http://dx.doi.org/10.17959/sppm.2018.24.2.209

Neurocognitive study on the ongoing merge of Korean vowels /e/(/ㅔ/) and /ɛ/(/ㅐ/): Comparing MMNs of younger and older generations*

Sun-Young Lee (Cyber Hankuk University of Foreign Studies)
Jiyeong Kim (Seoul National University)
Ki-Chun Nam (Korea University)
Hyeon-Ae Jeon (DGIST)
Youngjoo Kim** (Kyung Hee University)

Lee, Sun-Young, Kim, Jiyeong, Nam, Ki-Chun, Jeon, Hyeon-Ae and Kim, Youngjoo. 2018. Neurocognitive study on the ongoing merge of Korean vowels /e/(/ㅔ/) and /ɛ/(/ㅐ/): Comparing MMNs of younger and older generations. *Studies in Phonetics, Phonology and Morphology* 24.2. 209-224. This study investigated the perceptual differences of the Korean vowels, /e/(/ㅔ/) and /ɛ/(/ㅐ/) between younger and older generations, comparing their behavioral and neural responses in order to examine the ongoing phenomenon of a merge of the two phonemes in Korean. The results of the behavioral discrimination task from 20 younger and 20 older generation participants in their 20s and 50s, respectively showed high accuracy rates with no significant differences between the two groups (Older: 91%, Younger: 94%). The reaction times were also similar to each other (Older: 330 ms, Younger: 360 ms). In the same vein, the results of the ERP experiment revealed that both groups showed neural sensitivity to the phonological difference between /e/(/ㅔ/) and /ɛ/(/ㅐ/), eliciting the MMN (Mismatch Negativity) in all conditions at the frontal and central electrodes. Nevertheless, and more importantly, the MMN amplitude was significantly enhanced in the older generation in comparison with the younger generation in the case of the standard /e/ with deviant /ɛ/, but not in the reversed condition of standard /ɛ/ with deviant /e/. The findings indicate that the older generation is more sensitive than the younger in distinguishing /ɛ/ from /e/ and that the two vowels merge to /e/, not /ɛ/. The results of the different MMN amplitudes properly demonstrate the perceptual differences between the two groups conforming to the findings of the previous studies on the production of /e/ and /ɛ/ merging to /e/. The findings of this study provide neurophysiological evidence for the ongoing merge of the two vowels in Korean. **(Cyber Hankuk University of Foreign Studies, Professor, Seoul National University, Graduate Student, Korea University, Professor, DGIST, Assistant Professor and Kyung Hee University, Professor)**

---

* This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (2017S1A5A2A03067536). Principle Investigator: Youngjoo Kim

** Sun-Young Lee: First author, Youngjoo Kim: Corresponding author

Keywords: ERP, MMN, Korean vowel system, /ɛ/ (ㅐ), /e/(ㅔ), merge, phoneme distinction

1. Introduction

Korean has two types of mid front vowels: a mid-high front vowel /e/ (orthographically ㅔ) and a mid-low front vowel /ɛ/ (orthographically ㅐ). For the pronunciation of the two sounds, the highest point of the tongue is expected to be lower for /ɛ/ than it is for /e/ in standard Korean pronunciation (Lee 1996, Lee 2012). However, it has been pointed out that the distinction of the production between /ɛ/ and /e/ was lost among the younger generation in the Seoul dialect. The change in tongue position of /ɛ/, moving higher and closer to /e/, resulted in articulatory space overlap (Lee 1996, Shin 2015, Shin et al. 2013).

The ongoing phenomenon of the merge of the two sounds has been one of the most frequently examined topics in the field of Korean phonology in the past few decades since it deals with the prominent change of the vowel system of Korean. In particular, most of the studies in this line have focused on the acoustic analysis of native speakers' production of the sounds by mainly analyzing the acoustic quality of the two phonemes, showing similar results (Shin 2011, Yoon 2011, Choi 2002, Park 2011). First, in order to find the current status of the two vowels in Korean, some studies investigated the production of the two vowels by younger generations in their 20s among the same gender (e.g., Yoon 2011) and across genders (Shin 2011b). For example, Yoon (2011) analyzed Korean female speakers' production of Korean simple vowels in terms of F1 and F2, and found that /e/ and /ɛ/ were not distinguishable; the two sounds were situated as a mid-high front vowel /e/ with the F1 value of about 600 Hz and F2 value of 2,538 Hz. Similar results were also obtained in Shin's (2011b) study which compared male and female speakers in their 20s and showed similar mean values of F1 and F2 to Yoon's (2011) results. No statistically significant differences were found between the two vowels in both male and female speakers. These studies reveal that the two vowels /e/ and /ɛ/ have merged as /e/ in the Korean young generation's production.

