

**Comparison and Merger of Korean Mid Front Vowels on L1 and L2 Speakers**

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### **Abstract**

While the two Korean mid-front vowels “ㅐ” and “ㅔ” (/e/ and /ɛ/ respectively) are undergoing a merger (Igeta and Arai 2011, Kang 2013, Lee 2005), little has attempted to examine the merger among L2 learners of Korean. In this project, a production and perception experiments were conducted with both native Korean speakers and Mandarin-speaking Korean learners. In the production experiment, both groups of speakers were asked to read carrier sentences containing minimal pairs of /e/ and /ɛ/. In the perception experiment, different groups of speakers were asked to identify the vowels from the recordings obtained from the production experiment. The findings derived in this project shed light on the degree of vowel merger in L1 and L2 Korean speakers, respectively.

*Keywords:* Korean, mid front vowel, merger

## 1. Introduction

When learning Korean vowels for the first time, many learners encounter the same problem—the distinction of “ㅏ” and “ㅑ”, in that most of the Korean teachers instruct students to pronounce both vowels as /e/. However, the existence of minimal pairs such as 모래 /mo.le/ ‘the day after tomorrow’ and 모래 /mo.ɛ/ ‘sand’ indicates that the assumed merger didn't exist phonologically. This phenomenon got me interested in finding how close the two vowels are acoustically and perceptually for both Korean native speakers and Mandarin-speaking L2 learners of Korean.

The research questions are:

1. Are “ㅏ” and “ㅑ” produced differently for native speakers and L2 learners of Korean in terms of vowel space? Are the formant values of “ㅏ” and “ㅑ” distinctive? Are they sufficiently distinctive and comparable to the conventional /e/ and /ɛ/, respectively?
2. How far are the perceptual distances between “ㅏ” and “ㅑ” for native speakers and L2 learners? Do they perceive them as different vowels?

## 2. Literature Review

### 2.1 Native Speakers' Production of the Mid Front Vowels

The ongoing merger of Korean vowels “ㅏ” (/e/) and “ㅑ” (/ɛ/), is widely discussed in the academia (Igeta and Arai 2011, Kang 2013, Lee 2005). According to

Igeta and Arai (2011) and Kang (2013), the similarity of formant values demonstrated the overlapping vowel space of /e/ and /ɛ/. Nevertheless, Lee (2005) argued that the merger was not absolute based on evidence from regional dialects. Yoon et al. (2015) backed up Lee's opinion by presenting the geographical differences in the vowel merger. Some scholars discussed this merger in respect of the relation between perceptual distance and confusion rate (Lee 2017). However, age and gender factors play a major role in this ongoing merger. While Yang (1996) claimed that Korean female speakers might not make a distinction between /e/ and /ɛ/, Eychenne & Jang (2015) proposed that young Seoul women can differentiate the vowels in perception but not in production. Lee et al. (2018) adopted neurocognitive approaches to compare older and younger generations' ability in distinguishing the two vowels perceptually and confirm that /ɛ/ is merging into /e/ for both generations.

## **2.2 Nonnative Speaker's Perception and Production of the Mid Front Vowels**

Kim and Oh (2015) found the L1 influence on L2 from Chinese and English learners of Korean. Hwang and Moon (2005) suggested that the distributions of “ㅏ” and “ㅑ” in Korean are different from those of /ɛ/ and /æ/ in English, implicating the same IPA symbol in different languages may represent different positions in a vowel space. However, Yoon (2013) reported the similarities among Korean and English mid front vowels. Heo and Park (2012) further pointed out Korean “ㅏ” corresponds to

both /eɪ/ and /ɛ/ in English. In addition, Yang et al. (2017) found that Mandarin learners also confused the two mid-front vowels in Korean and further suggested a strong L1 influence on learners' acquisition of Korean vowels and the potential merger.

### **2.3 My Study**

The main focus of this proposed project is to compare Korean native speakers and Mandarin learners of Korean's production and perception of the two Korean mid front vowels, “ㅔ” and “ㅚ”. The result comparison between the two groups will shed light on the degree of vowel merger in Korean native speakers and L2 learners. The goal is to attest that the “ㅔ - ㅚ” merger also exists in L2 learners and that the merger direction is parallel to previous research.

