http://dx.doi.org/10.5392/IJoC.2014.10.4.030

Linear Precedence in Morphosyntactic and Semantic Processes in Korean Sentential Processing as Revealed by Event-related Potential

Choong-Myung Kim
Division of Speech, Language and Psychological Therapy,
Gwangju University, Gwangju, 503-703, Korea

ABSTRACT

The current study was conducted to examine the temporal and spatial activation sequences related to morphosyntactic, semantic and orthographic-lexical sentences, focusing on the morphological-orthographic and lexical-semantic deviation processes in Korean language processing. The Event-related Potentials (ERPs) of 15 healthy students were adopted to explore the processing of head-final critical words in a sentential plausibility task. Specifically, it was examined whether the ERP-pattern to orthographic-lexical violation might show linear precedence over other processes, or the presence of additivity across combined processing components. For the morphosyntactic violation, fronto-central LAN followed by P600 was found, while semantic violation elicited N400, as expected. Activation of P600 was distributed in the left frontal and central sites, while N400 appeared even in frontal sites other than the centro-parietal areas. Most importantly, the orthographic-lexical violation process revealed by earlier N2 with fronto-central activity was shown to be complexes of morphological and semantic functions from the same critical word. The present study suggests that there is a linear precedence over the morphological deviation and its lexical semantic processing based on the immediate possibility of lexical information, followed by sentential semantics. Finally, late syntactic integration processes were completed, showing different topographic activation in order of importance of ongoing sentential information.

Key words*: Event-related Potentials(ERPs), Morphosyntactic Process, Orthographic-lexical Process, Lexical Semantics, Anomaly screening test, Linear precedence, information immediacy*

1. INTRODUCTION

The Korean language so-called *hangul* has different structure from Indo-European languages and other Asian languages in terms of writing system and language processing. That is why Korean has a structure characterized by agglutinativity, in which the morphemes attached to roots or stems of words influence on their syntax and semantics in the unit of an eojeol. An eojeol could be defined as space-delimited orthographic words, being smaller than phrases but larger than words in English as is the case for a Korean verb eojeol, '먹+었+다, ate' (meok [verb stem, 'eat'] + eoss [pre-final ending for past] + da [final ending for declarative form]) in which the first constituent should be written in one constant shape of stem irrespective of its morpho-phonological sound changes. By contrast, the corresponding phonetic form will be /머거따/ (meo-geo-dda)' due to the effect of liaison and phonological change. Otherwise the other lexical items not required to spell a stem overtly will follow the rule that words should be written as they are pronounced such as '며칠/myo-cil/, how-many-days', '빨리/bbal-li/, fast', '살피다/sal-pi-da/, to care for' and so on. These characteristics of the Korean writing system might confuse most beginners of the Korean into excessive applying of 'writing-as-pronounced' rule by using a '마니/mani/' or '조아하다/joa-hada/' instead of making each stem like a '많이/mani/, many' or a '좋아하다/joa-hada/, to like' clear, respectively.

There was a study on orthographic lexical processing of Korean using ERPs which showed that the shallow and deep orthographies are recognized differently and that the ERP-patterns associated with the orthographic depth appear to be diverged after about 200 ms following the word onset [1]. In light of this characteristic of the Korean language, their shallow or transparent orthographies can be said to constitute the writing system being regular correspondence between phoneme and grapheme [2]. Due to this fact, Korean writing errors were often found when consonant in the position of coda within one syllable meets a succeeding initial vowel in the next syllable(as in /노기다/ from /녹이다/), resulting in its phonetic-related misspelled form instead of orthographic correct form. In the current study such orthographic or morphemic errors resulting from violating canonical orthographic rule will be considered in terms of immediacy in on-going available information together with a typical syntactic or semantic violation.

On the other hand, head-final SOV (Subject-Object-Verb) structure of Korean makes syntactic and semantic processing

* *Corresponding author, Email: cmkim@gwangju.ac.kr*
Manuscript received Jul. 28, 2014; revised Oct. 22, 2014; accepted Oct. 29, 2014

delay up to reaching the sentence-final verbs. The Korean language doesn't have the same pattern of syntactic error as shown in English-related literature due to the head-final verb and its function-based argument construction. Specifically, function words representing tense, voice and aspect are all tied to the verb only in the unit of an eojeol.

There is another type of function words, called case markers, attached to the noun phrase as well. Thus, the sentential meaning can be changed by inserting or deleting the corresponding morphological affixes following the verb-stem, or by attaching case markers following the nouns governed by the verb. These characteristics made their word order relatively free as in German [3]-[5], but the occurrence of error pattern regarding the syntactic violation generated by a morphological change of the function words was usually confined within one eojeol unit except for long-distance correspondency. This type of error forces the pattern of Korean syntactic violation to be distinct from many other languages as exemplified in gender or number disagreement, subagency constraint violation, garden-path sentences in English [3], [6]-[10]. With regard to this phenomenon, left anterior negativity(hereafter, LAN) and P600 (positive peak 600ms poststimulus) well-known as a syntactic first build-up and a late syntactic integration process, respectively, are in some controversy due partly to the absence or presence of word order variation or grammatical morpheme affixation in the language. In contrast, the semantic violation condition to be specified in this study was basically generated by replacing the verb eojeol with incongruent words against an appropriate or expected word. Enhanced N400 (negative peak 400ms poststimulus) related to semantic anomaly in ERP indexes has been observed consistently whenever semantic incongruency takes place in relation to the preceding context. Therefore, no one hesitates to say that this signature can be a language-general component marking a semantic anomaly.