Other studies investigated this issue from a chronological point of view by examining speakers from different generations. For example, Park (2011) examined the differences in vowel formants of the younger generation (age:10-20, n=4) and the older generation (age:60-70, n=4) using the Seoul dialect. The results showed that the mean value of the two formants (F1 and F2) of the two vowels of the younger generation did not show any significant difference while they were statistically distinguished for the older generation. The same tendency was also found in a previous study, Choi (2002), which analyzed the production data from 210 Korean speakers in their 20s to 70s. These findings provide positive evidence for the merge of the two vowels in Korean: from /ɛ/ and /e/ to /e/.

Compared to the production studies of the two vowels, fewer studies examined perceptual differences between the two vowels. A possible merge of /e/ and /ɛ/ was examined in the case of the Seoul dialect in particular. For example, differences between Seoul dialect and Kyungnam dialect speakers have been studied by Choi (2003). The study examined whether the same vowel sounds are perceived differently by Seoul dialect speakers (age:20-40; n=11) and Kyungnam dialect speakers (age: 20-40, n=11). Choi (2003) used synthesized vowel sounds created with different manipulations of two types of formants (F1 and F2). The participants heard each sound to categorize it into one of the 10 vowels. It was found that Seoul dialect speakers differentiated /e/ and /ɛ/ sounds while those were perceptually confused by Kyungnam dialect speakers. The result seems to indicate that the vowel systems are different between the two dialects in terms of perception.

However, it might have been possible to find an ongoing perceptual merge in Seoul dialect speakers, too, if age differences were taken into consideration. In other words, if we compare the younger generation with the older generation, we may find a change in the perception as in the production of Seoul dialect speakers. Moreover, consider the generation differences in the production of the two sounds found in Park (2011) and Choi (2002); Younger Seoul dialect speakers hardly distinguish the two sounds in their production while the older speakers do so. In other words, we might be able to find a tendency of the merge in the perception of the two sounds by Seoul dialect speakers if we compare the perception of the younger generation with that of the older generation.

From a different point of view, the conflicting data regarding the production and perception of Seoul dialect speakers might indicate the possible difference between the two modes of linguistic behavior, production and perception, which is well documented in the literature of language acquisition and processing. This issue should be investigated with more careful research methods to feed the discussion on the possible change of the Korean vowel system.

One of the methods to examine more directly how listeners perceive speech sounds is measuring their brain responses to the incoming sounds and sound differences using the Event Related Potentials (ERPs). In particular, the MMN (mismatch negativity) is an ERP component often used in the study of the speech sound perception. It is an increased negativity of electrical activity in our brain responding to an infrequent stimulus (i.e., deviant) against the background of a frequent stimulus or pattern (i.e., standard) (Näätänen et al. 2007). The MMN provides an index of the robustness of auditory representations at a more automatic level of processing, when attention is directed away to another modality (Näätänen 1990, Hisagi et al. 2010). In the field of linguistics, MMN has been frequently used as a measure of phonemic sensitivity of the language (e.g., Näätänen et al. 1997). As one of the representative studies, Näätänen et al. (1997) found different amplitudes of MMN between native vs. non-native phonemes. In their study, the amplitude of MMN for /õ/ upon standard /e/ was higher for the Estonians than that for the Finns; the result was ascribed to the fact that /õ/ existed in Estonian but not in Finnish, so that the Estonians were more sensitive to the contrast between the two phonemes /õ/ and /e/ than the Finns were.