## **3. Production Experiment**

There were two experiments—one production and one perception. In the production experiment, subjects were asked to produce sentences containing minimal pairs of the two target vowels. In the perception experiment, an identification task is implemented, in which subjects were asked to identify the vowel they have heard. Both native Korean speakers and Mandarin-speaking learners of Korean were recruited to complete the two experiments.

### 3.1 Subjects

Six subjects (3 males and 3 females; mean age, 23.5 years; SD, 3.56) were recruited voluntarily from National Taiwan University, including 2 Korean native speakers (subject 1 and subject 2) and 4 nonnative speakers. Nonnative speakers were Mandarin-speaking and had taken Korean courses for at least one year. Subject 1, subject 3, and subject 5 were the three female participants. All subjects must complete both the production experiment and the perception experiment.

### 3.2 Stimuli

The production experiment required subjects to read and record their natural utterances of the 9 minimal pairs provided in Table 1. To make sure they speak naturally, the carrier phrase used was 나는 \_\_\_\_ (이)라고 했다 /na.nun. \_\_\_\_ (i.)la.go.hɛd.da/ ‘I said \_\_\_\_.’

Table 1. Korean (near) minimal pairs of “ㄱ” and “ㄴ”.

게 /ge/ “crab”	개 /gɛ/ “dog”
세 집 /z̥ <sup>h</sup> e.d͡ʒib/ “three houses”	새 집 /z̥ <sup>h</sup> ɛ.d͡ʒib/ “new house”
모레 /mo.le/ “the day after tomorrow”	모래 /mo.lɛ/ “sand”
세로 /z̥ <sup>h</sup> e.lo/ “height, length”	새로 /z̥ <sup>h</sup> ɛ.lo/ “newly”
데모 /de.mo/ “demo”	대모 /dɛ.mo/ “godmother”
게임/ge.im/ “game”	개인 /gɛ.in/ “individual”
세다 /z̥ <sup>h</sup> e.da/ “tough”	새다 /z̥ <sup>h</sup> ɛ.da/ “leak”
메일 /me.il/ “email”	매일 /mɛ.il/ “everyday”
제산 /d͡ʒ <sup>j</sup> e.z̥ <sup>h</sup> an/ “division”	재산 /d͡ʒ <sup>j</sup> ɛ.z̥ <sup>h</sup> an/ “asset”

Subjects were also asked to pronounce other 20 filler words, which were mixed with the minimal pairs to veil the purpose of this experiment. Table 2 was the word list containing 18 target words and 20 filler words, and was presented to the subjects to read it aloud. These filler words are related to the minimal pairs in the following aspects:

- same lexical category, e.g., ‘cat’ and ‘dog’;
- loanwords, e.g., ‘gain’ and ‘game’;
- minimal pairs of a different set of vowels, e.g., ‘mile’ and ‘email’; and
- unrelated, e.g., ‘wallet’ and ‘shrimp’

Table 2. Scattered carrier phrases that contain minimal pairs and filler words.

나는 개 라고 했다	/na.nwun.gɛ.la.go.hɛd.da/	I said “dog”.
나는 지갑 이라고 했다	/na.nwun.dʒʲi.gab.i.la.go.hɛd.da/	I said “wallet”.
나는 대모 라고 했다	/na.nwun.dɛ.mo.la.go.hɛd.da/	I said “godmother”.
나는 미래 라고 했다	/na.nwun.mi.lɛ.la.go.hɛd.da/	I said “future”.
나는 개인 이라고 했다	/na.nwun.gɛ.in.i.la.go.hɛd.da/	I said “individual”.
나는 서로 라고 했다	/na.nwun.ɯ̹ʌ.lo.la.go.hɛd.da/	I said “each other”.
나는 새우 라고 했다	/na.nwun.ɯ̹ʌ.u.la.go.hɛd.da/	I said “shrimp”.
나는 세 집 이라고 했다	/na.nwun.ɯ̹ʌ.dʒʲib.i.la.go.hɛd.da/	I said “three houses”.
나는 게 라고 했다	/na.nwun.ge.la.go.hɛd.da/	I said “crab”.
나는 새다 라고 했다	/na.nwun.sɛ.da.la.go.hɛd.da/	I said “leakage”.
나는 늙다 라고 했다	/na.nwun.nwɭg.da.la.go.hɛd.da/	I said “old”.
나는 게임 이라고 했다	/na.nwun.ge.im.i.la.go.hɛd.da/	I said “game”.
나는 새 라고 했다	/na.nwun.ɯ̹ʌ.la.go.hɛd.da/	I said “bird”.
나는 메일 이라고 했다	/na.nwun.me.il.la.go.hɛd.da/	I said “email”.

