in long distance conditions. A visual inspection of the waveforms suggested a positivity for incorrect sentences ranging from 500 ms until 600 ms after the onset for the native group (Figures 5 and 7). For the learner group, the amplitudes for the correct sentences and incorrect sentences overlap throughout the time window provided (Figures 6 and 8).

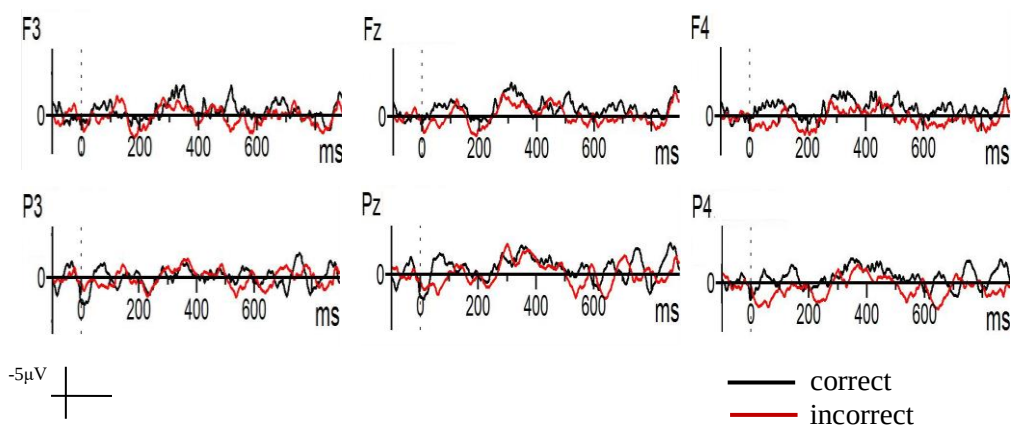

Figure 5 Grand average ERPs from native participants at the representative electrode from each region (short distance conditions)

[4] The y-axis indicates the size of amplitude and the x-axis indicates the time elapsed after the onset of the critical word. Waveforms are plotted with positive amplitudes downward and negative amplitudes upward.

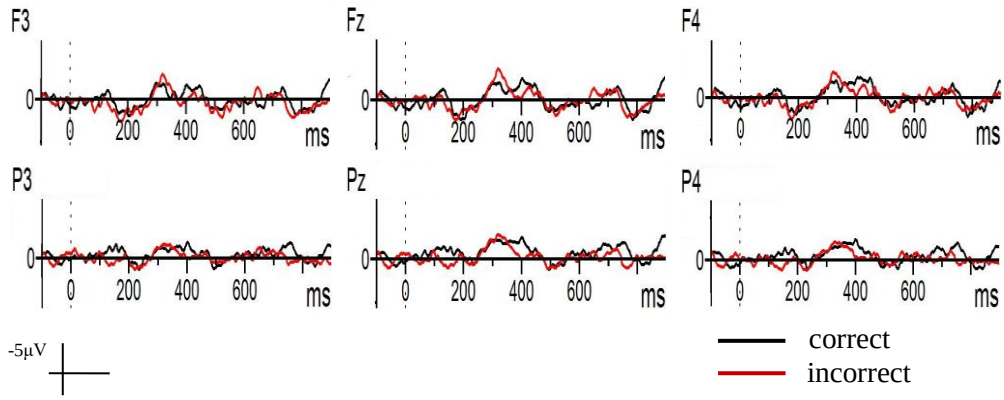

Figure 6 Grand average ERPs from nonnative participants at the representative electrode from each region (short distance conditions)

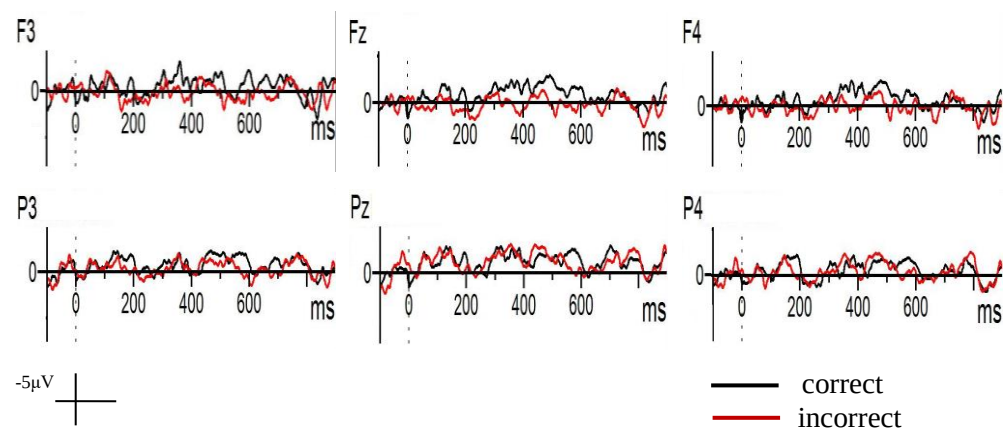

Figure 7 Grand average ERPs from native participants at the representative electrode from each region (long distance conditions)

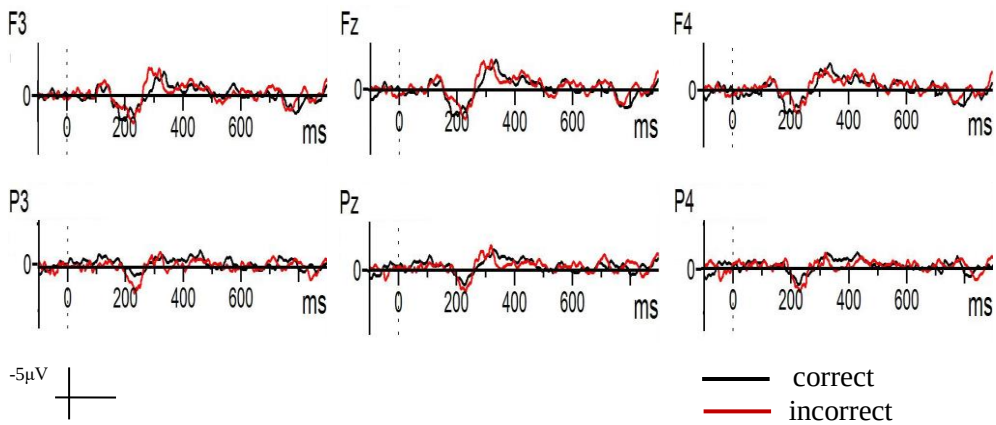

Figure 8 Grand average ERPs from nonnative participants at the representative electrode from each region (long distance conditions)

Table 5 presents main interaction effects revealed from ANOVAs in the time windows of 300-450 ms and 500-600 ms. Further statistical results are reported separately for the two time windows.

Table 5 F-statistics from the ANOVAs in the 300–450 ms and 500–600 ms time windows

	300-450 ms	500-600 ms
Midline		
Group*correctness (1, 28)	-	5.94* (0.04)
Group*correctness*electrode (2, 56)	7.25** (0.005)	-

Group*distance*electrode (2,56)	5.50* (0.002)	14.76*** (0.01)
Lateral		
Group*correctness (1,28)	-	7.83** (0.04)
Group*correctness*anteriority (1, 28)	7.15* (0.004)	-
Group*correctness*hemisphere*anteriority (1,28)	-	4.39* (0.001)
Group*correctness*distance*hemisphere (1,28)	4.78* (0.001)	-
Group*distance*anteriority (1, 28)	-	22.7*** (0.009)

Note. Degrees of freedom and effect sizes (generalized eta square) in parentheses. *$p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

4.2.1 300-450 ms

Figure 9 presents mean amplitudes of the native group and the learner group for correct and incorrect conditions in the time window of 300-450 ms. Distance was collapsed over data for visualization. For the native group, amplitudes are higher for incorrect conditions in the anterior regions. For the learner group, no big difference in amplitudes between correct and incorrect conditions can be seen, except for the electrode Pz.