More specifically several ERP components are known in relation with language processing. Firstly, LAN occurring around 100-500 ms has been known to hold a relationship with syntactic category violation or working memory. LAN has been treated as a reflection of the early syntactic processing mainly resulting from local phrase structure violations [11] or word-category identification with smaller cases of working memory reflexes related to the thematic role of the critical word [12]. Secondly, the N400 component is known to be sensitive to the semantic anomaly [13], [14]. N400 was proposed to be regarded as an inverted function of semantic integration between the target word and its preceding context in a lot of literatures. Though much is known about the modulation of N400 (as a function of incongruity between lexical constituents), its functional dissociation between automatic and controlled semantic processing remains to be solved. The controlled processing known widely in many literatures for semantics is found to be post-lexical and thus reflected as sentence integration while the former is thought to be pre-lexical and expectancy-based processing with regard to the partial information even when not perceived consciously. Lastly, an important ERP component related to language processing is P600, which can be an index of pure syntactic component or the extension of the P300 (positive peak 300ms poststimulus) component or the reflection of complexity of the task.

Among these there are many studies in which ELAN-P600 or LAN-P600 ERP patterns showing the LAN primacy were reported with respect to the modality-specific syntactic anomaly construction. However, only a few studies have shown the primacy effects of phrase structure build-up over semantic information in which no additive effect or even the absence of N400 were reported [15], [16]. These results may be stemmed from the decision of plausibility about phrase structure building being in favor of checking the syntax-first. This type of construction is clearly different from the current combined condition eliciting both violations within only one eojeol. Accordingly, this restriction on the occurrence for the LAN-N400 concurrent complexes may be unraveled if any evidence will be provided for the primacy of word form identification over lexical semantics within the same critical word (related to processing of orthographic-lexical combined condition.)

Thus the present study aims firstly at replicating the usual occurrence of ERP signatures related with morphosyntactic and semantic anomaly in line with other studies previously reported, and further at revealing another ERP response to both orthographic-deviated morphology and lexical-semantic absence co-occurred in the same verb eojeol as a condition of an orthographic-lexical violation. On the basis of previous ERP studies, an LAN-P600 sequence is supposed to be occurred for the violation of morphosyntactic integration and an N400 for the violation of semantic congruency in the first two conditions respectively. In addition, we would expect both an LAN and an N400 reflex to occur if the combined condition compsed of the violation of morphosyntactic integration and semantic congruency induces each ERP-pattern corresponding to morphological and lexical-semantic deviation. Otherwise, we would see the qualitatively different ERP deflection only related to the orthographic deviation having no semantic information exactly like a non-word due to the absence of the lexical meaning. In this respect, the linear precedence verified as the degree of salience will be explored among those information given in the anomaly screening test in accordance with the immediacy of available resources from sentence information.

2. METHODS

2.1 Subjects and Materials

Fifteen college students (mean age of 23.5 years; range of ages 19-26 years) who do not have neurological disorders and reading disabilities participated in this experiment. All of them were proven to be right-handed through the right-hand assessment test and they were given written informed consent. The Korean sentence materials were designed to examine the processing between correct and incorrect sentence differing only in one element in a within-subject design.

Table 1. Experimental conditions and exemplary sentences with critical words italicized({} denotes expected words corresponding to the orthographic-lexical violation stimulus).

Correct sentence
햇살이/ 지붕의/ 고드름을/ 녹인다 *[nog-in-da]*.

(Sunshine/ from the roof/ icicles/ *make melt*)
Semantic violation
햇살이/ 지붕의/ 고드름을/ *피운다 [pi-un-da]*.
(Sunshine/ from the roof/ icicles/ *smoke*)

Morphosyntactic violation
햇살이/ 지붕의/ 고드름을/ *녹는다 [nog-nun-da]*.
(Sunshine/ from the roof/ icicles/ *melt away*)

Orthographic-lexical violation
햇살이/ 지붕의/ 고드름을/ *노긴다 [no-gin-da]*.
(Sunshine/ from the roof/ icicles/ {*make melt*})

We prepared stimuli as either morphosyntactic, or semantic or orthographic-lexical violations varying in the sentence final position for each of 45 sentences corresponding to the correct condition as a control. Specifically, stimuli presented to the subjects were four-eojeol sentences in each condition as shown in Table 1. In the semantic violation sentences, correct words were replaced with an incongruent word instead of the expected final word, and the morphosyntactic violation sentences were most generated by an inappropriate function word illegally changed instead of correct voice marker. Lastly the orthographic-lexical violation sentences were constructed from simply applying morphophonological sound change as in '녹-이-다 /nog-i-da/' -> '노기다 /no-gi-da/' by means of the phonographic rule written as they were pronounced ignoring the rule that verb-stem should be as it is with an constant shape ('녹-' in this case). This type of error resulted in misspelling words namely, morphologically orthographic-deviate letter-strings. Therefore, the orthographic-lexical violation condition includes both illegal spelling and lexical semantics error at the same time. However, it should be noted that the tentative orthographic-deviate words were usually heard normal due to having the same phonetic representation as its spoken form. Next we encouraged 120 subjects to evaluate the degree of the naturalness of the experimental sentences on a 7-point scale in advance in order to see whether the stimuli in each experimental condition are adequate for the predefined standard. The more natural the sentence is assessed, the higher the rating score goes up.

