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Electrophysiological evidence for a subject-first strategy in visually situated auditory sentence processing in Korean

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ABSTRACT

This study investigated a subject-first strategy in prediction mechanism in visually situated sentence processing in Korean, using event-related potentials (ERPs). According to the subject-first strategy, parsers tend to generate sentences conforming to canonical sentence word order (i.e., SOV in Korean), subject-first sentence, mapping conceptually more prominent referent such as agent of the event on the subject position of the sentence. Therefore, in the predictive mechanism of language comprehension, the subject is pre-activated and anticipated for the first NP of the sentence at the initial phase of bottom-up language processing. This study tested this subject-first strategy in Korean by examining brain responses to object-initial sentences (OV) compared with subject-initial sentences (SV) under the context of clear thematic role relations set by a visual image. The results of an ERP experiment with 30 native Korean speakers identified neural effects for object-initial sentences compared with subject-initial sentences at the NP and Verb, reflecting a conflict between the pre-activated representation in the parser's mind and the encountered bottom-up input. An N400 effect was elicited at the NP, as early as at the noun, not at the following object case marker. Late frontal positivity (LFP) was also found in the sentence-final verb, proving the processing difficulty of non-canonical object-initial sentences compared with canonical subject-initial sentences. These results indicate that Korean native speakers build linguistic representation conforming to a canonical sentence in SOV language in the predictive mechanism supporting subject-first strategy but revise the predicted event structure rapidly upon newly encountering input.

1. Introduction

Sentence comprehension focuses on understanding the thematic role relations of the arguments involved in the event of the verb, that is, mainly*, who does what to whom.* Our mental representation of the thematic role relations is mapped onto linguistic representations in accordance with the specific word order of the language. In a Subject-Verb-Object (SVO) language such as English, the agent is usually mapped onto the subject position, whereas the theme or patient role is on the object potion, as per the canonical sentence structure. For example, given a visual context of a boy pushing a girl in a picture, our linguistic representation of the event is most likely to be "a boy pushes a girl." This phenomenon has been accounted for by conceptual accessibility, whereby the conceptually more prominent referent, such as the agent of the event, is more accessible and retrieved from memory more easily, so it is likely to be mapped onto the subject position of the sentence, generating an SVO or SOV word order, yielding the subject-first strategy (see Yano et al., 2019 for more details). There is substantial evidence for the subject-first strategy (also called canonical sentence strategy) in sentence processing. Subject-initial sentences are easier or faster to comprehend or learn than object-initial sentences; in other words, non-canonical object-initial sentences are more difficult to process (e.g., German: Fiebach et al., 2001; Rösler et al., 1998; Schlesewsky et al., 2000; and Korean: Kim, 2012; Kwon et al., 2006, among other languages).

In this study, we approach the subject-first strategy from a perspective of a *prediction* mechanism in language processing. Prediction is actively involved in language comprehension in daily life. Listeners or readers predict upcoming words using available contextual information, which makes comprehension rapid and instant. For example, as soon as we hear the verb "eat," we initiate a search for a noun phrase (NP) denoting something edible such as "an apple" or "a cake" due to its lexical (meaning) and syntactic (categorical) information. In other words, we restrict the range of possible words to retrieve or search from

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our mental lexicon. In this sense, prediction can be defined as the "pre-activation of stored or given representations before the bottom-up input is encountered" (Chow et al., 2018). Readers or listeners actively engage in top-down prediction in online sentence comprehension; they do not simply passively wait for bottom-up input. More importantly, pre-activated representation applies not only at the level of specific lexical items but also to various relevant features of mental representations such as phonological, semantic, and syntactic features. For example, Federmeier and Kutas (1999) found that our neural responses are enhanced when an unexpected closing word negatively correlates with the close probability of the word. They attributed the difference in neural response enhancement to the characteristics of the semantic features of the pre-activated representation (e.g., NP [+edible]) in a prediction mechanism that conflicted with those of the word in the encountered input (e.g., *a book* [−edible]).

Such a predictive mechanism has been widely shown to operate in language processing through various psycholinguistic and neuro-linguistics literature using different experimental methods. When the encountered linguistic stimuli, such as phonemes, morphemes, words, phrases, sentences, and prosodies, do not match the pre-activated representation in our mind, the mismatch results in specific behavioral responses (i.e., less accuracy, longer response time) that reflect processing difficulties (Huettig, 2015; see Kuperberg & Jaeger, 2016 for a review). Typical neural responses are characterized by the elicitation of particular electrophysiological responses or greater activation of particular regions in the brain. Various event-related potential (ERP) studies have found typical components such as N400, a negative-going wave at 250–400 ms after the stimuli onset (Kutas & Hillyard, 1980), to reflect the predictability of the word for the position (see Nieuwland, 2019, for a review of the neurolinguistics literature).[1] Eye-tracking studies have also provided evidence for a predictive mechanism, revealing the effect even *before* the input is received, which is different from other methods that only reveal the effects after input onset. For example, when a listener was presented with a Japanese sentence in the order "waitress-NOM customer-DAT hamburger-ACC served," their eyes were fixated on the hamburger (i.e., something edible) among the other things shown in the picture, even before they received the input "hamburger" (Kamide et al., 2003). This early fixation of the eye on the relevant argument before its bottom-up input, "*hamburger*," suggests that the language processor had already pre-activated the representation of something edible in their mind.

Moreover, a prediction can be made based on non-linguistic contexts, such as perceptual information, social relations, and world knowledge. For example, predictions develop in our minds when we perceive a visual scene, pre-activating the mental representation of the scene in our mind (Chatterjee et al., 1995; Chatterjee et al., 1999). By examining how a parser processes the upcoming linguistic stimuli word by word based on given visual information, we can infer how a mental representation is constructed and linguistically processed.

In a visual scene, thematic role relations can be adequately depicted. Thus, prior visual information enables the language processor to make predictions, pre-activating related nouns and verbs, including specific phonological, semantic, syntactic features, and even sentence structures, which can be congruent or incongruent (or match or mismatch) with the upcoming bottom-up input.

Studies of visually situated language processing have provided substantial evidence for the predictive mechanism (e.g., Knoeferle et al., 2011, 2014; Wassenaar & Hagoort, 2007). The effect of pre-activated representation at the beginning of the sentence can be identified as early as at the first NP. Such an early pre-activation effect was evidenced in Knoeferle et al.'s (2011, 2014) series of ERP studies; an N400 effect was found for the thematic role mismatch at the sentence-initial first NP, even before the critical word, the verb.[2] More specifically, for example, when the native English participants read a sentence "*a gymnast punches a journalist*" after they look at a picture of a journalist punching a gymnast in a role reversal condition, the N400 effect is elicited at the first NP "*a gymnast*." The authors have argued that "The role congruence effects prior to the verb (at the first noun), however, suggest more immediate incremental picture-sentence processing and active interpretation of the event depictions" (Knoeferle et al., 2014, p. 142). From a prediction mechanism perspective, "more immediate incremental processing" was possible due to the pre-activation of the stored representation triggered by the picture. The N400 effect elicited at "gymnast" indicates that the bottom-up input conflicts with the pre-activated linguistic representation for the first NP in the parsers' brain based on the visual context (i.e., *journalist*, +Nominative, +Agent). The particular visual scene causes pre-activation of related nouns (e.g., *a journalist*, *a gymnast*, *a woman*) and verbs (e.g., *punch*, *hit*), possibly with related semantic and syntactic features.