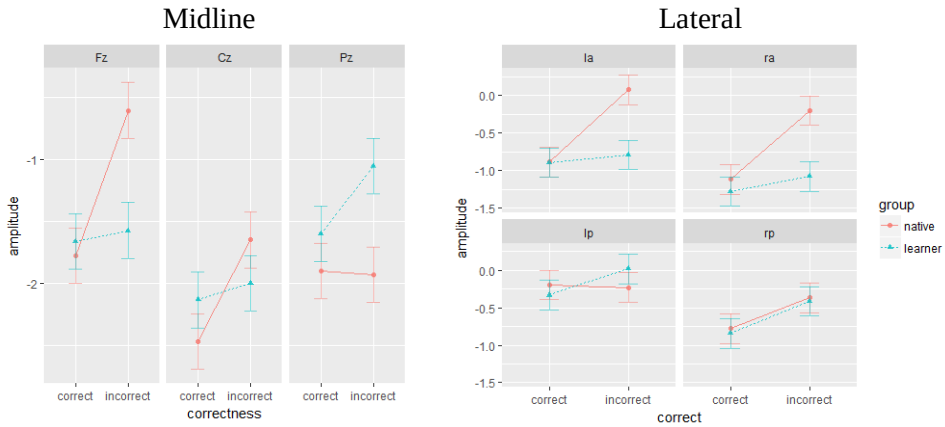

Figure 9 Mean amplitudes in the time window of 300-450 ms (collapsed over distance)

Note. Each block specifies brain regions (la = left anterior, ra = right anterior, lp = left posterior, rp = right posterior)

ANOVAs yielded a significant interaction of group, correctness and electrode in midline electrodes. For lateral sites, an interaction of group, correctness and anteriority and an interaction of group, correctness, distance and hemisphere was significant.

In post-hoc analysis for midline sites, no interaction between group and correctness was significant in any of the electrodes. The effect of correctness was also not significant. In lateral sites, both the left and the right hemispheres, and the anterior and the posterior regions did not have any significant interaction or main effect of correctness.

In order to observe the distance effect on amplitudes, a plot collapsed over correctness condition was plotted, which is presented in Figure 10. Long distance conditions have higher amplitudes in the electrode Fz for the native group, and in the electrode Pz for the learner group.

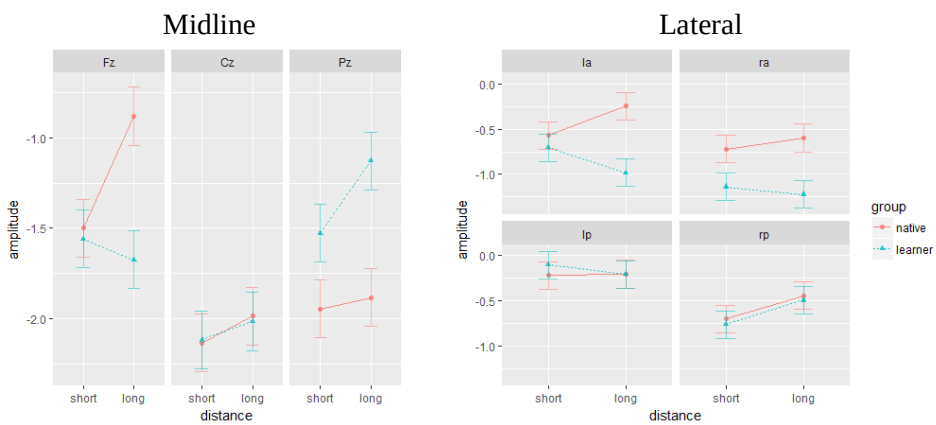

Figure 10 Mean amplitudes in the time window of 300-450 ms (collapsed over correctness)

According to ANOVA results, an interaction of group, distance and electrode was significant in midline electrodes. Separate statistical analysis for each group revealed a significant interaction between distance and electrode ($F(2,34)=4.38$, $p=0.03$, $\eta^2_{G=}0.002$) for the learner group. This was driven from positive amplitudes for long distance conditions in the electrode Pz, but the difference was not significant.

In short, correct and incorrect sentences did not yield any significantly different amplitudes in the time window of 300-450 ms. This indicates null LAN

effect to agreement violations in both groups. Regarding the distance effect, no meaningful result was found.

4.2.2 500-600 ms

Figure 11 shows mean amplitudes of the two groups for correct and incorrect conditions in the time window of 500-600 ms, collapsed over distance. The mean amplitudes for incorrect conditions are clearly more positive than correct conditions in all regions for the native group. There is no difference in the mean amplitudes between two conditions for the learner group.

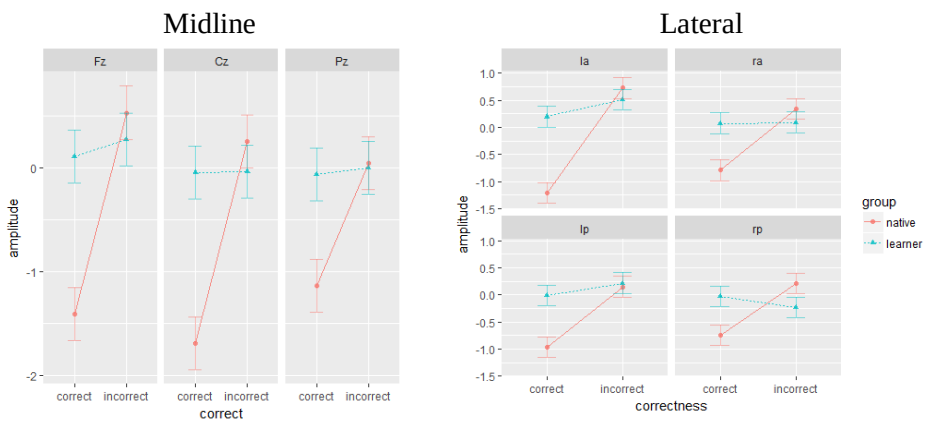

Figure 11 Mean amplitudes in the time window of 500-600 ms (collapsed over distance)

ANOVAs for the time window of 500-600 ms revealed a significant interaction between group and correctness in midline electrodes and an interaction of group, correctness, hemisphere and anteriority in lateral sites.

Repeated measures ANOVAs were conducted separately for the native group and the learner group in midline electrodes. For the native group, the main effect of correctness was significant ($F(1, 11) = 6.58$, $p = 0.02$, $\eta^2_G = 0.14$). For the learner group, the main effect of correctness did not reach a significant level ($F(1, 17) = 6.78$, $p = 0.79$, $\eta^2_G = 0.00$).

For lateral sites, there was a significant interaction between group and correctness in the anterior ($F(1, 28) = 6.05$, $p = 0.02$, $\eta^2_G = 0.07$) and the posterior regions ($F(1, 28) = 8.55$, $p = 0.006$, $\eta^2_G = 0.06$). The interaction was also significant in both hemispheres (left: ($F(1, 28) = 8.29$, $p = 0.007$, $\eta^2_G = 0.07$; right: $F(1, 28) = 6.21$, $p = 0.01$, $\eta^2_G = 0.06$). In post-hoc analysis, the native group showed a main effect of correctness in lateral regions (left anterior: $F(1, 11) = 8.93$, $p = 0.01$, $\eta^2_G = 0.26$; left posterior: $F(1, 11) = 18.91$, $p = 0.001$, $\eta^2_G = 0.21$; right anterior: $F(1, 11) = 4.85$, $p = 0.04$, $\eta^2_G = 0.14$; right posterior: $F(1, 11) = 7.35$, $p = 0.02$, $\eta^2_G = 0.13$) but the learner group did not. The native group also had a significant interaction between correctness and hemisphere ($F(1, 11) = 4.98$, $p = 0.04$, $\eta^2_G = 0.005$), driven from a stronger main effect of correctness in the left hemisphere (left: $F(1, 11) = 13.25$, $p = 0.003$, $\eta^2_G = 0.18$; right: $F(1, 11) = 6.69$, $p = 0.02$, $\eta^2_G = 0.1$). The learner group had a significant interaction between correctness and hemisphere ($F(1, 17) = 5.67$, $p = 0.02$, $\eta^2_G = 0.004$), but the effect of correctness was not significant both in the left

hemisphere ($F(1, 17) = 1.46$, $p = 0.24$, $\eta^2_G = 0.01$) and the right hemisphere ($F(1, 17) = 0.13$, $p = 0.72$, $\eta^2_G = 0.001$). In other words, the native group had a significant effect of correctness across all brain regions, with a stronger effect on the left hemisphere. For the learner group, the left hemisphere and the right hemisphere responded differently to correct and incorrect sentences, but the effect of correctness did not reach a significant level.