나는 모레 라고 했다	/na.nwun.mo.le.la.go.hɛd.da/	I said “the day after tomorrow”.
나는 핸드폰 이라고 했다	/na.nwun.hɛn.dw.pon.i.la.go.hɛd.da/	I said “cell phone”.
나는 새로 라고 했다	/na.nwun.ɯ̥lo.la.go.hɛd.da/	I said “newly”.
나는 새다 라고 했다	/na.nwun.ɯ̥da.la.go.hɛd.da/	I said “leak”.
나는 매일 이라고 했다	/na.nwun.mɛ.il.i.la.go.hɛd.da/	I said “everyday”.
나는 세기 라고 했다	/na.nwun.ɯ̥gi.la.go.hɛd.da/	I said “century”.
나는 소개 라고 했다	/na.nwun.ɯ̥o.gɛ.la.go.hɛd.da/	I said “introduce”.
나는 시계 라고 했다	/na.nwun.ɯ̥gi.gjɛ.la.go.hɛd.da/	I said “watch”.
나는 폭 이라고 했다	/na.nwun.pʰog.la.go.hɛd.da/	I said “width”.
나는 컵 이라고 했다	/na.nwun.kʰʌb.la.go.hɛd.da/	I said “cup”.
나는 소다 라고 했다	/na.nwun.ɯ̥o.da.la.go.hɛd.da/	I said “soda”.
나는 세다 라고 했다	/na.nwun.ɯ̥e.da.la.go.hɛd.da/	I said “tough”.
나는 펜 이라고 했다	/na.nwun.pʰen.la.go.hɛd.da/	I said “pen”.
나는 책 이라고 했다	/na.nwun.tɕʰɛg.la.go.hɛd.da/	I said “book”.
나는 고양이 라고 했다	/na.nwun.go.jaŋ.i.la.go.hɛd.da/	I said “cat”.
나는 새 집 이라고 했다	/na.nwun.ɯ̥ɕib.go.hɛd.da/	I said “new house”.
나는 데모 라고 했다	/na.nwun.de.mo.la.go.hɛd.da/	I said “demo”.
나는 높이 라고 했다	/na.nwun.nob.i.la.go.hɛd.da/	I said “height”.
나는 세로 라고 했다	/na.nwun.se.lo.la.go.hɛd.da/	I said “height, length”.
나는 모래 라고 했다	/na.nwun.mo.lɛ.la.go.hɛd.da/	I said “sand”.
나는 재산 이라고 했다	/na.nwun.dzʰɛ.ɯ̥an.i.la.go.hɛd.da/	I said “asset”.
나는 바다 라고 했다	/na.nwun.ba.da.la.go.hɛd.da/	I said “sea”.
나는 대부 라고 했다	/na.nwun.dɛ.bu.la.go.hɛd.da/	I said “godfather”.
나는 마일 이라고 했다	/na.nwun.ma.il.la.go.hɛd.da/	I said “mile”.
나는 제산 이라고 했다	/na.nwun.dzʰe.ɯ̥an.la.go.hɛd.da/	I said “division”.

### 3.3 Procedures

The subjects were recorded in a quiet room on campus. The recording program were Praat (Boersma & Weenink 2020) installed on an Asus ZenBook



UX510UXK, and the recording were made with the default setting at the sampling frequency at 44.1 Hz.