2.2 Procedures

ERP was used in this experiment to identify the characteristics of Korean sentence comprehension. As described above, the experiment sentences were presented visually, and EEGs across subjects and sentences within an experimental condition and at a scalp site were averaged. The first goal of the experiment was to separate ERP components associated with morphosyntactic, semantic, and orthographic-lexical processing in reading Korean sentences. In order to separate each ERP-pattern we used correct and incorrect sentences, and subjects were instructed to judge whether the presented sentences were natural or not. Correct sentences were presented together with incorrect sentences pertaining to a specific condition across three blocks separately.

Subjects were asked to gaze at eojeols in the center of a computer monitor. Final eojeols of the sentences containing a correct or incorrect critical word were used for data analysis. Each stimulus was visually presented in a standard form with every eojeol occurring on the center of the screen. Subjects were instructed to comprehend and judge whether those sentences were natural or not by pressing a key named in either 'yes' or 'no' as an procedure with an anomaly screening test. EEG recordings were made at the onset of the last eojeol with a sentential predicate involved in the stimulus sentence. After the EEG measurement, subjects were asked to answer short questions to check whether they read those sentences correctly and to take a pause for eye-blinking briefly.

2.3 EEG recordings and data analysis

The grass model 12 was used to record EEGs. EEG recording was done under the extended 10-20 system and Ag-AgCl electrodes were used. EEG data from 11 scalp positions (F7, Fz, F8, C3, Cz, C4, P7, Pz, P8, O1, O2) was utilised to analyse the contribution of each condition to the on-line error-related processing. A linked-mastoid reference attached behind both ears was used, and the electrode impedance was kept below 5 kΩ. Band-pass filter with cut-off frequencies at 0.5 Hz and 40 Hz was adopted, and EOG artifact rejection criterion was set at + 50 uV and – 50 uV. The ERPs were collected separately and sampled from 120 ms before and 1000 ms after the onset of the stimulus. Data analyses were done for 1000 ms ERPs and were divided into 28 ms ERPs. Every 28 ms ERPs between the correct and violation conditions were taken to test statistically whether the sentence type condition causes significant main effects. Taken together with explorative analysis including t-test between conditions two time windows were selected; 340-440 ms, 500-620 ms which the time interval corresponded to negative-going (N400) and positive-going wave (P600) respectively. Only twelve subjects' data were selected for analysis because of various artifacts such as head or eye movement, excessive impedance and so on. Only single trials associated with correct responses free from eye movements and blinking were averaged to obtain the event-related potentials. ERP peaks and latencies were firstly identified in visual inspection and then validated by a statistical measurement, and grand averages over conditions and subjects were then computed for each experiment. Mean amplitude data for each time window was subjected to a repeated measures analysis of variance (ANOVA) test. Significant levels were set at 0.05 and Greenhouse-Geisser corrections were reported with all effects having two or more degree of freedom in the numerator.

3. RESULTS

3.1 Overall analyses

In the preliminary study described earlier session, the naturalness evaluation scores was as follows: semantic correct, 5.81(SD:.5) and incorrect, 1.54, (SD:.3); morphosyntactic correct, 5.43 (SD:.7) and incorrect, 1.54(SD:.2); orthographic-lexical correct, 5.78(SD:.6) and incorrect, 2.45(SD:.3). Self-

assessment on the scale revealed a significant abnormality in naturalness during the evaluation (all *Ps* <.03).

To investigate the abnormality effect between the correct and violation sentences, the statistical comparison on the mean amplitude in the two time-windows was performed by using the paired *t*-test. Specifically these comparisons were done at each sentence type (i.e. correct [LexOk] vs. violation [LexNo]) to examine which sentence type affects more impact on N400 negativity and/or P600 positivity. Firstly in the N400 time-window, mean amplitudes between the correct and violation sentences at all sites were diverged significantly in semantic and orthographic-lexical condition but not in the morphosyntactic condition, and the order of the difference magnitude was as follows: semantic (SemNo) > orthographic-lexical (LexNo) > morphosyntactic (SynNo) violation. Precisely these differences revealed the most enhanced negativity on N400 in semantic condition rather than in orthographic-lexical or morphosyntactic condition throughout the given epoch. As for the P600 time-window, we can identify that a significant difference occurred in only syntactic-related processing, making consideration for the component which is sensitive to the later processing in sentence comprehension (Fig. 1(upper)).