Figure 12 shows distance effect on amplitudes for the two groups. While short distance conditions have higher amplitudes than long distance conditions, the effect is observed mostly in the posterior regions for the native group and in the anterior regions for the learner group.

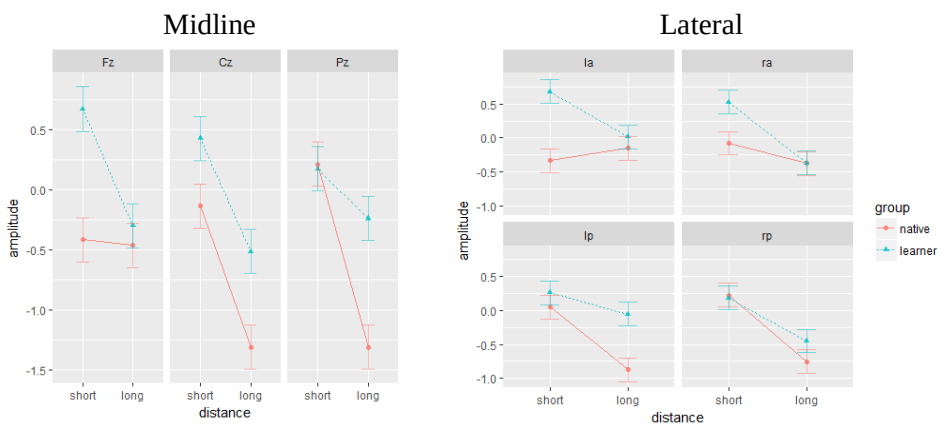

Figure 12 Mean amplitudes in the time window of 500-600 ms (collapsed over correctness)

ANOVAs yielded a significant group difference, with a significant interaction of group, distance and electrode in midline electrodes and an interaction of group, distance and anteriority in lateral sites. For the native group, an interaction between distance and electrode ($F(2, 22) = 7.97$, $p = 0.002$, $\eta^2_G = 0.02$) in midline and an interaction between distance and anteriority ($F(1, 11) = 11.52$, $p = 0.005$, $\eta^2_G = 0.17$) was significant. In the post-hoc analysis, the main effect of distance was significant in Cz ($F(1, 11) = 5.35$, $p = 0.04$, $\eta^2_G = 0.07$) and Pz ($F(1, 11) = 8.08$, $p = 0.01$, $\eta^2_G = 0.14$) but not in Fz ($F(1, 11) = 0.00$, $p = 0.92$, $\eta^2_G = 0.00$) and in posterior regions ($F(1, 11) = 6.21$, $p = 0.02$, $\eta^2_G = 0.1$) but not in anterior regions ($F(1, 11) = 0.02$, $p = 0.87$, $\eta^2_G = 0.00$). More positive amplitudes were elicited for short distance conditions compared to long distance conditions. The interaction between correctness and distance did not reach significance (midline; $F(1, 11) = 0.05$, $p = 0.81$, $\eta^2_G = 0.02$; lateral: $F(1, 11) = 0.00$, $p = 0.97$, $\eta^2_G = 0.00$). For the learner group, the interaction between distance and electrode in midline ($F(2, 34) = 6.91$, $p = 0.006$, $\eta^2_G = 0.0004$) and the interaction between distance and anteriority in lateral sites ($F(1, 17) = 7.97$, $p = 0.01$, $\eta^2_G = 0.003$) was also significant. Unlike the native group, the main effect of distance was found in Fz ($F(1, 17) = 10.24$, $p = 0.005$, $\eta^2_G = 0.06$), Cz ($F(1, 17) = 7.69$, $p = 0.01$, $\eta^2_G = 0.06$) and anterior regions ($F(1, 17) = 11.24$, $p = 0.003$, $\eta^2_G = 0.06$) as opposed to Pz ($F(1, 17) = 1.61$, $p = 0.22$, $\eta^2_G = 0.01$) and posterior regions ($F(1, 17) = 4.34$, $p = 0.05$, $\eta^2_G = 0.03$). As in the native group, short distance conditions yielded more positive waveforms compared to long distance conditions. No other interactions or main effects were significant, including

an interaction between correctness and distance (midline: $F(1, 17) = 0.00$, $p = 0.99$, $\eta^2_G = 0.00$; lateral: $F(1, 17) = 0.04$, $p = 0.82$, $\eta^2_G = 0.00$)).

To summarize, a P600 effect to agreement violations was observed only in the native group as can be seen in the topographic map (Figure 13). The absence of P600 effect in 500-600 ms for the learner group evinces the difference in processing agreement between the two groups. The main effect of distance was found in both groups, with short distance conditions eliciting more positive waveforms. More importantly, distance did not interact with correctness. That is, distance did not interfere with detecting agreement violations for the native group, while the learner group did not respond to agreement violations regardless of distance.

The native group

The learner group

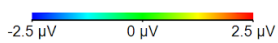

Figure 13 Voltage map: Participants' ERP response to agreement violations in the time window of 500-600 ms[5]

4.3 Effects of Working Memory Capacity

In order to investigate effects of working memory capacity, the participants were divided into three groups according to their OSPAN scores. Those at the upper

[5] Maps were created by using difference waves between grammatical and ungrammatical conditions.

third with the score of 63 or higher were classified as high working memory span group (n=10, native: 4, learner: 6), those with the score between 53 and 61 were classified into medium working memory span group (n=12, native: 4, leaner: 8), and those with the score of 43 or lower were classified into low working memory span group (n=8, native: 4, learner: 4). The cut-off for the low working memory span group was set at 43 despite the unbalanced number of participants in the medium group and the lower group, because of the large gap between the score of 53 and 43. For the purpose of comparison, only the high working memory span group and the low working memory span group were included in the statistical analysis, with working memory (high vs. low) as a between-subjects factor. The nonnative participants in the three groups did not differ in their English proficiency indicated by ECPE score ($F(2,15) = 0.684$, $p = 0.519$).

First, a repeated measures ANOVA was conducted in the time window of 500-600 ms, where a P600 effect was elicited by the native group. The dependent variable was the mean of amplitudes collapsed across regions, since the P600 was observed in all regions. Working memory and group were between-subjects factors and correctness and distance were within-subjects factors. A significant interaction of group, working memory and correctness was revealed ($F(1,14) = 5.12$, $p = 0.04$, $\eta^2_G = 0.04$). Following the interaction effect, repeated measures ANOVAs were conducted separately for the native group and the learner group with working memory as a between-subjects factor. This was to see whether the sensitivity to incorrect sentences differed as a function of participants' working memory span in

each group. The interaction between correctness and working memory was not significant in the native group ($F(1,6) = 1.75$, $p = 0.23$, $\eta^2_G = 0.04$) and the learner group ($F(1,8) = 4.03$, $p = 0.07$, $\eta^2_G = 0.04$), but the main effect of correctness was significant in the native group ($F(1,6) = 10.13$, $p = 0.01$, $\eta^2_G = 0.2$). This indicates the native participants were sensitive to agreement violations irrespective of their working memory span, while the nonnative participants were not sensitive to the violations, even those with high working memory span.

As noted, a P600 effect was not observed in the learner group in the time window of 500-600ms, in contrast to the native group. Neither was there any effect of working memory capacity. In other words, the learner group did not show a native-like ERP response to agreement violations, regardless of their working memory capacity. Nonetheless, visual inspection of the grand-averaged waveforms suggested a positive deflection in the time window of 700-800 ms for the learner group with high working memory span for short distance conditions (see Figure 14). This led to an additional statistical analysis for this time window.