Based on the findings of the previous studies regarding MMN, it seems possible to use MMN as a measure to examine the change of a phonological system in a language. For example, we can measure if the distinction of the two phonemes is perceived the same from generation to generation in order to examine any merge or split of the two phonemes. Regarding Korean phonology, it is expected that the ongoing merge of /e/ and /ɛ/, observed in Seoul dialect, would affect native speakers' perceptual processing of the two sounds and thus, be reflected not only in behavioral responses but also in brain responses. If the two sounds are in the process of merge, there would be differences between younger and older generations in terms of the MMN amplitude; the amplitude of MMN would be higher in the older generation than in the younger generation if it is different between the two groups. Previous studies of the perception of the two phonemes have been conducted using an identification task and found a possible merge of the two phonemes in Seoul dialect (Choi 2003). However, the difference between the generations has not been taken into consideration without providing more direct evidence for the chronological change of the two sounds. If it is true as shown in the previous studies on the production of the two phonemes that the younger generations do not distinguish ㅔ /e/, from ㅐ /ɛ/ anymore, producing both as ㅔ /e/, this tendency should be reflected in their perception of the two sounds as well. In other words, there should be perceptual differences between the younger and older generations which can be reflected in neural responses through the MMN: the amplitude of MMN for the difference between the two vowels will be larger for the older generation than for the younger generation.

The purpose of this study was to investigate the perceptual difference between Korean vowels, /e/ and /ɛ/, in order to examine whether the two sounds are processed differently in the younger generation and the older generation. In particular, we compared their behavioral and neural responses in the perception of the two vowels. The specific research questions are as follows:

(1) Does the Korean younger generation differ from the older generation in their behavioral responses to the perception of Korean vowels /e/ and /ɛ/?

(2) Does the Korean younger generation differ from the older generation in their brain responses (ERP) to the perception of Korean vowels /e/ and /ɛ/?

In order to observe any perceptual differences in the behavioral and neural responses, this study used a phoneme discrimination task for a behavioral task and an oddball paradigm for a brain response (ERP) task. Based on the review of previous research about the ongoing merge of the two phonemes, the hypothesis for each research question can be made as follows: (1) In their behavioral responses to the phoneme discrimination task, the Korean younger generation will not perform any better than the older generation in their phoneme discrimination task. (2) In their brain responses (ERP) to the oddball paradigm, the MMN amplitude of the Korean younger generation will not as big as that of the older generation. Furthermore, it can be expected that the MMN amplitude of the older generation will be bigger than that of the younger generation if the merge of the two phonemes are currently taking place through generations.

2. Methods

2.1 Participants

A total of 40 native Korean speakers of younger generation in their 20s (21-28 years old, M = 24.7; 10 male) and older generation in their 50s (52-59 years old, M = 56.8;

3 male) participated in our study[1]. All were right-handed Korean monolingual speakers, who have never lived outside of the capital area (Seoul, Gyeonggi Province, Incheon Metropolitan City) more than 6 months, with normal and uncorrected hearing. They all had normal or corrected vision and no history of neurological or psychiatric disorders. All participants gave written informed consent and were paid for their participation. The data of two female participants, one in the younger generation and the other in the older generation were excluded from all subsequent analysis because of high noise rate (more than 50%) in the ERP recording data, resulting in a total of 19 participants for each group: younger generation (21-28 years old, M = 24.8; 9 male) and older generation (52-59 years old, M = 56.7; 3 male).

2.2 Stimuli & Procedure

Two different Korean monosyllable sounds, /e/ and /ɛ/, combined with consonant /g/ were used in the experiment: /ke/ (게) and /kɛ/ (개)[2]. The stimuli were provided by the National Institute of Korean Language and were naturally recorded by a male native Korean, who can produce the distinguishing sounds of /e/ and /ɛ/. The stimuli were normalized in amplitude, intensity and controlled in duration (590 ms). To preserve the naturalness of the originally produced utterances, no further manipulation was conducted. All participants were introduced to a sound-attenuated shield room and sat approximately 70 cm in front of a computer screen. The sound stimuli were presented binaurally via headphones and the sounds were set to a comfortable volume. Stimuli were presented using PsychoPy (Psychology software in Python, www.psychopy.org).

2.3 Behavioral Experiment

For the behavioral experiment, a simple AX discrimination task was prepared. The

---

[1] An anonymous reviewer suggested to select much older generation such as those in their 70s instead of 50s for comparison. However, it was thought that MMN is sensitive enough to show subtle difference if there is between these two groups.