More specifically, considering the prediction account of N400 with semantic features by Federmeier and Kutas (1999), only those nouns with a nominative case and agent role are likely to be pre-activated for the first NP based on the canonical sentence strategy. In other words, the N400 effect found at the first NP in Knoeferle et al. (2014) results from the mismatch between the pre-activated representations of *journalist*, a subject with features [+nominative, +agent], and the encountered bottom-up input of *gymnast,* an object with features [+accusative, +patient], at the first NP. Thus, the language processor in Knoeferle et al. (2014) seems to have generated a linguistic representation using a subject-first strategy conforming to canonical sentence structure, SVO in

[1] There are two primary different views of the N400 component, the Access View and Semantic Integration View. The Access View focuses on the pre-activation of semantic features (e.g., Kuperberg & Jaeger, 2016; Kutas & Federmeier, 2000; Rabovsky & McRae, 2014) or the entire lexical item (e.g., DeLong et al., 2005) in memory through the context of a word before it is encountered. Conversely, the Semantic Integration View emphasizes the retrieval of the word from the memory after it is encountered and the integration of the word or semantic features into the currently processed context. The afore-mentioned behavioral and/or neural effects can thus be understood as reflecting the prediction effect or difficulty of integration in sentence processing. However, Nicenboim et al. (2020) argue that currently available research data provide supporting evidence for the Access Model of predictive processing rather than the Semantic Integration View. Such an early effect of the pre-activation of a noun has been frequently found at a prenominal element such as an article or adjectives as a phonological form mismatch or gender mismatch in sentence processing. For example, the seminal study by DeLong et al. (2005) compared prenominal articles before a highly predictable word and a less predictable word and found an N400-like effect at the prenominal article (e.g., The day was breezy so the boy went outside to fly a kite/an airplane). This result provides supporting evidence for the pre-activation of the phonological form (a vs. an) before the contextually more predictable word "kite" compared with the less predictable word "airplane" (however, see Ito et al., 2017; Nieuwland et al., 2018 for unexpected results). This type of pre-activation of various features is evidenced further mainly with gender marking of articles or adjectives that precede nouns in Spanish (e.g., Foucart et al., 2014; Giannelli & Molinaro, 2018; Martin et al., 2018; Molinaro et al., 2017; Wicha et al., 2003; Wicha et al., 2004), Dutch (e.g., Otten & Van Berkum, 2009; Van Berkum et al., 2005), Polish (e.g., Szewczyk & Schriefers, 2013) and German (Nicenboim et al., 2020). When the pre-activated features do not match the gender of predicted word, an N400-like effect is elicited (see Kutas et al., 2011; Pickering & Gambi, 2018; Van Berkum, 2009). Animacy in Polish adjectives has also been a relevant feature for this line of research (Szewczyk & Schriefers, 2013). Nicenboim et al. (2020), who recently conducted a Bayesian random-effects meta-analysis with publicly available data as well as their own data, concluded that they found a relatively clear but very small effect conforming to the pre-activation account, supporting the Access View.

[2] See Nieuwland (2019) for a review of the neurolinguistics literature.

English, based on the visual scene.

The subject-first strategy has been demonstrated in various languages other than English, such as German (Bader & Meng, 1999; Rösler et al., 1998), Finnish (Kaiser & Trueswell, 2004), Korean (Kim, 2012; Sung et al., 2019), Japanese (Hagiwara et al., 2007; Koizumi & Imamura, 2017; Mazuka et al., 2002; Tamaoka et al., 2005; Ueno & Kluender, 2003), and Russian (Sekerina, 1997). In particular, substantial bodies of research have evidenced subject-first preferences in German, an SVO language with rich morphological markings, not only in behavioral data (e.g., Bornkessel et al., 2002; Grewe et al., 2007; Rösler et al., 1998; Schipke et al., 2012; Strotseva-Feinschmidt et al., 2019), but also in neurophysiological data (e.g., Bornkessel et al., 2002; Bornkessel & Schlesewsky, 2006; Schipke et al., 2012 for ERP data; Knoll et al., 2012; Skeide et al., 2014 for fMRI data). For example, Schipke et al.'s (2012) ERP experiment (using a passive listening task) resulted in a more negative-going effect at 100–400 ms for object-initial sentences than for subject-initial sentences in German, for example, ***Der Tiger*** *küsst den Frosch* (subject-initial, "the tiger kisses the frog") vs. ***Den Frosch*** *küsst der Tiger* (object-initial, "the frog kisses the tiger"). They called such an effect "topicalization negativity," analogous to "scrambling negativity," referring to the neural effect associated with scrambled object NPs (Bornkessel & Schlesewsky, 2006). Note that the first NP in the object-initial sentence is evident in the case-marked determiner (*Der* vs. *Den*) before the noun, eliciting topicalization negativity as early as at the determiner, even before the parser encounters the following noun.

Case is overtly marked either as a determiner in German (e.g., [Det (case marked) + N]) or as a case particle in Korean (e.g., [N + Case particle]). In German, the neural effect on the object-initial sentences was found at the prenominal determiner as in Schipke et al.'s (2012) study, as mentioned above. Moreover, no ERP response was found at the second noun (NP_2), indicating that as soon as the parser received the object noun at the beginning of the sentence, they seemed to immediately revise the prediction and anticipated the next word to complete the argument structure of the sentence (i.e., a missing subject NP with nominative case). However, it seems still to be controversial where the neural effect on the object-initial sentences will be shown in Korean, another case-marking language. Unlike German, case marking is shown in post-nominal position as a case suffix. The neural effects on the object-initial sentences could be shown at the noun or post-nominal case marker.

Lee et al.'s (2021) ERP study found an N400 effect "at the case marker" in a similar picture-sentence verification task for case-marking mismatch, that is, *brother-ka (NOM)* vs. **brother-lul (ACC),* and long-lasting negativity at the sentence-final verb for the thematic role reversal effect. Similarly, Sung et al. (2019) also showed that Korean adults preferred the SOV to the OSV interpretation when hearing ambiguous NP-NP-V sentence structures without case markers (e.g., The Black-Ø The Blue-Ø chases). In addition, interestingly, Lee, Jeong, Nam (2016) found no N400 effect at the first NP in the thematic role reversal condition in a picture-sentence verification task when they had subject-initial sentences for both conditions (i.e., *brother-ka* (NOM) ([+nominative, +agent]) *push*-DEC. vs. *sister-ka* (NOM) ([+nominative, +patient]) *push*-DEC.). The role reversal effect was found later at the sentence-final verb as P600. Notice that *sister-ka* (NOM) can be the subject of a passive sentence with a passive morpheme suffixed to the verb in Korean (i.e., *sister-ka* (NOM) cap-**hye [PASS]** -yo, "*sister is caught*"). In other words, one possible interpretation of the null effect at the first noun in Lee, Jeong, Nam's (2016) results is that the parser anticipates the subject (+nominative, +agent/+patient), regardless of the thematic role of the referent in the image. In other words, the parser seems to attend to the nominative case rather than the thematic role of the argument.