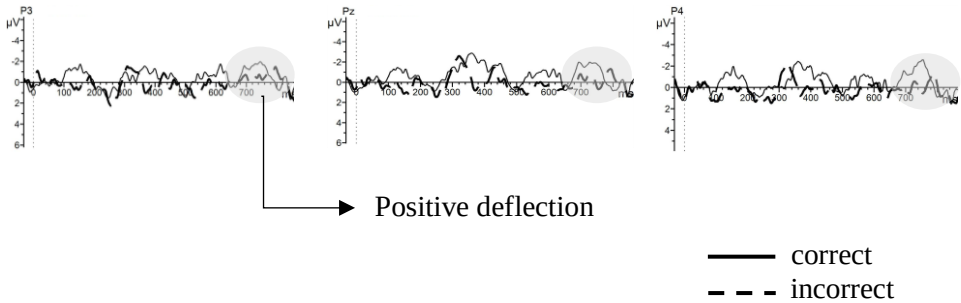

Figure 14 Grand average ERPs from nonnative participants with high working memory capacity (short distance conditions)

As in the time window of 500-600ms, a repeated measures ANOVA with correctness and distance as within-subjects factors and working memory and group as between-subjects factors was performed. The amplitudes were collapsed across regions. Working memory did not interact with correctness and group, indicating no difference in amplitudes as functions of correctness or participants' working memory span in both the native group and the learner group. The main effect of correctness was also not significant. This means within this time window, ungrammatical sentences did not elicit ERP responses for both groups. However, a separate statistical analysis for L2 learners with high working memory yielded a significant main effect of correctness in the posterior region ($F(1, 5) = 12.57$, $p = 0.01$, $\eta^2_G = 0.12$) and a marginal effect in the electrode Pz ($F(1, 5) = 6.22$, $p = 0.05$, $\eta^2_G = 0.13$). L2 learners with low working memory span did not show a significant effect of correctness in any region.

5. Discussion

The current study attempted to investigate the following issues: (1) whether advanced learners of English can detect number agreement violations in online processing, especially when their L1 does not have the number agreement feature, (2) the extent to which their performance is affected by the increased distance between the agreeing constituents, and (3) whether learners' working memory capacity is an influential factor in the acquisition and processing of number agreement.

Regarding the first research question, the learner group in the study did not show a P600 effect to agreement violations regardless of distance. The native group, on the other hand, showed a consistent P600 effect to ungrammaticality. This result indicates a lack of sensitivity to agreement violations by Korean participants when they are reading for comprehension. This is in line with previous ERP studies where P600 was not elicited in response to ill-formed constructions among L2 learners (Chen et al., 2007; Foucart & Frenk-Mestre, 2012; Hahne & Friederici, 2011; Meulman et al., 2014; Osterhaut et al., 2004). What these previous studies and the current study have in common is that the L2 target feature is absent in, or different from, the learners' L1. In Chen et al. (2007), ERP responses of Chinese learners of English to English subject-verb agreement violations (e.g. The price of the car(s) was/*were too high.) were examined. The Chinese participants, although highly proficient in English, showed a qualitatively different ERP responses – negativity in

500-700 ms was observed instead of typical P600. The authors interpret this result to be supporting the L1 effect, that L2 features that do not exist in L1 cannot be integrated in L2 learners' neural structure of L2 processing. Similarly, English learners of French in Foucart and Frenck-Mestre (2012) failed to show a P600 effect in response to gender disagreement in French between a noun and a pre-posed adjective (e.g. anciennes/*anciens montres *old-FEM/*MASC watches-FEM*). The nonnative participants' L1, which does not compute gender agreement between noun and adjective, might have interfered with their processing of the feature in L2.

Sabourin and Stowe (2008) more directly investigated L1 effects in processing L2 morphological features by comparing ERP responses of German speakers and Romance speakers to Dutch gender disagreement. German L2 learners, whose L1 has a similar gender system to Dutch, showed a P600 effect but Romance L2 learners, whose L1 are different from Dutch in their gender systems, did not.

On the contrary, several studies demonstrated that acquiring L2 features is possible for L2 learners, even those that differ from learners' L1 (Coughlin and Tremblay, 2013; Keating, 2009, 2010). In Keating (2009, 2010), English speakers could detect gender agreement violations in Spanish when the distance between constituents was short. Coughlin and Tremblay (2013), which also recruited English speakers, showed the L2 learners' sensitivity to gender agreement violations in French, indicated by their delayed reading times for ungrammatical sentences. It should be pointed out that the methods used in these studies and the current study were largely different. Unlike the current study, the three studies listed above used

behavioral methods: eye-tracking in Keating (2009, 2010) and self-paced reading in Coughlin and Tremblay (2013). While it is possible that online processing of English number agreement for Korean speakers is more difficult than that of Spanish and French gender agreement for English speakers, an alternative is that neural correlates are discrete from what is measured by eye-tracking or self-paced reading tasks. In fact, the English speakers learning French in Foucart and Frenck-Mestre (2012) showed native-like behavior in processing gender agreement in an eye-tracking experiment despite their insensitivity in the ERP response. According to the authors, online processing in an ERP study may be more burdening because of the manner materials are presented; whereas words are presented for a limited amount of time under ERP experiment designs, participants are able to spend as much time as they want, go back to previously read words, and even pause in eye-tracking studies.

Before moving on to the next research question, it is worth commenting on some differences in the ERP responses shown by the native participants in this study from those in previous literature. First of all, in contrast to previous studies that report a biphasic LAN-P600 pattern of native speakers to ungrammatical conditions (Barber and Carreiras, 2005; Dowens et al., 2010; Kutas and Hillyard, 1983; Molinaro et al., 2008a, 2008b; Molinaro et al., 2011; Silva-Pereyra & Carreiras, 2007), the LAN effect was absent in the English native participants in the present study. As Tanner et al. (2012) insist that LAN is an inconsistent index of detecting ungrammaticality, some studies found only P600 effect for native participants to agreement violations (Bañón et al., 2012; Meulman et al., 2014). While when LAN

is elicited and when it is not is under debate, the consistent P600 demonstrated by the native group in the present study cancels out the possibility that they did not detect ungrammaticality of the materials while reading.

In addition, the P600 effect elicited in this study is relatively smaller with a shorter duration compared to other studies. For example, the P600 effect shown by the native participants in Meulman et al. (2014) started from 600 ms after the target onset and sustained until 1200 ms. This can be accounted for by different tasks given after presentation of test materials. Whereas participants in Meulman et al. (2014) and others (Bañón et al., 2012; Rispens and de Amesti, 2017; Tanner et al., 2012) were asked to judge grammaticality or acceptability of sentences they read, the current study used comprehension questions. Therefore, the participants' attention was driven more on the content of the materials rather than the structure, which might have resulted in smaller P600 amplitudes (Gunter et al., 1997; O'Rourke and Van Petten, 2011; Osterhout and Mobley, 1995).

As to the second research question, it was revealed that the distance between agreeing constituents does not affect the agreement processing for both the native and the learner groups. Unlike the Spanish native participants in O'Rourke and Van Petten (2011), who showed a reduced sensitivity to ungrammaticality as distance increased, the native participants in the present study exhibited a consistent P600 effect to agreement violations even in long distance conditions. This can be attributed to different sentence structures used in the two studies. Whereas the agreement manipulation was established between a noun and an adjective in across-phrase

structures, the current study manipulated agreement between a determiner and a noun in within-phrase structures. Given that the structural distance also impacts ERP response as revealed in Bañón et al. (2012) and Dowens et al. (2010), where sensitivity to ungrammaticality decreased in across-phrase structures compared to within-phrase structures, it can be argued that the four-word distance in within-phrase structures was not a sufficient cognitive load to prevent the detection of ungrammaticality for the native participants. The learner group, on the other hand, showed no interaction between grammaticality and distance because they could not detect agreement violations in the long distance conditions as well as in the short distance conditions.