[2] No other sounds or fillers were used in the experiments because of any other possible effects that might have on the results. One anonymous reviewer mentioned possible effects of frequency of the words or sounds (e.g., using different consonants with the same vowels) which can be another research question in the further research.

participants were presented pairs of two consequent stimuli over headphones at a comfortable listening level and were asked to judge if each pair of sounds are the same or different as quickly and accurately as possible by pressing buttons, either “M (=same)” or “N (=different)”. Participants were given 1,500 ms to respond to each trial. Every possible pairwise combination of the two stimuli was prepared in order to balance the order of presentation: (i) /ke/-/kɛ/, (ii) /kɛ/-/ke/, (iii) /ke/-/ke/, and (iv) /kɛ/-/kɛ/. Each combination was presented five times making a total of 20 trials presented pseudo-randomly.

2.4 ERP Experiment

The sound stimuli were designed in two five-minute blocks (ISI=400 ms): (i) Condition 1: standard /ke/ (게) with deviant /kɛ/ (개) and (ii) Condition 2: standard /kɛ/ (개) with deviant /ke/ (게) (see Table 1). The block order was counter-balanced across the participants. Using the oddball paradigm, each block consisted of 250 standard and 50 deviant stimuli, and the blocks were also pseudo-randomized. During the EEG recording, the participants were told to ignore the series of sounds and to concentrate on the silent movie: “Oggy and the Cockroaches, 2013.” The participants were asked to sit quietly and avoid excessive eye and other movements. A short break was given between the ERP experiment and the behavioral test.

Table 1. ERP Experiment Stimuli Conditions

Condition	Standard (k = 250)	Deviant (k = 50)
Condition 1	/ke/	/kɛ/
Condition 2	/kɛ/	/ke/

2.5 EEG Recordings and ERP Analysis

EEGs were continuously recorded with Brainamp (Brain Products GmbH, München, Germany) from 32 Ag/AgCl electrodes according to the 10-20 system. Online filtering was set as 0.1 Hz – 70 Hz, the sampling rate was 500 Hz, and the interelectrode impedances were kept below 20 kΩ. To detect eye movements more precisely, four electrodes were used as a vertical electro-oculogram (VEOG) and a horizontal electro-oculogram (HEOG). Further offline data processing included a re-

referencing to the averaged left/right mastoids and a digital bandpass filter set to 0.2-30 Hz using the Brain Vision Analyzer 2.0 software (Brain Products GmbH, München, Germany). EEG data for individual participants were also examined for eye movements and other artifacts. For each participant, the averaged MMN responses contained at least 75% accepted deviant trials in each condition. As there were two different conditions for each participant, ERP responses in the two conditions were analyzed separately. Then, EEG data were epoched from −100 to 750 ms relative to stimulus onset and baseline corrected (100 ms pre-stimulus interval).

The MMN was calculated by subtracting the ERP response of the standard stimulus from that of the equivalent deviant stimulus. For statistical analysis, repeated-measures ANOVAs were performed on six representative lateral (F3, F4, C3, C4, P3, P4) and three midline (AntMid = Fz, CenMid = Cz, PosMid = Pz) electrodes, as effects were most prominent at these electrodes. For the lateral electrodes, analysis involved Group as a between-subjects factor (younger generation, older generation) and Anterior-Posterior (Anterior= F3 and F4, Central = C3 and C4, Posterior = P3 and P4) as the within-subjects factor. The same factors were also applied to the midline electrodes. The Greenhouse-Geisser correction was applied to all analyses when necessary and corrected p values are reported.

3. Results

3.1 Behavioral Results

For the analysis of the AX discrimination task, accuracy rates and response times were calculated for each group, and data from participants with lower accuracy rate (less than 50%) were excluded: two from the older generation and one from the younger generation were excluded[3], thus finally a total of 35 participants (Younger Group = 18, Older Group = 17) were further analyzed in the behavioral data. Preliminary analysis of the behavioral data across four conditions did not show any statistically significant difference, so that all the data were combined for group comparison. Table 2 below

[3] The excluded three participants in the older and younger generations showed consistently wrong answers in a specific type of stimulus (in which the expected answers are identical as "same" or "different"). A closer examination of their data found that they pushed a wrong key during the whole experiment.

displays the accuracy rates and reaction time for each group. A statistical analysis using a t-test showed no significant difference in the mean accuracy rates between the two groups ($t(33)=1.340$, $p = 0.189$). Furthermore, the average reaction time (RT) showed no significant difference between the two groups ($t(33) = 0.6\text{-}9$, $p = 0.546$).