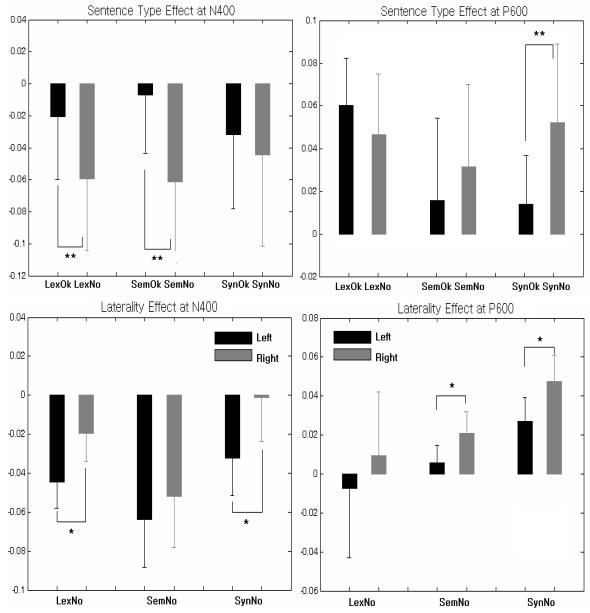

Fig. 1 Sentence type effect at N400 and P600 period (upper panel) and laterality effect at N400 and P600 period (lower panel). (Lex: orthographic-lexical, Sem: semantic, Syn: morphosyntactic, Ok: normal, No: abnormal)
* p <.05, **p<.01

Furthermore, mean difference amplitudes in each sentence type at specific locations were also computed across the two time-windows to know the local salience of N400 and P600 in terms of laterality. For statistical analysis, an analysis of variance on the 2-way repeated measures was conducted and divided into the following variables: 3 sentence type (semantic, morphosyntactic, and orthographic-lexical violation) X 2 electrode sites (laterality; C3 vs. C4). First of all, in the N400 (340-440 ms), responses to the sentence type diverged significantly among those three conditions ($F_{2,24}$=10.12, p<.01). The next epoch between 500 and 620 ms window named as P600 period also shows the significant difference over the mean difference amplitude in sentence type effects ($F_{2,24}$ = 19.19, p<.01) as verified in Fig. 1(upper). In addition, another main effect of laterality is also found in the two time-windows. As can be seen in Fig. 1(lower), while in laterality effect at N400 morphosyntactic and orthographic-lexical violation effect reveal the significant left lateralization under all violation condition ($F_{1,24}$ = 8.85, p<.01), semantic violation conditions did not reach the significance level. The next violation responses based on laterality at P600 reveal more positivity in the right central electrode ($F_{1,24}$= 6.33, p<.01) in semantic and morphosyntactic conditions. Lastly there was no interaction between the two factors at all two time windows.

3.2 Semantic violation

ERP response to semantic incongruence was a typical component of N400 irrespective of presentation modality or varied language structure [17], [18] As expected, the current semantically correct and violated condition showed the pronounced difference between them plotting a significant time period as a dense portion at around 350 and 400 ms as presented in Fig. 2(b). With regard to the N400 time window, semantic difference between conditions triggered a significant main effect of semantic abnormality ($F_{1,58}$= 26.33, p<.01), but not significant laterality electrode main effect ($F_{1,8}$= 0.53, n.s.) for the 340-440 ms period.

Above all, the semantic violation condition elicited a more enhanced N400 response as compared to the correct sentences. Apparent characteristic of this component is that an outstanding negative peak at around 350 ms poststimulus where the unexpected ending appeared is observed a bit earlier than in other literature. Their topographic distributions were found in most channels consistent with other previous studies [19] as shown in Fig. 2. This finding shows proportionate bilateral activation different from those of semantic violation in Finnish eliciting a more pronounced negativity on the left hemisphere [20]. On the other hand, there were no semantic abnormalities and laterality effects for the 500-620 ms time-window [21] but the following difference between the two conditions, mainly at fronto-central midline areas in the time window, ranged from 700 to 800ms should be noted presumably for the final sentence processing.

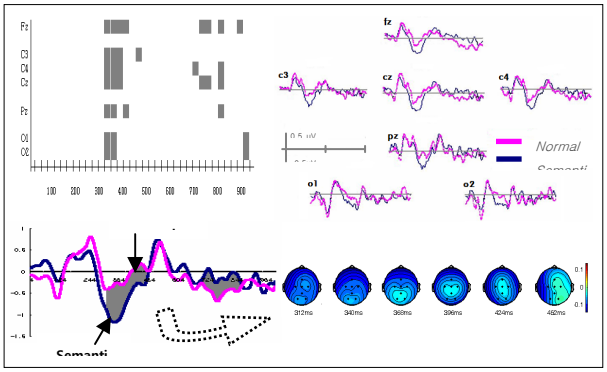

Fig. 2. Semantic-related significant ERP time course and regions(upper left; lighter grey: p <.05, darker grey: p<.01),

grand average waveforms overlaid by normal and abnormal condition on each site(upper right; Semantic:Semantic abnormal), and grand average waveforms collapsed over all sensors and topographical map for the corresponding, shaded significant area(lower panel). fz:frontal zero, c3:central left, cz:central zero, c4:central right, pz:parietal zero, o1:occipital left, o2:occipital right (the number is indexed from zero either to odd or to even in order)

In sum, typical N400 and the following the positive deflection without any difference between the two conditions identified a pronounced and consistent semantic-related processing as commonly shown in sentence processing. New observation in topography indicated the activation areas can be extended into frontal region in proportion to processing load together with less activation in occipital areas. Regarding the P600 time-window, as expected, semantically correct and violated conditions showed neither significant abnormality effect ($F_{1,48}$ = 2.34, n.s.) nor right lateralization effect.