If the subject-first strategy is right in the "prediction mechanism," the agent of the referent (*brother*) will be mapped onto the subject of the sentence, activating a nominative-case-marked NP for the first NP (e.g., "*brother-ka*") in the memory in Korean. Therefore, the parser will anticipate "brother-ka" in the upcoming input. However, when the parser encounters "*sister-lul*" for the first NP in the input, a surprisal effect will be elicited due to the mismatch between the anticipated "*brother-ka*" and encountered input "*sister-lul.*"

Therefore, in this study, we examined whether the subject-first strategy would be borne out in Korean and what kind of neural pattern would be elicited in which word or segment position We compared brain responses to subject-initial (i.e., agent noun + nominative case marker) sentences and to object-initial (i.e., patient noun + accusative case marker) sentences in a picture-sentence verification task using an ERP experiment. The specific research question is as follows: *Will the brain responses to object-inital sentences differ from those to subject-inital sentences? If so, where will the difference be found, the noun or its suffixed case marker?*

2. Research methods

2.1. Participants

Participants were 30 native Korean speakers (14 females, 16 males, mean age 24, range 20–29 years) who were right-handed and had no mental or other illnesses. No participants reported any unusual discomfort during the experiment. They provided written, informed consent before the start and after the end of the experiment. Each participant received monetary compensation after completing the experiment.

2.2. Materials

Since Korean is a language in which the grammatical relations of the NP in a sentence are identified with a case marker, the word order is more or less free. Therefore, a sentence that expresses the same event structure can be organized in various ways. For example, a picture describing the situation of a man catching a woman can be described in different sentences such as "*Namca-**ka** Yeoca-**lul** cap-ayo*" (a man catches a woman) / "*Yeoca-**lul** Namca-**ka** cap-ayo*" (a man catches a woman; scrambling) / "*Yeoca-**ga** Namca-**ege** cap-hyeoyo*" (a woman is caught by a man; passive) / "*Namca-**ka** ___cap-ayo*" (a man catches ___; object drop) / "___ *Yeoca-**lul** cap-ayo*" (___ catches a woman; subject drop) / "*Yeoca-**ga** ___cap-hyeoyo*" (a woman is caught ___; object drop in the passive sentence) / "___ *Namca-**ege** cap-hyeoyo*" (___ is caught by a man; subject drop in the passive sentence).[3]

In this study, however, we intended to confirm whether Korean speakers dominantly predict the agent or nominative case marker, based on the context image, for the first NP of the sentence. Therefore, comparing two constructions was critical, that is, "***Namca-ka*** ___*cap-ayo*" (a man catches ___) vs. "___ ***Yeoca-lul*** *cap-ayo*" (___ catches a woman). We constructed two experimental conditions: (1) the agent+NOM-first condition, where only the subject (the agent NP with nominative case marker *-ka*) was introduced with the verb without an object, and (2) the patient+ACC-first condition, where only the object

[3] With appropriate visual context, it is possible to establish a sentence with correct grammatical relations to match the image. In addition, either argument can be dropped without causing any difficulty in comprehension. For example, for a picture of "A monkey pinches a rabbit," both "A monkey-*ga* __ pinches" and "___ a rabbit-*ul* pinches" would be appropriate sentences and would sound colloquial enough (see Lee et al., 2021 for more details). Nevertheless, it was suggested by an anonymous reviewer that a control condition with all the arguments present should be included. We admit that results of the current study can be verified with such a condition to be included in a future study.

(the patient NP with accusative marker –*lul*) was introduced with the verb without a subject.[4] Sentences with only one argument were used to make the experimental items sound more colloquial with the visual context. Examples of each condition are shown in Table 1.[5]

The words in the sentences were used in a previous study by Lee et al. (2016, 2021). All words were of high frequency and easy to understand. If we use the same agent and patient involving the same event structure, such as "*Namca-ka cap-ayo*" and "*Namca-lul cap-ayo*" with a picture where a man catches another man, it could generate another compounding effect, so we used different agents and patients involving the same event structure. However, in this case, the nouns used in the Agent+NOM-first and Patient+ACC-first conditions may be different, and the effect due to lexical differences between conditions can be compounded. To additionally control this, we made another experimental set (Set B). The subject noun in Set A is used as the object noun in Set B, and the object noun in Set A is used as the object noun in Set B. For counter-balancing, reversible transitive verbs were chosen that take both arguments as animate nouns to avoid semantic asymmetry.

The noun pairs and verbs used in the experimental sentences are presented in Table 2. A total of eight noun pairs were used, resulting in 32 sentences for each condition. In order that all sentences contained different verbs, 32 verbs were employed for the experimental sentences. In addition, 64 filler sentences (syntactically or semantically violated ones) were also constructed, and the 128 experimental sentences and filler sentences per set were distributed into four lists and presented in pseudo-randomized order so that the same condition was not presented consecutively. Subjects were exposed to one of the sets (A or B, in half-and-half proportions). At the end of the sentence, they were asked to judge whether the previous sentence and the picture matched.

2.3. Procedure

The pictures and sentences used in the experiments were presented through E-Prime (E-Prime 2.0 Professional, Psychology Software Tools, USA) software. Participants were comfortably seated at a distance of 70 cm (27.55″) from the center of the 19″ display monitor. Before starting the experiment, instructions were visually presented on the screen, and the electrodes were attached to the participants' heads during this time. After completing the consent form, participants sat in front of the monitor and were exposed to the picture presented on the screen for 4000 ms (Fig. 1). Then, a fixation cross was shown and the sentence was presented aurally, word by word, clearly through the earphone after a delay of 200 ms. After a 1000-ms interval, when the question mark appeared, participants were asked to judge whether the aurally presented sentence matched the preceding picture. They were required to press a button indicating their response as quickly as possible. J and F keyboards were used as an indicator of match and mismatch, and the two keyboards were set differently for each participant (true-J or true-F). All experimental sentences were presented pseudo-randomly so that any effect of the presentation order of target sentences was avoided as much as possible. Before starting the experiment, participants were allowed to adapt naturally to the experiment using five practice sentences. The experimental sets consisted of 256 items (64 target items and 64 fillers for each set, A and B) and divided into four sessions. The participants were pseudo-randomly assigned to one of the two sets. The experiment lasted nearly 60 min, and participants were allowed to rest between the blocks.

2.4. EEG recording

EEG was recorded using a BrainAmp direct current (DC) amplifier (Brain Products, Germany) with 32 Ag/Agcl electrodes in an actiCAP (Brain Products GmbH, Gilching, Germany). The electrodes were located following the International 10–20 system. For the recording, we used an electrode attached to the tip of the nose as the reference and FCz as the ground channel. We re-referenced using mastoid channels during the pre-processing of the EEG data. For the ocular correction, we applied an independent component analysis method (Makeig et al., 1997). The impedance of all electrodes was kept below 5 kΩ prior to data recording. The raw EEG data were recorded at 250 Hz with an analog band-pass filter (0.1–70 Hz), and an offline filter (0.1–30 Hz) was applied in the pre-processing to display the ERP components clearly.

2.5. Data analysis

For the behavioral analysis, we calculated the accuracy and the response time of the participants' judgments. The statistical analysis for accuracy data was conducted using a mixed-effects logistic regression model (Baayen, 2008), using languageR libraries for the R statistics program. For response data, linear mixed-effect regression analyses were conducted using the lme4 (Bates et al., 2015) and languageR libraries for the R statistics program (R Development Core Team, 2019). For the structure of random effects, fully crossed and specified random effects were reduced step by step until the model converged. Only the effects that contributed to the significant improvement of the model were included in the final model.