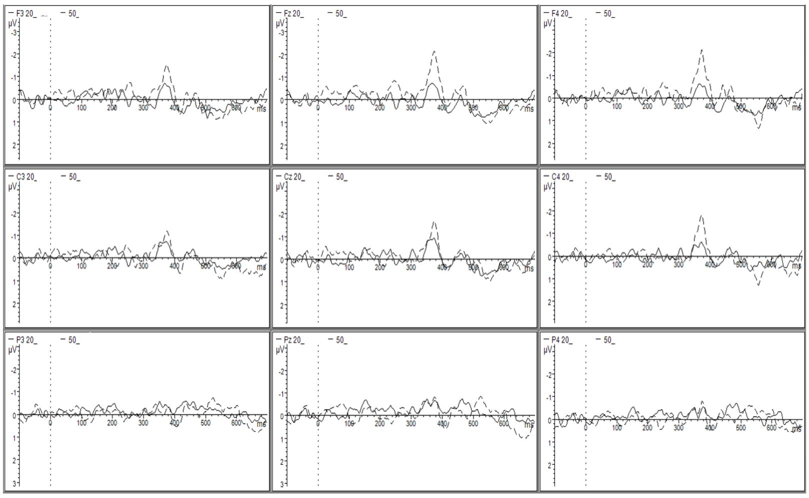
Table 2. Mean Accuracy & Reaction Time for the AX Discrimination Task

Group	Accuracy (%)		Reaction Time (ms)	
	Mean	*SD*	*Mean*	*SD*
Younger	94.44	7.84	366.23	159.38
Older	90.59	9.16	338.57	101.97

3.2 ERP Results

The ERP results for each condition are presented below. The comparisons are based on the difference waves from the two groups.

In Condition 1 (standard /ke/ with deviant /kɛ/), the following time windows were selected based on the visual inspection of the grand averages: 300-400 ms, 400-500 ms, 500-600 ms. Throughout the three time windows, statistical significance was only found in the 300-400 ms time window. The difference between the younger generation and older generation was overall significant in the frontal area as presented in Figure 1 and 2. Anterior*Group interaction was shown to be significant. Then, the Anterior*Group interaction was analyzed with the Mixed model, and Greenhouse-Geisser correction was conducted due to the violation of sphericity ($F(1.18, 42.40) = 4.557$, $p = .033$). In the post-hoc analysis, a significant difference was observed in frontal medial sites (F3, F4): Younger generation M = -.126, SD = .58; Older generation M = -.660, SD = .680; $t(36) = 2.592$, $p = .014$. For the analysis with midline, AnteriorMid*Group interaction also showed a significant difference ($F(2,35) = 4.39$, $p = .02$). The post-hoc analysis of Fz indicated a significant difference between the two groups (Younger generation: M = -.18, SD = .78; Older generation: M = -.85, SD = .78). Figure 1 shows the grand average difference waves of the two groups.

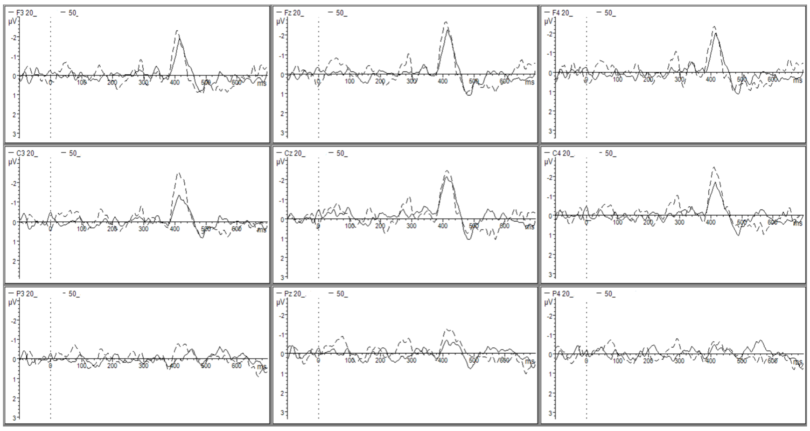


--- Older generation – younger generation

Figure 1. Grand average difference waves of the younger group and the older group (Condition 1)