Still, distance modulated amplitudes, short distance conditions eliciting more positive waveforms than long distance conditions, both in grammatical and ungrammatical sentences. This result is in line with what was found in Bañón et al. (2012), but is opposite to Rispens and de Amesti (2017). In Bañón et al. (2012) where Spanish native speakers read sentences with gender disagreement in Spanish, within-phrase structures yielded more positive waveforms compared to across-phrase structures. They interpret the positivity as indicating higher sensitivity to overall agreement processing. Another possibility they point out is different degree of predictability for the critical adjective between across-phrase structures and within-phrase structures. That is, their within-phrase structures were formed as *un edificio muy seguro* (a building very safe), where the adverb *muy* made it easy to predict an adjective would follow. In contrast, in across-phrase structures, formed as *el cuento*

es anonimo (the story is anonymous), there is less probability that an adjective will appear after the copular verb *es*. Nonetheless, it is unlikely that the matter of predictability affected the results in this study, considering the similar structure between short distance conditions and long distance conditions. In both cases, the critical noun was preceded by a noun or an adjective.

An alternative explanation is that the difference in amplitudes between the two conditions derives from relatively negative going wave elicited in long distance conditions, resulting from their higher working memory load. Several ERP studies have demonstrated that conditions that require more working memory elicit more negative waveform than lower working memory conditions (King and Kutas, 1995; Löw et al., 1999). King and Kutas (1995) compared English subject-subject (SS) relative clauses (9a) with subject-object (SO) relative clauses (9b). An SO sentence is predicted to need more working memory at the verb *attacked* because readers have to decide which of the noun phrases (*the reporter* and *the senator*) is the subject for the verb.

(9) a. The reporter who harshly attacked the senator admitted the error.

b. The reporter who the senator harshly attacked admitted the error.

Both behavioral and ERP methods revealed working memory effect; longer time was spent to read SO sentences than SS sentences as well as more negative waveform was elicited by SO sentences. Likewise, the distance effect on amplitudes found in

the current study may reflect different amount of working memory load between the short distance and the long distance conditions.

On the other hand, Rispens and de Amesti (2017) report more positive waveform for longer distance conditions. They examined effects of 1) distance between a subject and a verb (i.e. in an across-phrase structure) and 2) type of intervening constituents (adverb vs. prepositional phrase) in processing gender agreement in Spanish. While the type of intervening constituents had no influence in the native participants' ERP response, the distance affected P600, longer distance conditions causing more positive deflection in the time window of 500-1000ms. Given that distance was manipulated in within-phrase structures in Rispens and de Amesti (2017) [6] compared to the current study, where across-phrase structures were used as test materials, one can say that distance influences P600 in a different manner for the two types of structures. Future studies focusing on these variables might be able to provide more reliable evidence for this claim.

It can be concluded that overall, distance did not modulate the size of P600 as a function of grammaticality. The ERP results of the two groups for the variant distance conditions further highlight their differences in agreement processing: for the native group, the long distance conditions were not complex enough to cause

[6] The example sentences used in Rispens and De Amesti (2017) are as below:

a. El mueble guarda los platos. [no intervening words]
   The cabinet contains the dishes.
b. La secretaria intencionalmente saluda a la gente. [one-word distance]
   The secretary intentionally greets [to the] people.
c. Las amigas de la niña tipicamente comen en su casa. [four-word distance]
   The friends of the girl typically eat at her house.

Unlike in the current study, target structure was number agreement between the subject and the verb.

failure in detecting grammaticality; for the learner group, even the short distance conditions were taxing to process grammatical features while focusing on the content of the materials. This provides an evidence that native speakers' knowledge of grammatical features is intact as to be resilient to complexity of materials. L2 learners, on the other hand, cannot integrate grammatical knowledge and successfully use it in online processing, even for simple sentences.

In respect to the third research question, working memory capacity was found to play a moderate role in processing agreement for the learner group. While the Korean participants failed to show native-like sensitivity to agreement violations both in the short distance and long distance conditions in the time window of 500-600 ms, a late P600 effect starting from 700 ms after the onset of the critical word was observed among those with high working memory span. In other words, although highly proficient Korean learners generally do not process number agreement as early as English native speakers do, those with high working memory span are capable of agreement processing at a later time.

The relatively slow speed of on-line processing by L2 learners has been observed in a considerable number of studies.[7] L2 learners are generally slower in

[7] Several accounts are possible for L2 learners' slow processing. According to Ullman (2005)'s declarative/procedural model, the different processing speed of L2 leaners and native speakers is induced from their use of different memory system. Compared to native speakers whose language knowledge is stored in procedural memory and hence, automatic, L2 learners rely more on declarative memory whose retrieval needs additional time. Hopp (2014) attributes L2 learners' slow speed of language processing to their less automatized lexical access, owing to the low frequency of L2 lexical access routines.

reading in natural settings and self-paced reading tasks (Keating, 2009, 2010; Papadopoulou, 2005; Siyanova-Chanturia et al., 2011) and in recognizing words in lexical decision tasks (Silva and Clahsen, 2008). Similarly, appearance of ERP components tends to be delayed for L2 learners compared to native speakers (Wever-Fox and Neville, 1996; Sabourin and Stowe, 2008). In Weber-Fox and Neville (1996), latencies of N400 in response to semantic anomaly were 407 ms for English native speakers and 431 ms for late Chinese learners of English. Also in Sabourin and Stowe (2008), the P600 shown by L2 learners reached its peak at a later time window (721-900 ms) than native speakers (511-720 ms) when they read sentences with gender disagreement in Dutch. Given that P600 is related to syntactic reanalysis, the late P600 effect by the nonnative participants in the current study can be understood as their delayed effort to repair the syntactic error, resulting from slow L2 processing.

As hypothesized in the Hi-LAB model, working memory capacity is an important factor in learning a second language even for L2 learners at an advanced level. The central executive, in particular, facilitates language learning in a broad sense, in that it enables better performance in updating, inhibition, task-switching and attentional capacity (Linck et al., 2013). This was verified in the current study, which used OSPAN task to measure participants' working memory capacity. Unlike simple memory span tasks, OSPAN task tests how much information an individual can hold in his memory while performing a secondary task, i.e., a primary function of the central executive system. Moreover, the current study implicates that the target

materials given to proficient L2 learners should be of appropriate difficulty in order to observe working memory effects. Number agreement, the target feature used in this study, is one of the most lately acquired grammatical structure in SLA. It was expected to be even more challenging for Korean participants, whose L1 does not mandate number agreement. Indeed, most of Korean participants in the study failed at agreement processing. Likewise, previous studies where working memory effects were not found for highly proficient L2 learners (Chun and Payne, 2004; Gilabert and Muñoz, 2010) might yield different results when the difficulty of task demands is adjusted.

In general, the results of the current study most closely support the view of the Failed Functional Features Hypothesis (FFFH), which claims that L2 functional features that are absent in L2 learners' L1 are difficult to acquire. The Korean learners of English that participated in the present study, who were exposed to and learned English for more than ten years and achieved a high proficiency, were unable to compute number agreement in online processing when they were asked to read for comprehension. According to FFFH, this is because this feature that does not exist in their L1. Meanwhile, a closer look at the profiles of the Korean participants suggests even a stronger influence of L1 in learning second language that overrides age effects. Recall that the Korean participants in this study were not necessarily late learners; the average age of their first exposure to English was 6.68 (yrs) with a range of 3-12 (yrs). That is, most of the participants started to learn English as a child. Although the amount of exposure to English after the first onset may vary from

participant to participant, it seems that early exposure to L2 is not a sufficient condition for accessibility of functional features that differ from L1.

Still, the results of the L2 learners with high working memory span suggest that certain language aptitude can in part compensate for L1 disadvantage. Only the nonnative participants whose working memory span was at the upper third showed some sensitivity to agreement violations, although the effect appeared at a delayed time (700-800 ms) and was constrained to short distance conditions.