For the ERP analysis, we segmented each epoch with 900 ms from each stimulus onset time; the segments were aligned to a 100 ms pre-stimulus baseline. Artifacts surpassing an amplitude of ±100 μV, or higher than 70 μV within a moving 4-ms interval, were excluded from further processing. Trials for which the comprehension task was not performed correctly were excluded from the averaging procedure, as were trials containing ocular, amplifier-saturation, or other artifacts.[6]

As was suggested in a previous study (Bornkessel-Schlesewsky et al., 2011), it was difficult to specify pre-defined time windows to analyze the EEG data; thus, the time windows for the statistical analysis were selected based on a visual inspection of the data, and a 200–400 ms time-window at the noun and case-marker onset and 600–800 ms in the verb position were adopted. All of these time windows were chosen based on the grand-averaged waveforms and their individual variations.

For the statistical analysis of the ERP data, repeated-measures analyses of variance (ANOVAs) using Sentence type(nominative-first vs. patient+ACC-first) and Topographical factors were calculated for mean

[4] Korean is a subject and object pro-drop language. The null pronoun can be interpreted indefinitely, but there is a strong preference for a referential interpretation (Sohn, 2001, pp. 404–405; Choe, 2006). According to Kim (2000), the subject pro-drop rate is about 69 % and the object drop rate about 46 % in spoken language (Kwon et al., 2006), and they are equally felicitous. An anonymous reviewer pointed out that this asymmetrical statistical pattern would not support the authors' proposal of a subject-first strategy in sentence processing in Korean, given that subject-dropped sentences are more frequent than object-dropped ones. However, it should be noted that the subject is not always dropped, but only when the referent of the subject is clear from the context within which the sentence is presented. Even though it is not "overtly" expressed, it is constructed in the mental representation in the speakers' and listeners' minds at the time the dropped argument is processed. The authors propose that subject-dropped sentences would be more difficult than object-dropped sentences, all else being equal, as in this experimental condition, which is due to the subject-first strategy in sentence processing.

[5] Korean nominative and accusative case markers have phonological allomorphs (e.g., –*i* after ta word-final consonant and –*ka* after a word-final vowel in the case of nominative case marker). In order to avoid the coarticulation effect of the preceding noun and the suffixed case marker, only the nouns ending with vowels were used to ensure that they were followed by the case marker starting with a consonant: -*ka* (for the nominative) or -*lul* (for the accusative). Furthermore, the length of the nouns was manipulated using Praat (a free computer software package for speech analysis in phonetics) to be 700 ms across all the nouns before case marker.

[6] An average of 9 % of items were excluded under both conditions (around 29 trials in both)

Table 1
Experimental conditions.

Picture	Conditions	Examples
	(i) Agent+NOM first (object-drop sentence)	남자가__ 잡아요. *Namca-**ka*** __ *cap-ayo.* "A man catches__."
	(ii) Patient+ACC first (subject-drop sentence)	__여자를 잡아요. __ *Yeoca-**lul** cap-ayo.* "__ catches a woman."

Picture	Conditions	Examples
	(i) Agent+NOM first (object-drop sentence)	남자가____ 잡아요. *Namca-**ka*** ____ *cap-ayo.* "A man catches___."
	(ii) Patient+ACC first (subject-drop sentence)	____여자를 잡아요. ____ *Yeoca-**lul** cap-ayo.* "____ catches a woman."

Table 2
Nouns and verbs used in the experiment.

Set A		Set B		Transitive verbs
Agent first	Patient first	Agent first	Patient first	
Enni (*older sister*)	Oppa (*older brother*)	Oppa	Enni	kuhata (*save*), kitalita (*wait*), kkulta (*pull*), capta (*catch*)
Namca (*man*)	Yeca (*woman*)	Yeca	Namca	macihata (*welcome*), tulta (*raise*), palpta (*step on*), pota (*see*)
Nuna (*older sister*)	Ai (*child*)	Ai	Nuna	takkta (*wash*), sayngkakhata (*think*), anta (*hug*), phihata (*avoid*)
Appa (*father*)	Emma (*mother*)	Emma	Appa	kulita (*paint*), salanghata (*love*), epta (*carry*), hundulta (*shake*)
Kay (*dog*)	Twayci (*pig*)	Twayci	Kay	kulkta (*scratch*), tollita (*roll*), multa (*bite*), ilukhita (*raise up*)
Koyangi (*cat*)	Cwi (*mouse*)	Cwi	Koyangi	nemta (*go over*), mukkta (*tie*), cochta (*follow*), chacta (*search*)
Wensungi (*monkey*)	Tokki (*rabbit*)	Tokki	Wensungi	kkocipta (*pinch*), topta (*help*), milta (*push*), ponayta (*send*)
Saca (*lion*)	Holangi (*tiger*)	Holangi	Saca	mekta (*eat*), ikita (*win*), chata (*kick*), chita (*hit*)

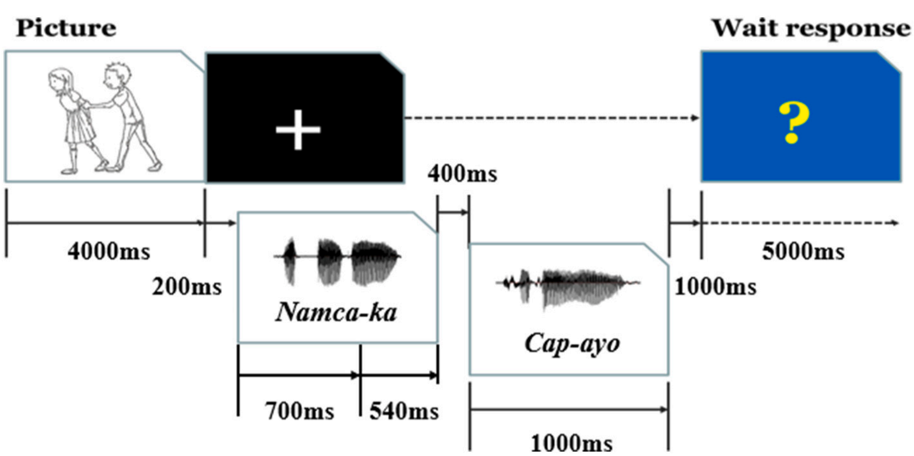

Fig. 1. Picture-sentence verification task with EEG recording.

amplitude values per time-window per condition. The statistical analysis was carried out hierarchically, that is, only significant interactions ($p <$ .05) were resolved. Additionally, the topographical effect was reported only when the interaction effect between sentence type and topography was significant.