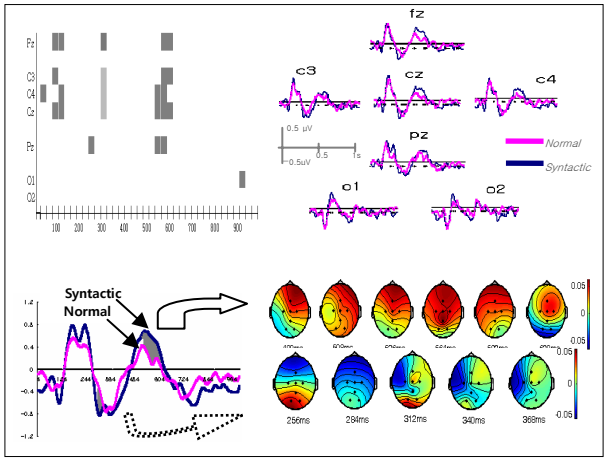

Fig. 3. Syntactic-related significant ERP time course and regions(upper left; lighter grey: p <.05, darker grey: p<.01), grand average waveforms overlaid by normal and abnormal condition on each site(upper right; Syntactic:syntactic abnormal), and grand average waveforms collapsed over all sensors and topographical map for the corresponding shaded, significant area(lower panel). fz:frontal zero, c3:central left, cz:central zero, c4:central right, pz:parietal zero, o1:occipital left, o2:occipital right(the number is indexed from zero either to odd or to even in order).

3.3. Morphosyntactic violation

The morphosyntactic violation condition showed a significant differentiation from the correct counterpart largely at two classified sections consisting of early and late processing as shown in Fig. 3(b). For the pronounced portion of the differential responses during the 500-620 ms, violation sentences relative to the correct type gives rise to a significant main effect of syntactic abnormality ($F_{1,48}$ = 22.32, p<.01), as well as that of laterality electrode effect ($F_{1,10}$ = 7.38, p<.05) showing right-hemisphere dominant activation. More specifically, the violation sentences elicited an enhanced P600 and interestingly showed more positivity at right electrode than the opposite site.

By contrast, for the N400 time-window, the syntactically correct and violated difference did not reach the significant level but showed a trend towards a more enhanced negativity ($F_{1,58}$ = 3.3, p=.07) and evident left lateralization ($F_{1,8}$ =5.4, p<.05) of an early morphosyntactic processing. Seemingly, this result supports the view that syntactic first-pass processing was associated with more negative-going peak for the mophosyntactic anomaly termed LAN. Further topographical analysis confirmed that this component starting at about 250 ms poststimulus and peaking at about 300 ms later was evidenced by left fronto-central negativity, LAN effect [22] as can be seen in Fig. 3(c). Although the shape of the LAN is similar at first glance to the N400 component related to semantic processing, the latencies and activation areas of the LAN is quite different from N400 in that the LAN component showed left lateralized, even a little earlier in latency and shorter in duration. Particularly, the activation areas are limited in anterior fronto-central areas differently from global activation in the semantic-related component. This is partly parallel to the results from other languages [23] and to the hypothesis that a filtering process for the morphosyntactic anomaly, such as phrase structure deviation, occurs earlier than a semantic one before the dominant and late syntactic-related processing is completed.

To sum up, our finding of the first component at N400 time period is in line with many previous studies and therefore seems to be a LAN as mentioned above. The first differential response shown at the time before 100 ms just after the target word presentation is likely to be sensory stimulus-related processing must be noted as indicated in word onset effect only referred to as sensory processing before cognitive processing [24], [25].

3.4. Orthographic-lexical violation

Electrophysiological responses and their topography to orthographic-lexical violation sentence thought to be related with morphological and semantic error were given in Fig. 4. Sentence materials comprising this condition were put by making the Korean phonetic form representation against the orthographically correct form as a condition of orthographic-lexical violation. It should also be noted that the lexical-semantic processing in this combined condition is different from the first sentential-based semantic condition in that the automatic semantic processing is related to the lexical form deviation rather than the controlled processing for the lexical items replaced against prior context.

First, as with the N400 time-window, the orthographic-lexical violation condition compared to the correct type showed not only significant main effect of abnormality ($F_{1,58}$ = 11.68, p<.01), but also main effect of laterality ($F_{1,8}$ = 7.99, p<.05) showing more negative in the left hemisphere in the 340-440 ms window starting at about 250 ms over occipital and frontal electrodes as can be seen in Fig. 4. As for the given P600 time-window, orthographic-lexically correct sentences did not differ from the violation condition neither for the abnormality nor laterality ($F_{1,48}$ = 1.15; $F_{1,10}$ < 1.0, n.s.) at the time period 500-620 ms. In addition, we can also find that bilateral occipital divergence appeared at around 250 ms post-stimulus leading to a negative component with left fronto-central differential activation (Fig. 4a). These temporal activations can be

compared to these elicited by the earlier morphosyntactic and semantic components. Also, the peak latency and topographic distribution of earlier processing in orthographic-lexical sentences are very similar to that of earlier processing labeled as LAN in morphosyntactic-related sentences.