### **3.4 Data Analysis**

After collecting the data, the formant values (especially F1 and F2) were obtained by Praat (Boersma and Weenink 2020). The most stable segments were observed to avoid influences from adjacent consonants. Vowel quadrilaterals of native and nonnative speakers were diagrammed. Afterwards, a mixed effect ANOVA were implemented for the formant values F1 and F2 using analysis software R (R Core Team 2018) in order to examine the inter- and intra-subject difference and variability. Speakers' "gender" and "native language" were the between-subject factors and "vowel" was the within-subject factor.

### **3.5 Results**

Significant difference was only found in "gender", but not in "vowel" nor "native language" according to the mixed-effect ANOVA analysis. In other words, the production results indicated that the /e/-/ɛ/ merger appeared on Korean speakers, regardless of gender and native language. Moreover, though every subject did not distinguish the two vowels, individual differences existed between subjects.

## **4. Perception Experiment**

### **4.1 Subjects**

The subjects were the same six subjects who had participated in the production experiment.

## **4.2 Stimuli**

The stimuli each subject heard in the perception experiment were other subjects' recordings obtained from the production experiment. Every subject had to listen to 90 sentences, which contained 18 minimal pair words of the other 5 subjects.

## **4.3 Procedures**

In the perception experiment, the recordings from the production experiment were utilized as stimuli. Subjects participated in an identification task where they first listen to a stimulus and then determine whether the vowel they heard was “ㅏ” or “ㅑ”. The experiments were run on Praat. The subjects were asked to distinguish between the two vowels in carrier phrases by clicking on one of the icons (“ㅏ” or “ㅑ”) before they moved on to the next trial. Stimuli in each trial could repeat ten times in case of distractions. During the task, subjects' responses and reaction times were recorded.

## **4.4 Data Analysis**

A subject's accuracy rate was first compared with his own production experiment results by using analysis software R (R Core Team 2018). For both the native speakers and the L2 learners, the comparison between one's production and perception can shed light on whether subjects can differentiate the two vowels by both

listening and reading. Moreover, each subject, native or nonnative, heard other subjects' recordings in the perception task. This was a further attempt to examine whether native speakers perceived nonnative speakers' vowel production differently, and/or vice versa.

## Results

As suggested by the production experiment results, subjects performed poorly on the vowel identification task.

## 5. General Discussion

As a reminder, the aim of this study is to answer the following research questions:

1. Are “ㅓ” and “ㅕ” produced differently for native speakers and L2 learners of Korean in terms of vowel space? Are the formant values of “ㅓ” and “ㅕ” distinctive? Are they sufficiently distinctive and comparable to the conventional /e/ and /ɛ/, respectively?
2. How far are the perceptual distances between “ㅓ” and “ㅕ” for native speakers and L2 learners? Do they perceive them as different vowels?

The first question will be justified in **Production Discussion** while the second will be discussed in **Perception Discussion**.

### 5.1 Production Discussion

### 5.1.1 Overall Results

#### *Within Subjects*

To account for the differences between /e/ and /ɛ/, we conducted t-tests on the F1, F2, and F3 values of subjects. F1 value influences height, while F2 value determines frontness, F3 indicates roundness. Since neither /e/ and /ɛ/ are rounded vowels, plus the fact that F3 t-test results did not demonstrate significance (see Table 15 in appendix), F3 values were excluded from future discussions.

The t-test results indicated that the six subjects did not differentiate the two phonemes, neither by F1 nor by F2, as collected in Table 3.