Topographical factors were chosen as follows: For the midline electrodes, the region was labeled as anterior central (Fz, FC1, FC2) and centro-parietal (Cz, CP1, CP2, Pz, P3, P4); for the lateral electrodes, the factors Hemisphere (Hemi; left vs. right) and Region (anterior, posterior) were chosen as levels. Consequently, 6 Region of interest were included in the analysis, with 2 region (anterior vs. posterior) factors × 3 laterality (left vs. midline vs. right) factors.[7]

3. Results

3.1. Behavioral results

Sentences with incorrect responses were included in the analysis of behavioral results of accuracy, but were excluded from the response time analysis. The overall accuracy was 97 % ($SD = 18.09$; Nominative-first [$M = 98.02$, $SD = 13.94$], Accusative-first [$M = 95.21$, $SD = 21.37$]). Statistical analysis with a mixed-effects logistic regression model for accuracy data showed no significant differences among the conditions ($\beta = -0.9829$, $SE = 0.7083$, z-value $= -1.388$, $p > .05$).[8] The overall mean reaction time was 393.94 ms ($SD = 304.47$ ms; Nominative-first, $M = 407.23$, $SD = 327.85$; Accusative-first, $M = 380.27$, $SD = 277.88$). Statistical analysis with a linear mixed-effects model revealed no significant differences among the conditions (absolute t-value smaller than 2; $\beta = -23.48$, $SE = 14.01$, $df = 71.02$, $t = -1.675$, $p > .05$).[9]

3.2. ERP results

3.2.1. At the noun

Fig. 2 shows the grand average ERP responses at each electrode site in the 6 ROI under the two conditions (Agent+NOM-first vs.

[7] Specific information about the ROIs is included in Figs. 2, 3, and 4.
[8] Optimal model: glmer(correct ~ type + (1|subject) + (1|item)
[9] Optimal model: lmer(rt_correct ~ type + (1 | subject) + (1 | item)

Patient+ACC-first) at the noun. According to visual inspection of the differences between conditions across the whole data as depicted in Fig. 2(b), final statistical analysis was conducted on the mean amplitudes in the 200–400-ms time windows at the noun.[10]

In the statistical analysis, as summarized in Table 3, a negativity effect in the Patient+ACC-first condition compared to the Agent+NOM-first condition was significant in the 200–400 ms time-window (NOM-first: −0.191 vs. ACC-first: −0.629; $F(1,29) = -4.690$, $p < .05$), and the interaction between type and region was marginally significant ($F(1,29) = 3.807$, $p = .06$). Follow-up analysis revealed that the difference in brain response between Agent+NOM-first and Patient+ACC-first was only significant in the posterior regions (agent+NOM-first in posterior −0.121 vs. accusative-first in posterior −0.709; $F(1,29) = -12.252$, $p < .01$).

3.2.2. At the case-marker onset

To confirm whether participants were affected by the case-marker following the noun, we conducted an additional time-locked analysis on the case-marker onset, that is, after 700 ms of the noun onset. In order to compare the results from the noun onset, the amplitudes in the 200–400 ms time-window were analyzed. As a result, there was no type effect on the case-marker onset in this time-window. Instead, there was a three-way interaction between type, region, and laterality, as shown in Table 3. Additional analysis showed that the brain wave was deflected in the positive direction in the posterior region but in the negative direction in the anterior region. However, the difference between ACC-marker and NOM-marker was not significant even in both regions.[11]

Subsequently, we conducted the repeated-measures ANOVA with the onset (noun onset or case-marker onset) as an additional factor and found that a three-way interaction between onset, type, and region factor was significant ($F(1,29) = 8.435$, $p < .01$). Post-hoc analysis revealed that the interaction of the onset and type was significant ($F(1,29) = 8.455$, $p < .01$), and the type effect between agent+nominative-first and patient+accusative-first condition was only significant in the noun onset analysis ($F(1,29) = 12.252$, $p < .01$).

3.2.3. At the verb

At the verb position, an interaction effect between type and region ($F(1,29) = 9.055$, $p < .01$) and a three-way interaction effect between type, region, and laterality ($F(2,58) = 4.243$, $p < .05$) were significant. A follow-up analysis revealed that the positivity effect was more significant under the patient+accusative-first condition (0.339 μV) than the agent+nominative-first condition (−1.515 μV) in the anterior region ($F(1,29) = 25.951$, $p < .001$).

4. Discussion

The present study examined the subject-first strategy in visually situated sentence processing in Korean from the perspective of the prediction mechanism in sentence processing. We compared Korean speakers' ERPs between subject-initial (agent+NOM) and object-initial (patient+ACC) sentences in a picture-sentence verification task using auditory stimuli, testing the subject-first strategy in the prediction mechanism in Korean.

The results showed that although the behavioral responses revealed no difference between the two types of sentences, with an overall accuracy rate of 97 %, differences were borne out in the ERP responses. There was a negativity effect at 200–400 ms at the noun before the case marker, and no specific ERP effect was found at the case marker *-lul* of the NP even though it was an accusative case marker. In addition, Late frontal negativity (LFN)-like effect reflecting the processing difficulty was found at the sentence-final verb.

The results of the ERP experiment provide clear answers to our research question: *Will the brain responses to object-initial first sentences differ from those to subject-initial sentences? If so, where will the difference be found, the noun or its suffixed case marker?* The neural effect found in the object-initial sentence compared to the subject-initial sentence seems to indicate that object-initial sentences are processed differently from the subject-intial sentences. More importantly, the neural effect, N400 was found as early as at the first noun, but not at the post-nominal case markers, along with LFN at the sentence-final verb.

We can interpret the N400 effect at the noun as evidence that reflects the strategy of predicting the entire subject NP with an agent+nominative marker. The entire subject-first strategy means that the NP is activated along with the case feature "noun+NOM" for the subject in the linguistic representation in the listener's mind. This interpretation is possible because there is a possibility that the prediction for the case in the position of the noun occurs in advance. If we predict that the accusative case marker follows the patient noun when the patient noun is auditory presented as the incoming word, it is contrary to the expectation of the subject with [+agent, +NOM]. When the anticipated "subject" [*brother-ka*, +agent, +NOM] conflicts with the encountered "object" [*sister-lul*, +patient, +ACC], it will elicit a neural effect as early as possible (before the case marker).

The previous literature also found a similar kind of indicative of predictive processing (based on the pre-seen visual context). For example, Knoeferle et al. (2008) compared a non-canonical OVS sentence with a canonical SVO sentence in German where the first NP was temporarily ambiguous (subject or object) due to the neutral female determiner but disambiguated at the following verb compared with the pre-seen visual context. P600 effect was found at the verb for the non-canonical OV sentence (i.e., OV vs. SV) but with no other effect at the 2nd NP where the sentence is linguistically disambiguated by its case marker (OV<u>S</u> vs. SV<u>O</u>). The findings also indicate that the listeners anticipated the canonical SVO sentence, assuming the first NP as the subject (and the agent of the verb). Notice that the non-canonical object-initial sentence elicited neural effect as early as at the verb where the grammatical role of the first NP was disambiguated (based on the scene), but no other effect was found at the linguistically disambiguating point with case marker, the 2nd NP.