An earlier onset by about 100 ms over the occipital areas is likely to be interpreted as the initial filtering processes related to morphological illegal words under processing of word form identification (cf. Fig. 3 vs. Fig. 4). Fronto-central activation beginning at 350 ms after word onset can be considered as a transformation (isomorphemic component) of semantic violation activation. The overall wave shape regarding the ending illegal words is shown to be added up to the short-termed LAN at the earlier stage and N400 at subsequent stage. Accordingly the orthographic-lexical component in question can be represented partly with complexes of LAN and N400 (hereafter referred to as N2) in that the component shares the properties of earlier processes in morphosyntactic information and of main signature in the following semantic processing. Lastly, topographic distribution about the semantic-related process at the orthographic-lexical processing stage was found to be of larger activation at fronto-central sites showing left lateralization. This regional result is in line with the topographic distribution reporting the N400 effect to pseudohomophones [26].

In a word, the analysis in which the correct verb-forms or orthographic-deviate violation forms revealing additive N2 effect of both morphosyntactic LAN-like deflection and lexical-semantic N400-like components were present. The main

evidences for the additivity were resulted from the earlier divergence occurring at occipital sites as a function of orthographic legality and from the focal activation distributed over left fronto-central areas as a function of lexicality, respectively.

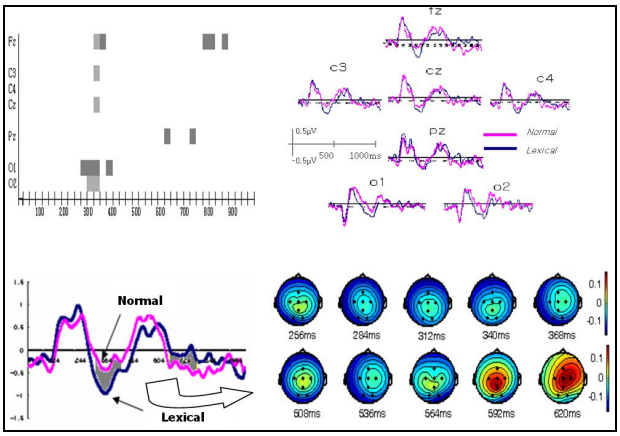

Fig. 4. Lexical-related significant ERP time course and regions(upper left; lighter grey: p <.05, darker grey: p<.01), grand average waveforms overlaid by normal and abnormal condition on each site(upper right; Lexical: lexical abnormal), and grand average waveforms collapsed over all sensors and topographical map for the corresponding shaded, significant area(lower panel). fz:frontal zero, c3:central left, cz:central zero, c4:central right, pz:parietal zero, o1:occipital left, o2:occipital right(the number is indexed from zero either to odd or to even in order).

4. DISCUSSION

The language-general ERP responses to visually presented correct and deviate words located in final position were investigated across the error types while reading the sentence and performing an overt plausibility judgment task. Particularly, the focus of the study was given to the modulation of orthographic-lexical deviant ERP with respect to the morphosyntactic and lexical-semantic components. According to the results taken in this study, the orthographic-lexical process was reflected on N2 in which the component occurred earlier in the occipital lobe with regard to morphological illegal words and a succeeding component serves as automatic processing related to lexical-semantic non-words mainly in fronto-central areas. In contrast, the conventional semantic processes were recorded only by the N400 component showing the activation in most of the brain areas and syntactic processes were divided into early one reflected on LAN and late one on P600 stages. These components would suggest that late sentential integration occurs after undergoing all types of error-related ingredients including lexical-morphological and semantic processes. Specifically, orthographic-lexical violation as a process of the Korean phonetic form recognition resulted in an additive effect on the deviant ERP together with a processing of lexical-semantic function.

For the morphosyntactic processing, LAN and P600 are all found mainly at fronto-central areas, and their temporal profile showed an earlier processing with an anterior negativity peak at around 300 ms and a late processing with an anterior right fronto-central positivity just after the offending word respectively. LAN and P600 all showed both sentence type and laterality effects supporting the view that syntactic processing is composed of a two stage analysis in which an early morphological processing based on a word-form check-up process and a late sentential syntactic processing occurred in good order. These results are in accordance with the suggestion that syntactic processing is related to abnormality including error detection and its reanalysis processes [27].

N400 was recorded in most sites differently from most other studies with centro-posterior bilateral activation. This finding represented the fact that sentential semantic-related processing distributed over posterior region is somewhat different from the lexical semantics showing its activation mainly on the fronto-central region [28]. On that score, semantic processing influencing over whole sentence scope does not seem to be associative memory-oriented processing, rather to be active and progressive meaning construction processing such that the whole areas are engaged in integrating the sentential semantics. This suggestion is in line with the hypothesis that left anterior regions reflect decisions based on the word categorization for the mophosyntactic processing and the posterior areas reflect decisions related to the sentential semantics [28]. Interestingly, semantic violation-related conditions over the ERP morphology can be compared to that elicited by orthographic-lexical violation conditions. In these respects, the temporal profile after about 300 ms poststimulus is similar to that of semantic conditions except an earlier differential onset. However, in other respects, they showed a small difference. N400 for the semantic processing are

distributed across all scalps, but the counterpart for the orthographic-lexical processing are located only in the occipital and frontal regions. This difference verified that the lexical semantics and the sentential semantics are differentially reflected in the very component with the differential activations. On the other hand, there was no significant laterality effect in the N400 window suggesting that a semantic violation sentence will be processed bilaterally.