Table 3. Two-sided paired t-test comparing each subject's formant values of /e/ and /ɛ/

Subject number	Formant	Df	95% confidence interval		p value
Subject 1	F1	8	-127.44097	81.34812	.6244371
Subject 1	F2	8	-184.5985	194.4336	.9537539
Subject 2	F1	8	-69.90018	36.25360	.4856857
Subject 2	F2	8	-155.9413	136.2472	.8803327
Subject 3	F1	8	-63.45524	106.61970	.5745082
Subject 3	F2	8	-43.76794	174.90759	.2040633
Subject 4	F1	8	-32.61779	18.11138	.5281475
Subject 4	F2	8	-80.28093	79.17224	.9876001
Subject 5	F1	8	-110.16566	73.94519	.6621238
Subject 5	F2	8	-125.2022	174.7527	.7131672
Subject 6	F1	8	-62.70326	45.77741	.7283116
Subject 6	F2	8	-71.56982	174.13357	.3639409

All results had not shown significance (i.e., no  $p < 0.05$ ), thus rejecting the null hypothesis that “ㅏ” and “ㅑ” are separate phonemes. In other words, for native speakers and L2 learners, they produced the two words with the same tongue height and frontness.

Moreover, to discuss whether the distribution of the target vowels in the subjects' vowel quadrilateral, we use X-Y scatter plots to demonstrate the positions in 95% confidence eclipses, as Figure 1 through Figure 6 presented.

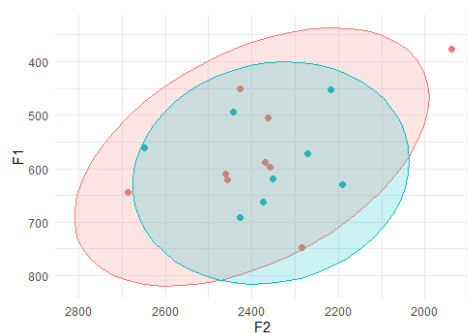


Figure 1. Vowel distribution of subject 1



Figure 2. Vowel distribution of subject 2

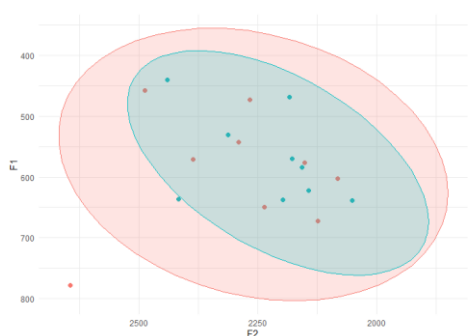


Figure 3. Vowel distribution of subject 3

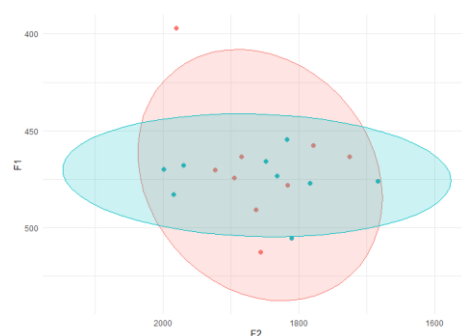


Figure 4. Vowel distribution of subject 4

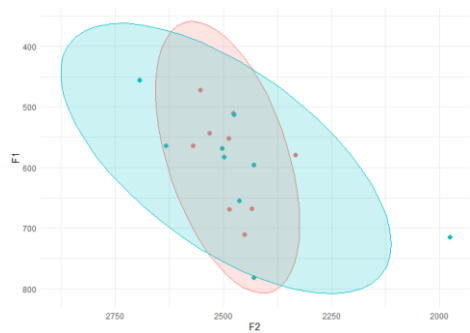


Figure 5. Vowel distribution of subject 5

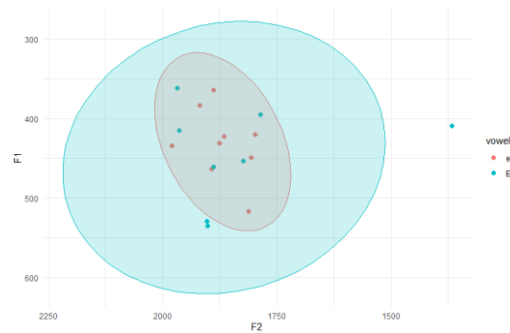


Figure 6. Vowel distribution of subject 6

Figure 7 integrated all subjects as one group and diagrammed the high similarity between /e/ and /ε/, as the areas on the vowel quadrilateral were largely collided.