This interpretation also conforms to previous studies such as Knoeferle et al. (2014) and Schipke et al. (2012). In Knoeferle et al.'s study, which used English stimuli, an N400 effect was found at the first NP ('a' + N), where N accounts for the difference, while it was found as early as at the case-marked determiner in German (Det + N), where the determiner indicates the grammatical role of the NP (subject or object). However, the fact that N400 effect was found at the noun before the case marker in Korean seems to indicate that the parser identifies the *agent* as the subject of the sentence following the subject-first strategy in canonical sentences, activating [agent-NOM]. This can also explain the comprehension and processing difficulty of object-initial sentences in 3-year-olds who have not yet acquired grammatical features such as the case marking of determiner found by Schipke et al. (2012), who seemed to comprehend the first NP as the subject without knowing the case marking of the first NP. Therefore, if the subject-first strategy is correct, it seems plausible to suggest that similar negativity will be found for object-initial sentences without the case-marking determiner (or the same determiner for subject and object) in German corresponding to a clear event structure in the visual context. In the same vein, let us consider German studies (e.g., Bader & Meng, 1999; Rösler et al., 1998), which found topicalization effects of object-initial sentences as early as at the prenominal determiner of the first NP, where the thematic role (agent or patient) cannot yet be identified. This indicates that the comprehender expects the subject as the first NP of the sentence they are

[10] Previous ERP studies on the N400 had reported that a typical statistical time window is 300–500 ms. However, we found no significant differences at this time window at all, but instead found a significant difference at 200–400 ms.

[11] The analysis for 300–500 ms was also conducted according to the visual inspection. However, the results showed the same pattern as the one in the 200–400 ms time window, so we do not report this result to avoid redundancy.

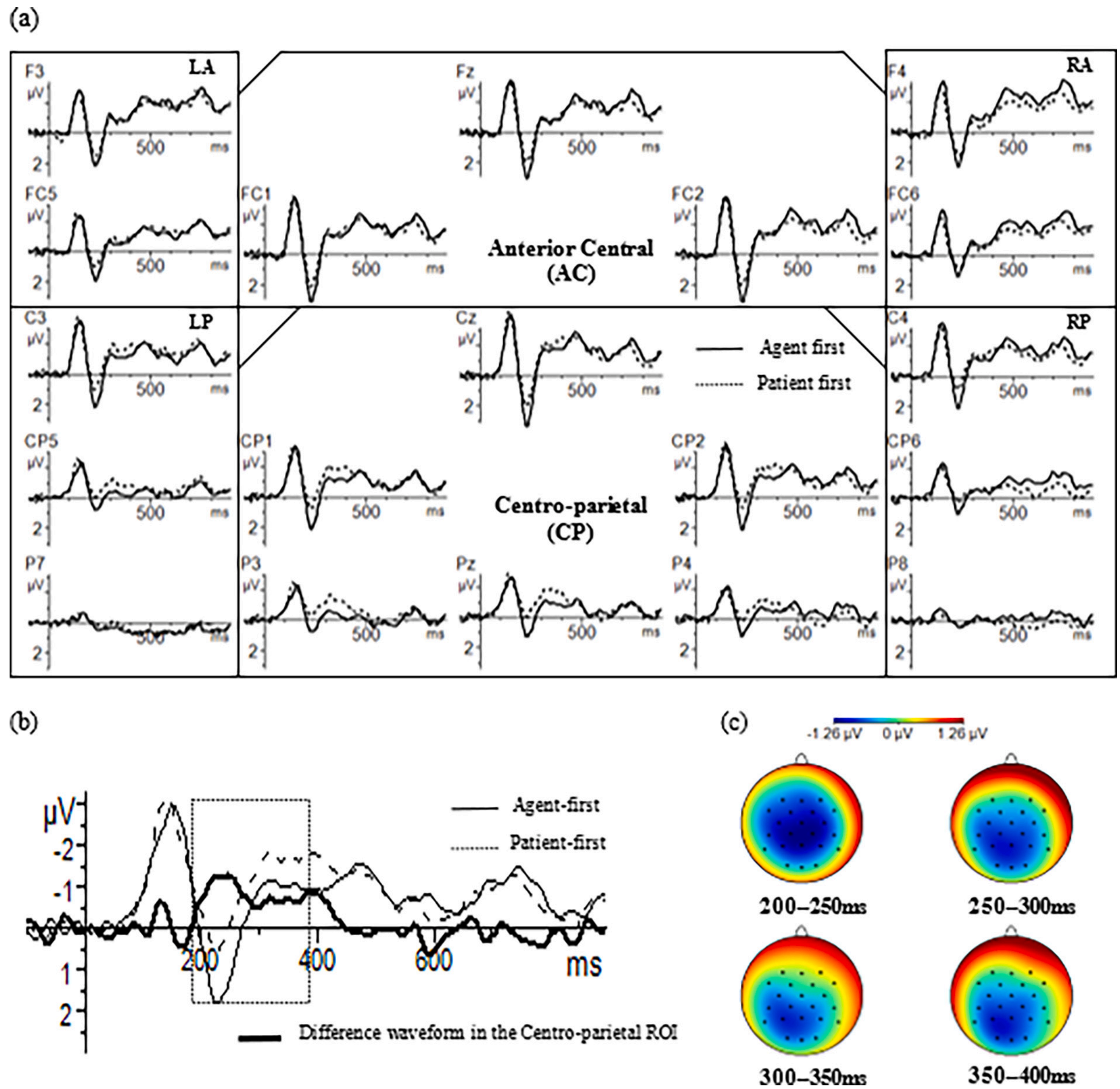

Fig. 2. (a) The ERP grand-average waveforms from −100 ms pre-onset to 900 ms post-onset of the critical words; (b) patient+ACC-first minus agent+NOM-first difference wave at Centro-parietal ROI; and (c) the topographical distribution of differences at the noun position.

going to listen to or read.

Based on these observations, we can reinterpret the results of Knoeferle et al. (2014) from the perspective of a subject-first strategy in the prediction mechanism. Suppose that the parser has established a linguistic representation of "*the gymnast applauds the journalist*" based on the pre-seen image. When the parser encounters "the journalist" for the first NP, it causes N400 for the thematic role reversal effect. However, suppose that when it was pre-activated in the parser's mind, there was information on not only the patient role but also accusative case (i.e., [journalist, +patient, +ACC]). When it is encountered as the first NP of the sentence in subject position, the case feature must have been conflicted, rather than the "thematic role." We can speculate that the neural effect found at the first NP caused by the mismatch between the picture and its corresponding sentence might have been elicited by the conflict of case features between the pre-activated anticipated subject "the gymnast" with nominative case and the encountered input "the journalist" with accusative case, rather than by the conflict of thematic roles. An accusative-case-marked NP cannot appear as the first NP in standard English word order.

Finally, a non-canonical word order effect (i.e., topicalization effect) was revealed at the verb through the elicitation of the late positivity component in the anterior region (frontal region). We interpreted this ERP component as LFP, as reported by Kuperberg et al. (2019). In that study, the authors tried to tease apart the brain responses related to different prediction violations. They found an increased late frontal positivity effect in a high-constraint unexpected condition, such as "*The lifeguards received a report of sharks right near the beach. Their immediate concern was to prevent any incidents in the sea. Hence, they cautioned the trainees*..." In this sentence, "the trainees" are plausible in the sentence context, but it was not expected in the cloze test. Therefore, Kuperberg et al. (2019) argued that the late frontal positivity reflects a large change in activity associated with successfully updating the comprehender's current situation model with new unpredicted information. Such a processing cost has also been reported in previous fMRI studies in Japanese. Ikuta et al. (2009) found an activation of the left inferior frontal gyrus at the second NP in non-canonical OSV sentences. They suggested that "the processing cost for a syntactically complex sentence is found at verb recognition, in contrast, at the end of a sentence" (Ikuta et al., 2009,