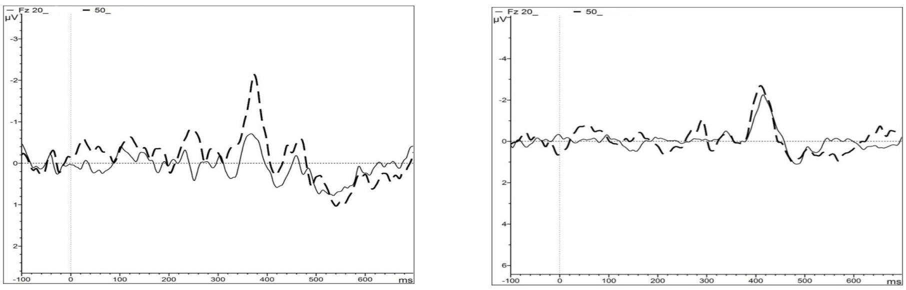
In Condition 2 (standard /kɛ/ with deviant /ke/), the following time windows were selected based on the visual inspection of the grand averages: 300-400 ms, 350-500 ms, 500-600 ms. Other than the 350-500 ms time window, no significant effect was found. In the time window of 350-500 ms, the main effect was only significant in Anterior sites ($F(2,35) = 10.066$, $p < .05$). There was no group difference in Condition 2 contrary to Condition 1 (Younger: M = -.37, SD = .71; Older: M = -.48, SD = .91). Anterior*Mid*Group interaction was shown to be significant ($F(2,35) = 6.497$, $p < .05$). The post-hoc analysis indicated no significant interaction in Anterior*Group analysis. Figure 2 shows the grand average difference waves of all the sites for Condition 2.

Now, the different brain responses between Condition 1 and Condition 2 are well depicted in Figure 3 showing the difference waves of the two groups in the two conditions. The MMN amplitude of the older generation is higher than that of the younger generation in (a) Condition 1 whereas no significant differences between the two groups are shown in (b) Condition 2.



--- Older generation – younger generation

Figure 2. Grand average difference waves of the younger group and the older group (Condition 2)



(a) Condition 1 (b) Condition 2

--- Older generation – younger generation

Figure 3. Difference waves of the younger group and the older group at Fz site (Condition 1 & 2)

4. Discussion

This study investigated perceptual differences between the Korean vowels /e/ and /ɛ/ in order to find any psychologically real evidence for the merge of the two vowels. A behavioral experiment was conducted to examine native speakers’ ability to hear the differences between the two sounds. An ERP experiment was also conducted to find possible different neural responses to the two sounds between younger and older generations which might not be revealed in the behavioral task. The results of the two experiments are discussed here according to our research questions set out for this study.

The first research question was concerned with behavioral differences between the younger and older generations in their perception of Korean vowels, /e/ and /ɛ/. The results of the AX discrimination task revealed that there was no statistically significant difference between the younger generation and the older generation in terms of the accuracy and response times in their perception of Korean vowels /e/ and /ɛ/. Both groups distinguished the two sounds well with high accuracy rates (over 90%) with similar response time in their behavioral task. These results indicate that the different acoustic properties of the two phonemes can be noticeable when they are presented parallel as in this AX discrimination task (i.e., the same or different task) even though it might be difficult to identify each sound when it is presented by itself (/e/ or /ɛ/) or embedded in a word. The results also conform to the findings of Choi (2003) that the two vowel sounds were perceived differently by Seoul dialect speakers of age range of 20-40. In contrast, compared to these data from perception studies, remember, the data from production studies showed different results; the production of the two sounds by the Seoul dialect speakers (especially the younger generation) did not distinguish the two sounds in terms of their F1 and F2. Still, the older generation produced the two sounds differently. Now, taken together, these findings seem to indicate that the merge of the two sounds starts with production, which is plausible since the younger generation still understands the speech of the older generation. As the younger generation gets older, their ability to distinguish the two sounds might get weaker in their perception because they get fewer chances to hear the two different sounds from the older generation. In any case, the results of the behavioral study do not show any indication of a merge of the two sounds in the perception of the Seoul dialect speakers, either young or old speakers.