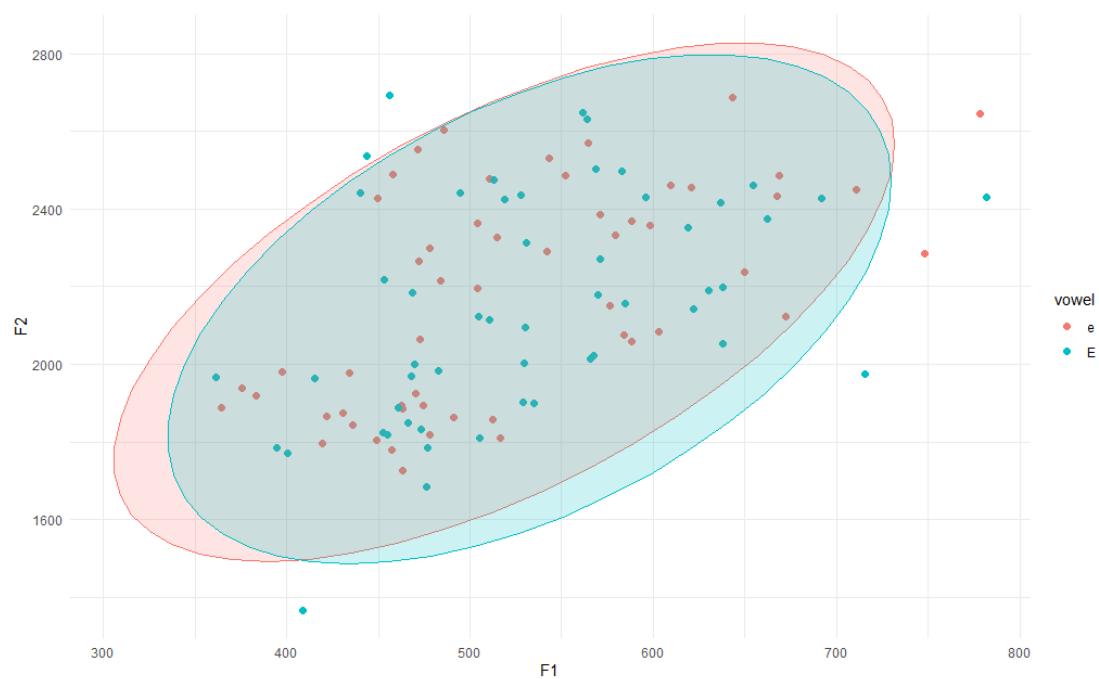


Figure 7. Vowel distribution between /e/ and /ε/ (E stands for /ε/)

Furthermore, the formant values indicate that the merger is significantly influencing both native and nonnative Korean speakers. Revisiting Figure 1 through Figure 6, we found that every subject's distributions of /e/ are equal to or smaller than that of /ɛ/. According to Yang (1996), the conventional F1 and F2 values of Korean male speakers, along with this experiments' results, are listed in Table 4 below. The vowel formants nowadays are closer than that in 1996, which attests that the merger has been ongoing at least since then. F1 is showing the symptom of colliding closer to the /e/ traditional F1 value, while both F2 values of /e/ and /ɛ/ are higher (fronted in the oral space) than that of the traditional values. This is an indication that /e/ is merging into /ɛ/, which agrees with Lee et al. (2018).

Table 4. Mean vowel formant comparisons with Yang (1996) (Unit: Hz)

	Mean F1	Mean F2
/e/ in Yang 1996	490, (105)	1968, (150)
/ɛ/ in Yang 1996	591, (75)	1849, (106)
/e/ in this experiment	525, (94)	2177, (276)
/ɛ/ in this experiment	534, (88)	2155, (286)

(The standard deviations of the formants are shown in the parentheses.)

### *Between Subjects*

**Individual Differences.** As gender and native language are between subject independent variables (IV), and vowel is a within subject IV, three-way mixed

ANOVA tests were conducted twice, respectively on F1 and F2, which was the dependent variable (DV) we expect to observe in the two ANOVA tests. We could see how gender, native language, vowel, and their interactions were correlated to the subjects' production of /e/ and /ɛ/.