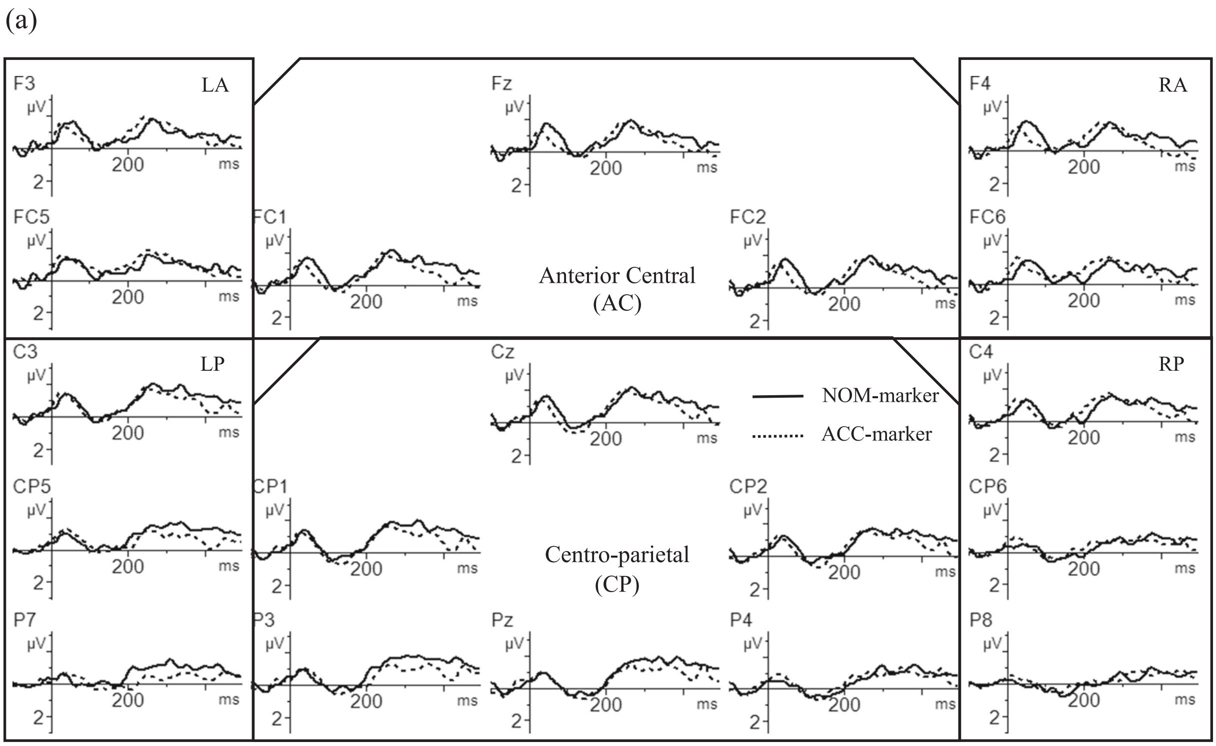

Fig. 3. The ERP grand-average waveforms from −100 ms pre-onset to 900 ms post-case marker onset of the critical words.

p. 534). Applying this to our results, we can understand that LFP indicated that Korean native speakers did not expect a patient-ACC-first sentence. However, they might have recognized that it was entirely plausible in the situation given by the picture and updated their situation model with the patient with an accusative marker as the main argument instead of the subject with a nominative marker. Going back to Schipke et al.'s study (2012), which did not find such a processing cost at the NP_2 (NP_1-V-NP_2) in the non-canonical OVS sentences in adults, it is plausible to conjecture that the processing coast might have been detected at the verb, even before the NP_2 updating the representation upon encountering the input (verb) in the rapid prediction mechanism. Unfortunately, no ERP responses at the verb have been reported in adults. In contrast, the processing cost is revealed in NP_2 in 6-year-olds, who are still developing the use of case-marking cues. In addition, considering the processing cost found at the verb in this study, which used a similar OV construction, we can infer that the comprehenders in Schipke et al.'s study might have resolved the processing difficulty upon hearing the verb and expected to hear the missing subject, leading to no difficulty in the processing of NP_2.

Although we argue that the negativity effect found in the noun position (not at the following case marker) provide supporting evidence for the subject-first strategy, different interpretation of the data can still exist. One might propose that the negativity effect found at the noun position could be interpreted as the conflict of argument roles. Notably, the negativity was found at the noun, not at the case marker at 700 ms after the noun (remember that the length of nouns was set as 700 ms across test items, so the case marker was heard starting at 700 ms). One might claim that this result indicates that the parser expected the agent, not the entire subject, to conform to the agent-first strategy following the conceptual accessibility account, suggesting further that no neural effects in the position of the case marker indicate that the parser already expects nominative case marker after the agent noun and accusative case marker after the patient noun, hence no additional neural effect at the position of case marker.

However, this interpretation is somewhat contradictory to the results of Lee, Jeong, Nam (2016) which also compared the neural effect at the case marker separately from the noun. If the parser uses an "agent-first" strategy, there should be some kind of neural effect at "sister-ka" (patient-NOM) compared with "brother-ka" (agent-NOM) because the sister is not the agent in the image. However, Lee, Jeong, Nam (2016), as reviewed in the introduction, found no neural effect when they were compared. Instead, the results seem to indicate that the comprehender focuses more on the case marker. Since the first NP was the subject (with nominative case) in both sentences, it did not elicit any neural effect.[12] Nevertheless, the data from the previous studies should be confirmed in further study with a bigger sample size and a more controlled experimental method.[13]

Consequently, this study holds the following implications. First, the predictive mechanism rapidly operates upon receiving new input by revising the predicted representation and accommodating the newly received contextual information, such as lexical or syntactic. The pre-activated elements seem to be at various levels, such as the feature level (e.g., +nominative, +agent, +human) and the levels of bound morphemes (e.g., −*ka*, −*lul,* −*s*), words (e.g., *brother, sister*), and phrases (e.g., *brother-ka, sister-ka, sister-lul*). Assume that the participant had a

[12] Anonymous reviewer suggested that we should compare [patient-ACC] and [patient-NOM] at the first NP. A pilot study of the authors (i.e., Lee et al., 2014) used the same method and compared them, but found no particular neural effect at the first NP. However, the crucial difference between the two studies is that Lee et al. (2014) included not only active voice verbs but also passive voice verbs which can finalize the sentence as a passive sentence matching with the event in the visual image. Therefore, the listeners at the task might have focused more on the verb rather than the case marker of the first NP; the listeners might have anticipated either subject or object for the first NP and processed it as rapidly as possible to focus on the verb form to see if the sentence matched with the picture or not.

[13] In Lee, Jeong, Nam (2016), 15 native speakers participated in the experiment, which is insufficient to confirm the N400 effect at the noun position. In addition, using a high-pass filter of 0.3 Hz in the ERP analysis in Lee, Jeong, Nam (2016) might have reduced the N400 effect on patient nouns and induce the P600-like effect (Tanner, Morgan-Short & Luck, 2015).