Lastly, orthographic-lexical sentences showed sentence type and laterality effects during the first given time-window (340-440 ms). Judging by appearance of the ERP-patterns, the N400 time-window showing significant difference is similar to that evoked by the semantic violation condition as indicated in the results. Although temporal profile of peak latency has much similarity between them, topographic distribution is very dissimilar to each other. This difference is likely to suggest that the activation of lexical semantic processing associated with orthographic deviation is functionally different from that of semantic deviation involved in comprehension of propositions integrated among several words. The former showing left and anterior lateralized activation peaked about 300 ms with a little earlier divergence starting at about 250 ms from occipital areas possibly is especially likely to reflect a spelling error violating orthographic rule, while the latter shows global activation without a specific lateralization. The orthographic-lexical component does not exactly represent sentential semantic processing but rather shows intermixed processes integrating early morphological processes based on word-form construction and semantic adjustment related to the corrected words. These findings suggest that the orthographic-lexical violation condition originally designed to process the deviated orthography must be filtered out firstly through the Korean writing system at an earlier processing stage just before lexical access was completed via existing corrected form. To sum up, we can say that neural activation for orthographic-lexical processing including word-form legality processing begins from monitoring physical feature of the input stimulus and then reaches at semantic processing for the corrected form in order of information immediacy or salience.

Our electrophysiological evidence for this implication is manifested by earlier bilateral occipital activation, a bit later following anterior fronto-central negativity, and just succeedingly overlaid N400 lexical semantic-related distribution without posterior activation, which indicated a functional automatic primacy of morphological information over semantic processes. In addition, the absence of P600 in this combined condition suggests that syntactic integration process reflected on P600 will not be elicited without the reference of a syntactic relation between the constituents. To date, though LAN effect has consistently been reported mainly in the course of syntactic structural processing, or content and function word contrast [29], there were no studies with regard to orthographic deviation including latent semantic representation. N400 effect has also been explored in several studies such as the anomalous arithmetic operation or incongruent stimulus-independent semantics [30].

In the current study, ERPs to orthographic-lexical deviation was newly recorded as an earlier processing over occipital sites with regard to the lexical–morphological features and the following later processes as a signature over left fronto-cental sites recruited by lexical-semantic attributes separately. Taken together, it can be reasoned that semantic processing based on lexicality occurs after the lexical-related morphological process is completed, suggesting that the lexical meaning can be classified largely into an early structure-based process and a successive local semantics-based process. In this respect, it is possible that the linear precedence over orthographic-lexical processing including orthographic deviation was verified as the degree of salience among these information given in the anomaly information screening test.

ACKNOWLEDGEMENT

This study was conducted by research funds from Gwangju University in 2014.

REFERENCES

[1] H. Lee, K. Nam, and H. Kim, “Different ERP Patterns in Recognizing Hangul, Hanja,” and English Words, Korean Journal of Cognitive Science, vol. 7, 1996, pp. 111-140.

[2] H. Kwon, S. Kuriki, J. M. Kim, Y. H. Lee, K. Kim, and K. Nam, “MEG study on neural activities associated with syntactic and semantic violations in spoken Korean sentences,” Neuroscience Research, vol. 51, 2005, pp. 349-357.

[3] I. Bornkessel, B. McElree, M. Schlesewsky, and A. D. Friederici, “Multi-dimensional contributions to garden path strength: Dissociating phrase structure from case marking,” Journal of Memory and Language, vol. 51(4), 2004, pp. 495-522.

[4] M. Schlesewsky, I. Bornkessel, and S. Frisch, “The neurophysiological basis of word order variations in German,” Brain and Language, vol. 86, 2003, pp. 116-128.

[5] A. D. Friederici and M. Meyer, “The brain knows the difference: two types of grammatical violations,” Brain Research, vol. 1000(2), 2004, pp. 277-289.

[6] A. Beretta, C. Schmitt, J. Halliwell, A. Munn, F. Cuetos, and S. Kim, “The Effects of Scrambling on Spanish and Korean Agrammatic Interpretation: Why Linear Models Fail and Structural Models Survive,” Brain and Language, vol. 79, 2001, pp. 407-425.

[7] M. H. Davis, W. D. Marslen-Wilson, and M. G. Gaskell, “Leading Up the Lexical Garden Path, : Segmentation and Ambiguity in Spoken Word Recognition,” Journal of Experimental Psychology: Human Perception and Performance, vol. 28(1), 2002, pp. 218-244.

[8] N. Y. Y. Wicha, E. A. Bates, E. M. Moreno, and M. Kutas, “Potato not Pope: human brain potentials to gender expectation and agreement in Spanish spoken sentences,” Neuroscience Letters, vol. 346(3), 2003, pp. 165-168.

[9] R. F. Young and J. Lee, “Identifying units in interaction: Reactive tokens in Korean and English conversations,” Journal of Sociolinguistics, vol. 8(3), 2004, pp. 380-407.