Now, the second research question of this study relates to the brain responses to the two sounds in order to find out if the Korean young generation differs from the old generation in electrophysiological responses to the perception of Korean vowels /e/ and /ɛ/. The answer to this question turned out to be positive. The MMN was elicited in all conditions at the frontal and central electrodes for both groups, which means that both groups distinguished the two sounds, /e/ and /ɛ/. However, more importantly, the MMN amplitude was significantly enhanced in the older generation in comparison to the younger generation in the case of the standard /e/ with deviant /ɛ/ condition. The results indicate that the older generation was more sensitive than the younger generation to the distinction between /ɛ/ and /e. This also conforms to the previous findings that the two sounds are in the process of merge, not of split, in the Korean vowel system.

Moreover, notice that the significant difference between the two generation groups in terms of the MMN amplitude was found in Condition 1 with the standard /e/ and deviant /ɛ/, but not in Condition 2 with standard /ɛ/ and deviant /e/. This resulted from the relatively low MMN amplitude of the young generation in Condition 1 with standard /e/ and deviant /ɛ/; when younger speakers were provided with the sound /e/ which is the sound the two vowels are merging to, they were less sensitive to the deviant sound /ɛ/ compared to the older generation. This result conforms to the previous finding that MMN is more prominent when the standard sounds are from the phonemic inventory of the listeners' native language and the deviant sounds are not (Näätänen 1997). On the other hand, when they were provided with standard /ɛ/, younger speakers were able to notice the deviant /e/ with similar sensitivity to the older generation. The sound change seems to be noticeable to both groups with similar sensitivity because it would be easier to hear the difference once they got to be trained to the standard sound (whatever it is) and hear the sound (deviant) that they have in their phoneme inventory. These results provide neurophysiological evidence for the direction of the merge of the two vowels to /e/ rather than /ɛ/.

In addition, the MMN data provides us with information that might not be able to be obtained in the behavioral data. The generation difference revealed in the ERP experiment was not captured in our behavioral experiment with a sound discrimination task; both groups were good at discriminating the two sounds from each other, with high accuracy rates (Older: 91%, Younger: 94%) and similar response time (Older: 330ms, Younger 360ms). This proves that measuring the listeners' brain responses with ERPs using MMN reveals the listeners' phonemic sensitivity more precisely and accurately compared to a behavioral task such as a sound discrimination task.

In sum, the findings of this study provide a new piece of neurophysiological evidence for the on-going merge of the two Korean vowels /ɛ/ ㅐ and /e/ ㅔ in the direction of /e/ ㅔ. The data also provide parallel results to the findings from previous studies on the production of the two vowels (e.g., Choi 2003, Shin 2011, Yoon 2011, Choi 2002, Park 2011). The younger generation's ability to perceive the two sounds differently are weaker than the older generation's. This direction of the change conforms to the phenomenon of a merge, not a split.

5. Conclusion

This study examined the perceptual difference between Korean vowels, /e/ (/ㅔ/) and /ɛ/ (/ㅐ/), using behavioral and neurophysiological methods. We investigated the perceptual difference between the two Korean vowels by comparing the responses in a behavioral discrimination task and through neural mismatch negativity (MMN) in order to examine any differences between the younger generation and the older generation. The results revealed the older generation was more sensitive than the younger generation in distinguishing /ɛ/ from /e/ in their brain responses even though this difference was not captured in the behavioral discrimination task. The different brain responses properly reflect the perceptual difference in the two groups in accordance with the previous observation for /e/ and /ɛ/. In conclusion, the findings provide neurophysiological evidence for the merge of the two vowels for us to better understand the changes of the Korean vowel system.

The findings of this study can be also useful information in the field of Korean language teaching as well as in Korean linguistics. For example, the acquisition of the two phonemes by L2 learners of Korean can be tested not only using behavioral tasks such as discrimination and distinction tasks but also using MMN. In addition, we have to consider the difference between perception and production of the two sounds by native speakers: a merge in the production, but not in the perception yet. Therefore, it would not be appropriate to force learners to pronounce the two sounds differently in the classroom since the native speakers apparently also have difficulty in doing so. As for perception, however, learners should be encouraged to distinguish the two sounds in listening since native speakers can do so well in their behavioral tasks such as AX discrimination task.