Table 5. Three-way mixed ANOVA evaluating the effects of gender, native language, and vowel on F1 values

Effect	DFn	DFd	F	p	p<.05	ges
gender	1	50	43.703	2.44e-08	*	3.26e-01
native language	1	50	3.230	7.80e-02		3.50e-02
vowel	1	50	0.699	4.07e-01		6.00e-03
gender:native language	1	50	4.556	3.80e-02	*	4.80e-02
gender:vowel	1	50	0.004	9.51e-01		3.35e-05
native language:vowel	1	50	0.376	5.42e-01		3.00e-03
gender:native language:vowel	1	50	0.083	7.75e-01		7.36e-04

Table 6. F1 Post-hoc test computing simple two-way interaction of gender and native language at each level of vowel (‘\*\*\*\*’=0.001 ‘\*\*\*’=0.01 ‘\*\*’=0.05)

vowel	Effect	DFn	DFd	F	p	ges
/e/	gender	1	50	22.4	1.86e-5 ***	0.309
/e/	native language	1	50	0.784	3.80e-1	0.015
/e/	gender:native language	1	50	2.88	9.60e-2	0.055



/ɛ/	gender	1	50	26.5	4.51e-6 ***	0.346
/ɛ/	native language	1	50	3.39	7.10e-2	0.064
/ɛ/	gender:native language	1	50	2.17	1.47e-1	0.042

The fact that female's F1 is significantly higher than male's F1 means that females tended to have a lower tongue position making the vowels than males. The interaction between gender and native language, along with further post hoc t-tests show that female Korean speakers' tongue height was similar to nonnative speakers'.

There was a statistically significant simple two-way interaction between gender and both vowels, but not between native language or its related interactions.

Table 7. Three-way mixed ANOVA evaluating the effects of gender, native language, and vowel on F2 values

Effect	DFn	DFd	F	p	p<.05	ges
gender	1	50	71.969	3.00e-11	*	5.09e-01
native language	1	50	17.722	1.06e-04	*	2.03e-01
vowel	1	50	0.416	5.22e-01		2.00e-03
gender:native language	1	50	17.080	1.36e-04	*	1.97e-01
gender:vowel	1	50	0.116	7.35e-01		6.47e-04
native language:vowel	1	50	0.551	4.62e-01		3.00e-03
gender:native language:vowel	1	50	0.002	9.61e-01		1.38e-05

Table 8. F2 Post-hoc test computing simple two-way interaction of gender and native

language at each level of vowel (‘\*\*\*’=0.001 ‘\*\*’=0.01 ‘\*’=0.05)

vowel	Effect	DFn	DFd	F	p	ges
/e/	gender	1	50	61.9	2.68e-10 ***	0.553
/e/	native language	1	50	11.5	1.00e-3 ***	0.187
/e/	gender:native language	1	50	14.2	4.37e-4 ***	0.221
/ɛ/	gender	1	50	44.0	2.27e-8 ***	0.468
/ɛ/	native language	1	50	14.0	4.66e-4 ***	0.219
/ɛ/	gender: native language	1	50	10.8	2.00e-3 **	0.178

In contrast to the simple two-way interaction of F1, all p values in the F2 post-hoc were significant, hinting that being female and having Korean as native language contribute to production of higher F2s. This could be better explained by observing Figure 8 below. Notice that the major axes of most ellipses were perpendicular to the X-axis, indicating that the vowel distributions were more focused on the X-axis (a smaller F2 range) than on the Y-axis (a larger F1 range).



Figure 8. Scatter plot of /e/ and /ε/ distributions of all subjects (E stands for /ε/)

In addition, Figure 8 provides a clear scatter plot for intuitively viewing the differences between every two subjects. Subject 4, a Korean learner, pronounced both vowels in a focused manner, while other subjects' distributions tend to be scattered. Nonetheless, within-subject comparisons stress once again the merger of the two mid front vowels.