[10] W. O'Grady and M. Lee, "A mapping theory of agrammatic comprehension deficits," Brain and Language vol. 92, 2005, pp. 91-100.
[11] A. D. Friederici, A. Hahne, and A. Mecklinger, "Temporal structure of syntactic parsing: Early and late event-related brain potential effects elicited by syntactic anomalies," Journal of Experimental Psychology: Learning, Memory, and Cognition, vol. 22, 1996, pp. 1219-1248.
[12] F. Rösler, T. Pechmann, J. Streb, B. Röder, and E. Hennighausen, "Parsing of sentences in a language with varying word order: Word-by-word variations of processing demands are revealed by event-related brain potentials," Journal of Memory and Language, vol. 38, 1998, pp. 150-176.
[13] C. M. Brown, P. Hagoort, and M. Kutas, *Postlexical integration process in language comprehension: evidence from brain-imaging research. In M. S. Gazzaniga, (Eds.), The Cognitive Neuroscience,* MIT Press, Cambridge, Mass., 2000.
[14] M. Kutas and S. A. Hillyard, "Event-related brain potentials to semantically inappropriate and surprisingly large words," Biological Psychology, vol. 11, 1980, pp. 99-116.
[15] A. Hahne and J. D. Jescheniak, "What's left if the jabberwock gets the semantics? An ERP investigation into semantic and syntactic processes during auditory sentence comprehension," Cognitive Brain Research, vol. 11, 2001, pp. 199-212.
[16] A. Hahne and A. D. Friederici, "Differential task effects on semantic and syntactic processes as revealed by ERPs," Cognitive Brain Research, vol. 13, 2002, pp. 339-356.
[17] T. C. Gunter, J. L. Jackson, and G. Mulder, "An electrophysiological study of semantic processing in young and middle-aged academics," Psychophyiology vol. 29(1), 1992, pp. 38-54.
[18] A. D. Friederici, A. Hahne, and D. Y. von Cramon, "First-pass versus second-pass parsing processes in a Wernicke's and a Broca's aphasic: Electrophysiological evidence for a double dissociation," Brain and Language, vol. 62, 1998, pp. 311-341.
[19] C. Van Petten, S. Coulson, S. Rubin, E. Plante, and M. Parks, "Time course of word identification and semantic integration in spoken language," Journal of Experimental Psychology: Learning, Memory, and Cognition, vol. 25, 1999, pp. 394-417.
[20] M. Palolahti, S. Leino, M. Jokela, K. Kopra, and P. Paavilainen, "Event-related potentials suggest early interaction between syntax and semantics during on-line sentence comprehenshion," Neuroscience Letters, vol. 384, 2005, pp. 222-227.
[21] A. D. Friederici, K. Steinhauer, and S. Frish, "Lexical integration: sequential effects of syntactic and semantic information," Memory and Cognition, vol. 27, 1999, pp. 438-453.
[22] P. Hagoort, M. Wassenaar, and C.M. Brown, "Syntax-related ERP-effects in Dutch," Cogintive Brain Research, 16, 2003, pp. 38-50.
[23] A. Angrilli, B. Penolazzi, F. Vespingnani, M. De Vincenzi, R. Job, L. Ciccarelli, D. Palomba, and L. Stegagno, "Cortical brain responses to semantic incongruity and syntactic violation in Italian language: an event-related potential study," Neuroscience Letters, vol. 322, 2002, pp. 5-8.
[24] L.D. Sanders, E. L. Newport, and H. J. Neville, "Segmenting nonsense: an event-related potential index of perceived onsets in continuous speech," Nature Neuroscience, vol. 5(7), 2002, pp. 700-703.
[25] M. A. Niznikiewicz, B. F. O'Donnell, P. G. Nestor, L. Smith, S. Law, M. Karapelou, M. E. Shenton, and R. W. McCarley, "ERP Assessment of Visual and Auditory Language Processing in Schizophrenia," Journal of Abnormal Psychology, vol. 106(1), 1997, pp. 85-94.
[26] M. Braun, F. Hutzler, J. C. Ziegler, M. Dambacher, and A. M. Jacobs, "Pseudohomophone Effects Provide Evidence of Early Lexico-Phonological Processing in Visual Word Recognition," Human Brain Mapping, vol. 30(7), 2009, pp. 1977-1989.
[27] P. Indefrey, P. Hagoort, H. Herzog, R. J. Seitz, and C. M. Brown, "Syntactic processing in left prefrontal cortex is independent of lexical meaning," NeuroImage, vol. 14(3), 2001, pp. 546-555.
[28] M. I. Posner and A. Pavese, "Anatomy of word and sentence meaning," Proc. Natl. Acad. Sci. USA, vol. 95, 1998, pp. 899-905.
[29] H. J. Neville, D. J. Mills, and D. S. Lawson, "Fractionating language: differenct neural subsystems with different sensitive periods," Cortex, vol. 2, 1992, pp.244-258.
[30] M. Niedeggen, F. Rösler, and K. Jost, „Processing of incongruous mental calculation problems: Evidence for an arithmetic N400 effect," Psychophysiology, vol. 36, 1999, pp. 307-324.

Choong-Myung Kim

He received the B.S., M.S in linguistics from Seoul national university, Korea in 1993,1995 respectively and also received Ph.D. in Cognitive Science from Seoul national university, Korea in 2003. Since the next year, he had been with the Behavioral Science Institute, Korea university for 3 years. Now he is working as a professor of speech-language pathology and psychology dept. at Gwangju university. His main research interests include language acquisition, speech-language pathology, and cognitive neuro-science using EEG.