6. Conclusion

The current study addressed English number agreement processing in a determiner phrase by advanced Korean learners and effects of distance and working memory capacity. The ERP responses of English native participants and Korean participants indicates lack of sensitivity by Korean participants to agreement violations. This supports the Failed Functional Features Hypothesis, which argues for unacquirability of L2 features nonexistent in L2 learners' mother language. The effect of distance did not interact with grammaticality for both the native group and the learner group. Although more positive waveforms were elicited in short distance structures, the size of P600 was not affected by distance. The native group was not hindered by long distance in processing number agreement, evinced by their consistent P600 response to ungrammatical sentences. The learner group did not show a P600 effect in either short distance conditions or long distance conditions. Lastly, working memory capacity was found to help integration of L2 grammatical features, even for L2 learners with high proficiency.

As far as I am concerned, this is the first study to examine distance effects in agreement processing between English determiner and noun by L2 learners. The study has its value in that it provides a neurological evidence in the long-discussed topic of morphosyntactic processing by L2 learners. The result implicates the role of learners' L1 in their L2 processing, especially when measured by ERP; the Korean participants in the study were revealed to be ignorant of agreement violations when

reading for comprehension, despite their high English proficiency. Still, the waveform difference between short distance and long distance conditions suggest the possibility that distance affects their language processing in some way, although a further interpretation is not possible at the current stage. Moreover, a late sensitivity to agreement violations shown by the high working memory span group implies that L2 learners can benefit from high working memory capacity in L2 processing. Nonetheless, the small sample size in the current study makes it difficult to argue for a robust relationship between working memory capacity and agreement processing, so a study with larger population is in need. Another limitation of the current study lies in the materials used. Long distance sentences differed from short distance sentences not only in their linear but also structural distance. Hence, it is unclear whether the distance effect yielded in the study was due to the linear distance or structural distance, or both.

For future studies, the following suggestions can be made. Considering the different results yielded from an eye-tracking study and an ERP study (Foucart and Frenk-Mestre, 2012), it is worth comparing the ERP results with those of other behavioral methods in L2 learners' agreement processing. In addition, while the current study asked comprehension questions to participants, a different task, such as a grammaticality judgment task or an acceptability task can be used to explore whether there is any task effect in ERP responses. Finally, more research focusing on the role of working memory capacity for high proficiency learners is desirable.

Investigation of working memory effects for different language features will provide a more detailed picture of the nature of L2 processing.

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Appendices

Appendix A: Language Background Questionnaire

1. 영어를 처음 접한 시기는 몇 세입니까?

2. 영어를 주로 어떤 방식으로 학습했습니까?
a. 학원
b. 학교수업
c. 과외
d. 해외거주
e. 독학

3. 해외 거주 경험이 있습니까? (국적/나이/기간)

4. 영어 이외에 구사할 수 있는 외국어가 있습니까?

5. 평소 하루에 영어를 얼마나 접합니까/사용합니까?

읽기: (분)
듣기: (분)
쓰기: (분)
말하기: (분)

6. 자신이 생각하는 영어실력을 평가해주십시오.

읽기: 1 2 3 4 5
듣기: 1 2 3 4 5
쓰기: 1 2 3 4 5
말하기: 1 2 3 4 5

Appendix B: Test Materials

- gs: grammatical, short distance condition
- us: ungrammatical, short distance condition
- gl: grammatical, long distance condition
- ul: ungrammatical, long distance condition

Item	Condition	Sentence
1	gs	This smart student took the exam that turned out to be too easy.
	us	This smart students took the exam that turned out to be too easy.
	gl	This smart and honest university student took the exam that turned out to be too easy.
	ul	This smart and honest university students took the exam that turned out to be too easy.
2	gs	This famous author wrote the novel that discussed the harsh life during the Civil War.
	us	This famous authors wrote the novel that discussed the harsh life during the Civil War.
	gl	This famous and friendly fiction author wrote the novel that discussed the harsh life during the Civil War.
	ul	This famous and friendly fiction authors wrote the novel that discussed the harsh life during the Civil War.
3	gs	This young artist painted the portrait that gained instant popularity among the collectors.
	us	This young artists created the portrait that gained instant popularity among the collectors.
	gl	This young and attractive female artist painted the portrait that gained instant popularity among the collectors.
	ul	This young and attractive female artists created the portrait that gained instant popularity among the collectors.
4	gs	This novice reporter wrote the article that discussed some controversial issues.
	us	This novice reporters wrote the article that discussed some controversial issues.
	gl	This novice and humble news reporter wrote the article that discussed some controversial issues.
	ul	This novice and humble news reporters wrote the article that discussed some controversial issues.

5	gs	This cruel killer murdered the cowboy that wore a red vest.
	us	This cruel killers murdered the cowboy that wore a red vest.
	gl	This cruel and merciless serial killer murdered the cowboy that wore a red vest.
	ul	This cruel and merciless serial killers murdered the cowboy that wore a red vest.
6	gs	This ambitious teacher taught the student that entered the top university.
	us	This ambitious teachers taught the student that entered the top university.
	gl	This determined and ambitious math teacher taught the student that entered the top university.
	ul	This determined and ambitious math teachers taught the student that entered the top university.
7	gs	This stressed driver bought the car that looked expensive but old-fashioned.
	us	This stressed drivers bought the car that looked expensive but old-fashioned.
	gl	This busy and stressed taxi driver bought the car that looked expensive but old-fashioned.
	ul	This busy and stressed taxi drivers bought the car that looked expensive but old-fashioned.
8	gs	This stubborn farmer bought the land that looked rather dry after drought.
	us	This stubborn farmers bought the land that looked rather dry after drought.
	gl	This stubborn and poor coconut farmer bought the land that looked rather dry after drought.
	ul	This stubborn and poor coconut farmers bought the land that looked rather dry after drought.
9	gs	This celebrated athlete received the trophy that weighed more than five kilograms.
	us	This celebrated athletes received the trophy that weighed more than five kilograms.
	gl	This celebrated and triumphant Olympics athlete received the trophy that weighed more than five kilograms.
	ul	This celebrated and triumphant Olympics athletes received the trophy that weighed more than five kilograms.
10	gs	This talented florist arranged the flowers that survived longer than I expected.

	us	This talented florists arranged the flowers that survived longer than I expected.
	gl	This talented and gifted local florist arranged the flowers that survived longer than I expected.
	ul	This talented and gifted local florists arranged the flowers that survived longer than I expected.
11	gs	This beautiful actress loathed the film that cost more money than expected.
	us	This beautiful actresses loathed the film that cost more money than expected.
	gl	This beautiful and gorgeous movie actress loathed the film that cost more money than expected.
	ul	This beautiful and gorgeous movie actresses loathed the film that cost more money than expected.
12	gs	This heroic officer grabbed the spy that wounded a woman during the struggle.
	us	This heroic officers grabbed the spy that wounded a woman during the struggle.
	gl	This bald and heroic police officer grabbed the spy that wounded a woman during the struggle.
	ul	This bald and heroic police officers grabbed the spy that wounded a woman during the struggle.
13	gs	This old pilot flew the helicopter that transferred the soldiers.
	us	This old pilots flew the helicopter that transferred the soldiers.
	gl	This old and wrinkled professional pilot flew the helicopter that transferred the soldiers.
	ul	This old and wrinkled professional pilots flew the helicopter that transferred the soldiers.
14	gs	This arrogant visitor despised the comedian that charmed all other dinner guests.
	us	This arrogant visitors despised the comedian that charmed all other dinner guests.
	gl	This arrogant and rude drunken visitor despised the comedian that charmed all other dinner guests.
	ul	This arrogant and rude drunken visitors despised the comedian that charmed all other dinner guests.
15	gs	This cautious lifeguard noticed the swimmer that disappeared into the vast ocean.
	us	This cautious lifeguards noticed the swimmer that disappeared into the vast ocean.