REFERENCES

CHOI, HYEWON. 2002. *Research on Standard Pronunciation (Vol.2).* Seoul: The National Institute of the Korean Language.

CHOI, YANGKYU, HYUNJUNG SHIN, and OH-SIK KWON. 1997. A study on the differences between vowel perception of Seoul and Kyungnam dialectal speakers = The perception of vowels synthesized in vowel space by F_1 and F_2. *Speech Science* 1, 201-211.

CHOI, YANGKYU. 2003. Perceptual vowel space and mental representation of Korean single vowels. *Speech Science* 10.2, 287-301.

HISAGI, MIWAKO, VALERIE L. SHAFER, WINIFRED STRANGE, and ELYSE S. SUSSMAN. 2010. Perception of a Japanese vowel length contrast by Japanese and American English listeners: Behavioral and electrophysiological measures. *Brain Research* 1360, 89-105.

LEE, HOYOUNG. 1996. *Korean Phonetics*. Paju: Thaehaksa.

LEE, JINHO. 2012. *Standard Pronunciation and Actual Pronunciation of Korean*. Acanet.

NÄÄTÄNEN, RISTO. 1990. The role of attention in auditory information processing as revealed by event-related potentials and other brain measures of cognitive functions. *The Behavioral and Brain Sciences* 13, 201-288.

NÄÄTÄNEN, RISTO, LEHTOKOSKI, A., LENNES, M., CHEOUR, M., HUOTILAINEN, M., IIVONEN, A., and ALLIK, J. 1997. Language-specific phoneme representations revealed by electric and magnetic brain responses. *Nature* 385.6615, 432.

NÄÄTÄNEN, RISTO, P. PAAVILAINEN, T. RINNE, and K. ALHO. 2007. The mismatch negativity(MMN) in basic research of central auditory processing: A review. *Clinical Neurophysiology* 118, 2544-2590.

PARK, JIYOON. 2011. Formant measurement of /ㅔ/ and /ㅐ/ between old and young generations within Seoul-focusing on articulatory phonetic features and spectrogram. *Korean Education* 88, 295-313. The International Association for Korean Language Education.

SHIN, JIYOUNG. 2011. Phonology and 'Regulation of Korean (Eomungyujeong)'. *Korean Linguistics*, 50, 29-49.

SHIN, JIYOUNG, JIEUN KIAER and JAEEUN CHA. 2013. *The Sounds of Korean*. Cambridge: Cambridge University Press.

SHIN, JIYOUNG. 2015. Vowels and consonants. Lucien Brown and Jaehoon Yeon (eds.). *The Handbook of Korean Linguistics*, 3-21. Oxford: Wiley Blackwell.

YOON, EUNKYUNG. 2011. Teaching Pronunciation of Korean Vowels Based on Acoustic Analysis. *Journal of Korean Language Education* 22.2, 281-302.

Sun-Young Lee (Professor)
Department of English
Cyber Hankuk University of Foreign Studies
107, Imun-ro, Dongdaemun-gu, Seoul
Korea 02450
e-mail:alohasylee@cufs.ac.kr

Jiyeong Kim (Graduate Student)
Department of Linguistics
Seoul National University
1, Gwanak-ro, Gwanak-gu, Seoul
Korea 08826
e-mail: kimjy04@snu.ac.kr

Ki-Chun Nam (Professor)
Department of Psychology
Korea University
145 Anam-ro Seongbuk-gu, Seoul
Korea 02841
e-mail: kichun@korea.ac.kr

Hyeon-Ae Jeon (Assistant Professor)
Department of Brain and Cognitive Sciences
DGIST (Daegu Gyeongbuk Institute of Science and Technology)
333 Techno jungang-daero, Daegu
Korea 42988,
e-mail jeonha@dgist.ac.kr

Youngjoo Kim (Professor)
Department of Korean Language
Kyung Hee University
Deokyoungdaero Yongin, Gyunggido
Korea 17104
e-mail: yjkims@khu.ac.kr

received: August 7, 2018
revised: August 16, 2018
accepted: August 22, 2018