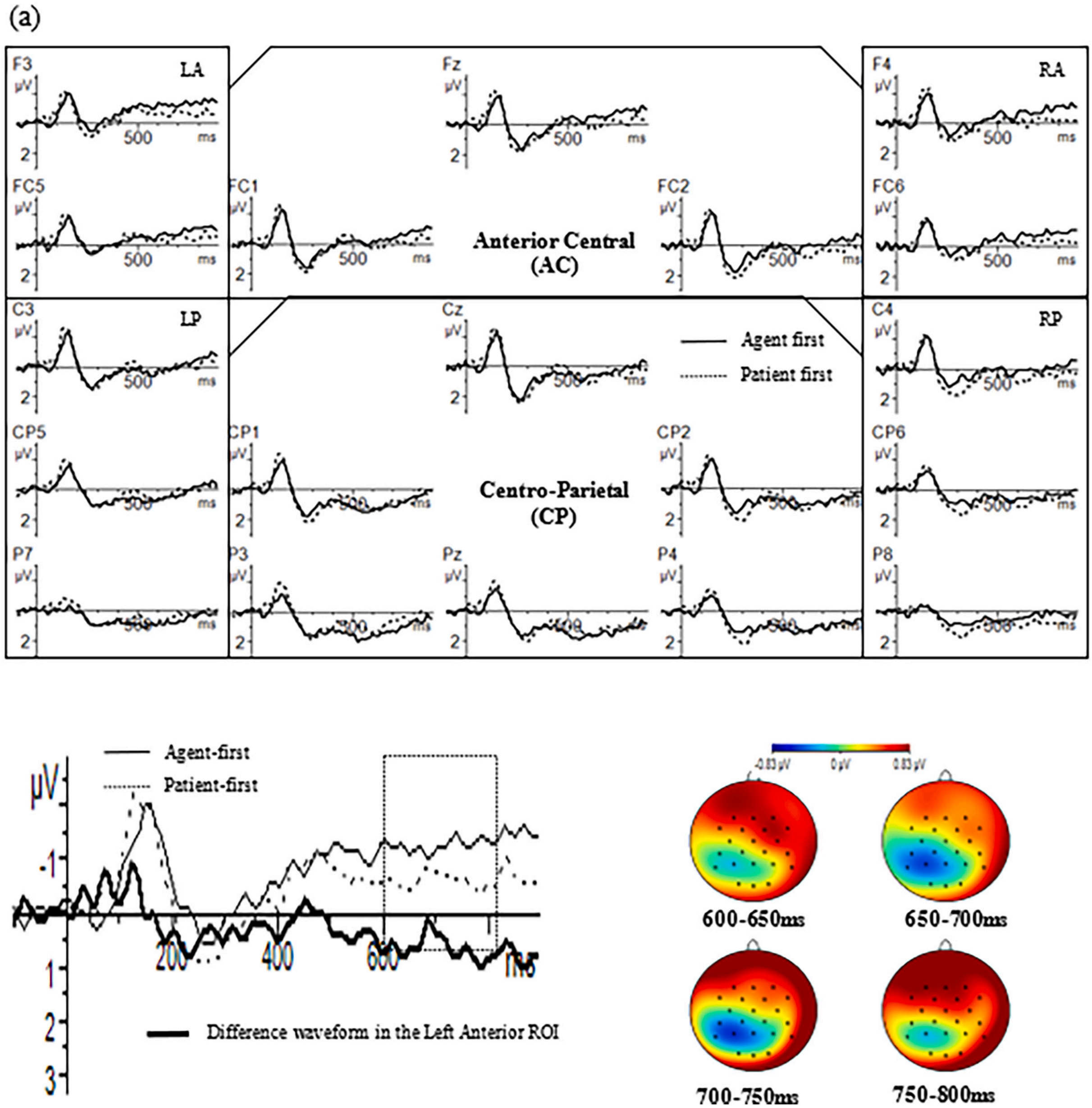

Fig. 4. (a) The ERP grand-average waveforms from −100 ms pre-onset to 900 ms post-onset of verb words; (b) patient+ACC-first minus agent+NOM-first difference wave at Centro-parietal ROI; and (c) the topographical distribution of differences at the verb position.

Table 3
Summary of the results of the statistical analysis.

Variables	Degree of freedom	Noun onset	Case-marker onset	Verb
		200–400 ms	200–400 ms	600–800 ms
Type	*F*(1,29)	4.690*	0.005	2.695
Region (Reg.)	*F*(1,29)	0.004	7.218***	24.400***
Laterality (Lat.)	*F*(2,58)	1.931	3.290*	8.091**
Type × Reg.	F(1,29)	3.807ˆ	4.860*	9.055**
Type × Lat.	F(2,58)	0.966	0.696	0.759
Reg. × Lat.	F(2,58)	1.823	0.370	0.370
Type × Reg. × Lat.	F(2,58)	0.865	5.358*	4.243*

*** $p < .001$.
** $p < .01$.
* $p < .05$.
ˆ $.05 < p < .1$.

pre-activated representation [*Brother-ka*(S), *sister-lul*(O) *catches*(V)] upon seeing the image of a boy catching a girl. Then, as soon as they encounter "*sister-lul*" for the first NP which conflicts with the pre-activated first NP "*brother-ka*," it will elicit a neural effect indicating processing difficulty, and prediction correction comes with "*sister-lul*" being activated and processed. This process is rapidly done because it has already been pre-activated in the linguistic representation in our mind through the prediction mechanism, as mentioned above.

Next, the negativity effect found at the first NP (i.e., object of the verb in this experiment) provides neurophysiological evidence for the psychological entity of the subject in the sentence, even though it is not necessarily overtly expressed in Korean as a pro-drop language, as pro-drop languages are those where the subject of the sentence can be dropped without impairing the grammaticality of a sentence. Korean adults use subject-dropped sentences nearly 70 % of the time (Kim, 2000). However, the fact that a sentence-initial object (i.e., subject-dropped sentences) elicited negativity in this study indicates that the linguistic representation of the event in mind is realized as a subject-first sentence even though people are more frequently exposed to subject-dropped sentences in colloquial speech in Korean.

5. Conclusion

This study examined the subject-first strategy of a prediction mechanism in visually situated sentence processing in Korean based on the data of an ERP experiment using a picture-sentence verification task. The results of the ERP experiment revealed that an object-initial sentence in Korean elicited N400 at the first NP, reflecting the conflict between the subject-initial sentence representation and the encountered input. This provides positive evidence for the subject-first strategy in the prediction for the upcoming sentence with given image or context. The linguistic representation is constructed as a canonical sentence (SOV) in the parser's mind, conforming to conceptual accessibility, even before the input is received in Korean, an SOV language. Furthermore, the N400 found at the noun (even before the case marker is heard) shows that the NP is pre-activated as a full representation of the NP (with case marker), which seems to make sentence processing fast and rapid regardless of sentence type (whether in a case-marking language or not). In the same vein, the ERP response was found as early as the determiner preceding the NP in the case of German. These types of neural data from various cross-linguistic studies provide supporting evidence for the subject-first strategy in the prediction mechanism in rapid sentence processing in general.

Furthermore, the Late Frontal Positivity found at the verb showed that even though the event structure is organized around the agent, the mental representation is updated with new information within a very short time if it is determined that the new input does not violate the event structure at the position of the verb (i.e., S_V > _OV).

This experimental study makes important contributions. It provides fine-grained neural evidence for the subject-first strategy from the point of view of a prediction mechanism. In doing so, by adding data from Korean, which has not yet been studied in much detail, especially by ERP experiments using a picture-sentence verification task, it provides more cross-linguistic evidence for the better understanding of the prediction mechanism in language processing.

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Data availability

Data will be made available on request.

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