	gl	This cautious and careful junior lifeguard noticed the swimmer that disappeared into the vast ocean.
	ul	This cautious and careful junior lifeguards noticed the swimmer that disappeared into the vast ocean.
16	gs	This cancer patient survived the operation that took many hours for surgeons.
	us	This cancer patients survived the operation that took many hours for surgeons.
	gl	This bright and optimistic cancer patient survived the operation that took many hours for surgeons.
	ul	This bright and optimistic cancer patients survived the operation that took many hours for surgeons.
17	gs	This lucky cyclist avoided the accident that caused a number of serious injuries.
	us	This lucky cyclists avoided the accident that caused a number of serious injuries.
	gl	This lucky and avid racing cyclist avoided the accident that caused a number of serious injuries.
	ul	This lucky and avid racing cyclists avoided the accident that caused a number of serious injuries.
18	gs	This wounded captain watched the ship that turned unexpectedly toward the rocks.
	us	This wounded captains watched the ship that turned unexpectedly toward the rocks.
	gl	This wounded and sick naval captain watched the ship that turned unexpectedly toward the rocks.
	ul	This wounded and sick naval captains watched the ship that turned unexpectedly toward the rocks.
19	gs	This bright detective located the killer that appeared on the television program.
	us	This bright detectives located the killer that appeared on the television program.
	gl	This bright and intelligent private detective located the killer that appeared on the television program.
	ul	This bright and intelligent private detectives located the killer that appeared on the television program.
20	gs	This creative architect trusted the assistant that built the new house.
	us	This creative architects trusted the assistant that built the new house.
	gl	This creative and radical modernist architect trusted the assistant that built the new house.

	ul	This creative and radical modernist architects trusted the assistant that built the new house.
21	gs	This curious boy saw the wagon that dragged the statue to the yard.
	us	This curious boys saw the wagon that dragged the statue to the yard.
	gl	This curious and cheerful wild boy saw the wagon that dragged the statue to the yard.
	ul	This curious and cheerful wild boys saw the wagon that dragged the statue to the yard.
22	gs	This investment banker organized the fund that supports local schools.
	us	This investment banker organized the fund that supports local schools.
	gl	This wealthy and wise investment banker organized the fund that supports local schools.
	ul	This wealthy and wise investment banker organized the fund that supports local schools.
23	gs	This successful writer wrote the journal that described Eyptian women's rights.
	us	This successful writers wrote the journal that described Eyptian women's rights.
	gl	This prolific and successful freelance writer wrote the journal that described Eyptian women's rights.
	ul	This prolific and successful freelance writers wrote the journal that described Eyptian women's rights.
24	gs	This football cheerleader fell in love with the quarterback.
	us	This football cheerleaders fell in love with the quarterback.
	gl	This slim and blonde football cheerleader fell in love with the quarterback.
	ul	This slim and blonde football cheerleaders fell in love with the quarterback.
25	gs	This teenage babysitter put the kids that refused to sleep to bed.
	us	This teenage babysitters put the kids that refused to sleep to bed.
	gl	This kind and gentle teenage babysitter put the kids that refused to sleep to bed.
	ul	This kind and gentle teenage babysitters put the kids that refused to sleep to bed.

26	gs	This super hero defeated the villain that killed thousands of lives.
	us	This super heroes defeated the villain that killed thousands of lives.
	gl	This strong and brave super hero defeated the villain that killed thousands of lives.
	ul	This strong and brave super heroes defeated the villain that killed thousands of lives.
27	gs	This abstract painter had the show that was a huge success in the United States.
	us	This abstract painters had the show that was a huge success in the United States.
	gl	This silent and anonymous abstract painter had the show that was a huge success in the United States.
	ul	This silent and anonymous abstract painters had the show that was a huge success in the United States.
28	gs	This surgical nurse cleaned the wound that required extra attention.
	us	This surgical nurses cleaned the wound that required extra attention.
	gl	This energetic and friendly surgical nurse cleaned the wound that required extra attention.
	ul	This energetic and friendly surgical nurses cleaned the wound that required extra attention.
29	gs	These newborn infants loved the teddy bear that lost a botton.
	us	These newborn infant loved the teddy bear that lost a botton.
	gl	These tiny and fragile newborn infants loved the teddy bear that lost a botton.
	ul	These tiny and fragile newborn infant loved the teddy bear that lost a botton.
30	gs	These competitive applicants met the committee that explained their decision.
	us	These competitive applicant met the committee that explained their decision.
	gl	These competitive and ideal job applicants met the committee that explained their decision.
	ul	These competitive and ideal job applicant met the committee that explained their decision.
31	gs	These veteran musicians preferred the instrument that arrived right before the concert began.

	us	These veteran musician preferred the instrument that arrived right before the concert began.
	gl	These original and veteran classical musicians preferred the instrument that arrived right before the concert began.
	ul	These original and veteran classical musician preferred the instrument that arrived right before the concert began.
32	gs	These skilled troops attacked the castle that held important information.
	us	These skilled troop attacked the castle that held important information.
	gl	These skilled and dedicated military troops attacked the castle that held important information.
	ul	These skilled and dedicated military troop attacked the castle that held important information.
33	gs	These childish kids disliked the girl that became more attractive each year.
	us	These childish kid disliked the girl that became more attractive each year.
	gl	These childish and mean little kids disliked the girl that became more attractive each year.
	ul	These childish and mean little kid disliked the girl that became more attractive each year.
34	gs	These fearless hikers followed the deer that moved quickly down the mountain.
	us	These fearless hiker followed the deer that moved quickly down the mountain.
	gl	These fearless and tough amateur hikers followed the deer that moved quickly down the mountain.
	ul	These fearless and tough amateur hiker followed the deer that moved quickly down the mountain.
35	gs	These wicked politicians accepted the envelopes that were full of cash.
	us	These wicked politician accepted the envelopes that were full of cash.
	gl	These wicked and deceitful leading politicians accepted the envelopes that were full of cash.
	ul	These wicked and deceitful leading politician accepted the envelopes that were full of cash.
36	gs	These injured refugees attacked the camp that was located in the forest.
	us	These injured refugee attacked the camp that was located in the forest.

	gl	These hapless and injured war refugees attacked the camp that was located in the forest.
	ul	These hapless and injured war refugee attacked the camp that was located in the forest.
37	gs	These generous neighbors loved the kids that came to the Christmas party.
	us	These generous neighbor loved the kids that came to the Christmas party.
	gl	These generous and gentle upstairs neighbors loved the kids that came to the Christmas party.
	ul	These generous and gentle upstairs neighbor loved the kids that came to the Christmas party.
38	gs	These married ladies admired the athlete that seemed very charming.
	us	These married lady admired the athlete that seemed very charming.
	gl	These bored and tired married ladies admired the athlete that seemed very charming.
	ul	These bored and tired married lady admired the athlete that seemed very charming.
39	gs	These great knights protected the kingdom that stood tall and proud.
	us	These great knight protected the kingdom that stood tall and proud.
	gl	These great and brave medieval knights protected the kingdom that stood tall and proud.
	ul	These great and brave medieval knight protected the kingdom that stood tall and proud.
40	gs	These rural peasants detested the tractor that ruined all the crops.
	us	These rural peasant detested the tractor that ruined all the crops.
	gl	These displaced and landless rural peasants detested the tractor that ruined all the crops.
	ul	These displaced and landless rural peasant detested the tractor that ruined all the crops.
41	gs	These prospective lawyers provided the evidence that turned out to be powerful.
	us	These prospective lawyer provided the evidence that turned out to be powerful.
	gl	These rich and prospective public lawyers provided the evidence that turned out to be powerful.

	ul	These rich and prospective public lawyer provided the evidence that turned out to be powerful.
42	gs	These caring doctors treated the patient that used to smoke a lot.
	us	These caring doctor treated the patient that used to smoke a lot.
	gl	These caring and respected medical doctors treated the patient that used to smoke a lot.
	ul	These caring and respected medical doctor treated the patient that used to smoke a lot.
43	gs	These amazing singers provided the music that became a symbol of resistance.
	us	These amazing singer provided the music that became a symbol of resistance.
	gl	These amazing and inspiring pop singers provided the music that became a symbol of resistance.
	ul	These amazing and inspiring pop singer provided the music that became a symbol of resistance.
44	gs	These qualified workers built the railroad that connected California with the east coast.
	us	These qualified worker built the railroad that connected California with the east coast.
	gl	These healthy and qualified construction workers built the railroad that connected California with the east coast.
	ul	These healthy and qualified construction worker built the railroad that connected California with the east coast.
45	gs	These armed soldiers attacked the town that consisted of more than thousand houses.
	us	These armed soldier attacked the town that consisted of more than thousand houses.
	gl	These armed and angry combat soldiers attacked the town that consisted of more than thousand houses.
	ul	These armed and angry combat soldier attacked the town that consisted of more than thousand houses.
46	gs	These sorrowful victims accused the suspect that arrived at the courthouse early.
	us	These sorrowful victim accused the suspect that arrived at the courthouse early.
	gl	These sorrowful and helpless robbery victims accused the suspect that arrived at the courthouse early.
	ul	These sorrowful and helpless robbery victim accused the suspect that arrived at the courthouse early.

47	gs	These excited tourists visited the restaurant that served a wide variety of cuisines.
	us	These excited tourist visited the restaurant that served a wide variety of cuisines.
	gl	These excited and enthusiastic group tourists visited the restaurant that served a wide variety of cuisines.
	ul	These excited and enthusiastic group tourist visited the restaurant that served a wide variety of cuisines.
48	gs	These trained experts reviewed the trial that focused on multiple rapes.
	us	These trained expert reviewed the trial that focused on multiple rapes.
	gl	These trained and experienced law experts reviewed the trial that focused on multiple rapes.
	ul	These trained and experienced law expert reviewed the trial that focused on multiple rapes.
49	gs	These unlucky editors received the letter that contained threat of a terrorist attack.
	us	These unlucky editor received the letter that contained threat of a terrorist attack.
	gl	These unlucky and unfortunate radio editors received the letter that contained threat of a terrorist attack.
	ul	These unlucky and unfortunate radio editor received the letter that contained threat of a terrorist attack.
50	gs	These credible scientists presented the study that proved the ill-effects of the compounds.
	us	These credible scientist presented the study that proved the ill-effects of the compounds.
	gl	These credible and diligent chemical scientists presented the study that proved the ill-effects of the compounds.
	ul	These credible and diligent chemical scientist presented the study that proved the ill-effects of the compounds.
51	gs	These political spies had access to tools that could cause incredible damages.
	us	These political spy had access to tools that could cause incredible damages.
	gl	These shady and dangerous political spies had access to tools that could cause incredible damages.
	ul	These shady and dangerous political spy had access to tools that could cause incredible damages.
52	gs	These party hosts offended the guest that ruined the show.

	us	These party host offended the guest that ruined the show.
	gl	These serious and stern party hosts offended the guest that ruined the show.
	ul	These serious and stern party host offended the guest that ruined the show.
53	gs	These leading diplomats insulted the congressman that ended the nogotiations.
	us	These leading diplomat insulted the congressman that ended the nogotiations.
	gl	These untrustworthy and apathetic leading diplomats insulted the congressman that ended the nogotiations.
	ul	These untrustworthy and apathetic leading diplomat insulted the congressman that ended the nogotiations.
54	gs	These movie actors respected the director that brought the film to life.
	us	These movie actor respected the director that brought the film to life.
	gl	These stunning and confident movie actors respected the director that brought the film to life.
	ul	These stunning and confident movie actor respected the director that brought the film to life.
55	gs	These book critics praised the writer that wrote a bestseller of the time.
	us	These book critic praised the writer that wrote a bestseller of the time.
	gl	These sharp and harsh book critics praised the writer that wrote a bestseller of the time.
	ul	These sharp and harsh book critic praised the writer that wrote a bestseller of the time.
56	gs	These country bands recommended the guitarist that recorded the song in the album.
	us	These country band recommended the guitarist that recorded the song in the album.
	gl	These loud and intense country bands recommended the guitarist that recorded the song in the album.
	ul	These loud and intense country band recommended the guitarist that recorded the song in the album.

국문 초록

영어 명사구 수 일치의 형태 처리-한국인 영어 학습자 대상 ERP 연구

본 연구는 한국인 영어 학습자들을 대상으로 영어 명사구 내의 수 일치 처리를 알아보고자 하였다. 더불어 수 일치를 이루는 지시형용사와 명사 사이의 거리가 학습자들의 제 2 언어 처리에 주는 영향을 확인하고 작업기억능력 간의 관련성을 살펴보았다. 수/성 일치 문제는 제 2 언어 습득에 있어 비교적 늦은 단계에서 이루어지며, 고급 수준의 제 2 언어 학습자들도 실시간 언어 처리에 있어서는 수/성 일치를 제대로 처리하지 못한다고 알려져 있다. 영어의 수 일치도 마찬가지이며, 특히 제 2 언어 학습자들의 모국어에 이러한 수 일치 체계가 없는 경우 그 어려움이 두드러진다 (Chen et al., 2007; Jiang, 2004; Tanner et al., 2012). 그러나 영어 수 일치를 다룬 대부분의 연구는 주어–동사 간의 구조를 다루어 왔으며, 제 2 언어 학습자들이 명사구 내의 한정사와 명사 간의 수 일치를 어떻게 처리하는지에 대해서는 연구된 바가 없다. 또한 한정사와 명사 사이의 거리가 멀어짐에 따라 제 2 언어 학습자들의 작업기억능력이 수 일치

처리에 어떤 역할을 하는지 알아보고자 한다. 제 2 언어 습득에 있어 작업기억능력은 중요한 언어 능력이라고 주장되어 왔으나, 고급 학습자들에게도 높은 작업기억능력이 도움을 주는지에 대해서는 아직 논란의 여지가 있다. 따라서, 본 연구는 작업기억능력이 상이한 (상급, 중급, 하급) 고급 영어 학습자들을 대상으로 사건관련뇌파전위(ERP)를 이용한 영어 명사구 내 수 일치 처리를 살펴보았다.

실험에는 열두 명의 영어 원어민 화자들과 열여덟 명의 한국인 영어 학습자들이 참가하였다. 이들이 수 일치가 된 문장과 되지 않은 문장들을 읽는 동안의 뇌파를 측정하였다. 문장들은 또한 한정사와 명사 사이의 거리에 따라 짧은 거리 조건과 긴 거리 조건으로 나뉘었다. 실험 결과, 두 그룹 모두에서 LAN (300-450ms)은 발견되지 않았으며, 원어민 집단의 경우 500-600ms 구간에서 P600 이 검출되었다. 학습자 그룹에서는 같은 구간에서 짧은 거리 조건과 긴 거리 조건에서 모두 P600 이 발견되지 않았다. 두 그룹 모두에서 짧은 거리 조건의 경우 긴 거리 조건에서보다 양성의 뇌파가 나타났으나, P600 의 크기에는 영향을 주지 않았다. 마지막으로 작업기억능력이 높은 학습자 집단의 경우 700-800ms 구간에서 짧은 거리 조건에 대한 P600 이 관찰되었다.

본 연구의 결과는 모국어에 존재하지 않는 문법 자질에 대해서는 고급 수준의 학습자들도 원어민 수준으로 처리하지 못한다는 것을 보여준다.

거리에 따른 원어민 집단과 학습자 집단의 반응은 두 집단의 차이를 더 극명하게 보여주는데, 원어민 집단의 경우 거리가 긴 조건에서도 수 일치를 제대로 처리할 수 있었던 반면, 학습자 집단의 경우 거리가 짧은 조건에서도 수 일치를 처리하지 못하였다. 하지만 작업기억능력이 우수한 학습자들은 제한적인 수준의 영어 수 일치 처리가 가능하였다.

본 연구는 제 2 언어 습득과 관련하여 다음과 같은 함의를 갖는다. 첫째, 영어 명사구 내 수 일치 처리에 있어 모국어의 영향이 중요하다. 둘째, 고급 수준의 제 2 언어 학습자들에게도 우수한 작업기억능력이 성공적인 제 2 언어 습득의 유의미한 요소가 될 수 있다.

주요어: 사건관련뇌파전위 (ERP), 제 2 언어 습득, 수 일치, 성분 간 거리, 작업 기억 능력

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