### 5.1.2 Native vs. Nonnative

While native and nonnative differences were not important factors to F1 ( $F(1,50) =$

0.699,  $p = .407$ ), would native language influence F2 as much as Table 7 had claimed

( $F(1, 50) = 17.722$ ,  $p = .000106$ )?

The t-tests results collected in Table 9 below indicate that the way native and nonnative speakers of Korean pronounce the vowels were significantly different. Both within-group comparisons demonstrate signs of merger between “ㅏ” and “ㅑ”; however, the two pairs of ellipses distinguished by native language validate the between-group differences, confirming that native language did affect formant values.

As we can see from Figure 9, the vowel distributions are fairly separated, further backing up the observations from Table 9.

Table 9. Vowel formant comparisons between native and nonnative Korean speakers

Vowel	Formant	Df	95% confidence interval		p value
/e/	F1	17	493.1356	582.9803	6.351517e-15 ***
/ɛ/	F1	17	522.6313	593.3543	6.39866e-17 ***
/e/	F2	17	2168.879	2389.549	6.91181e-19 ***
/ɛ/	F2	17	2185.943	2377.415	6.187128e-20 ***

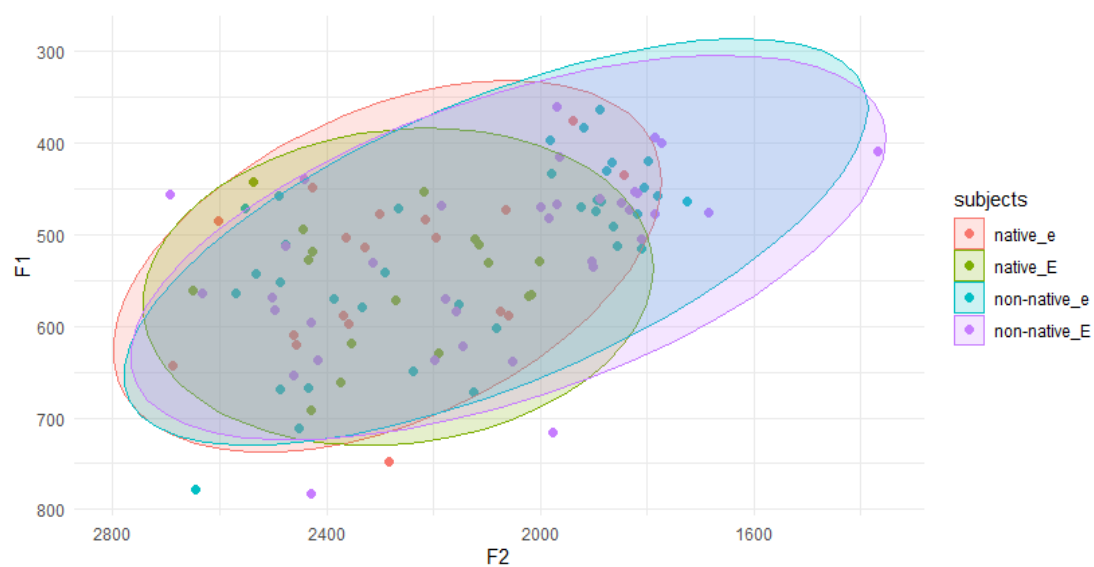


Figure 9. Vowel distribution of native and nonnative Korean speakers (E stands for /ɛ/)

## 5.2 Perception Discussion

From Table 10, we can observe that subject 2, a native Korean, has the highest accuracy at distinguishing other subjects' vowels. This can attribute to the fact that subject 2 has more experience with Korean phonetics, which might help him identify the minute differences between vowels. Other five subjects have the accuracy around 50%, which are close to mere guesses.

Table 10. Accuracy of six subjects (subject 1 and 2 are Korean native speakers)

	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6
accuracy (%)	40	65.6	37.8	54.4	48.9	56.7

Table 11. Correct answer counts of subjects listening to others (S stands for subject)

speaker \ listener	S1	S2	S3	S4	S5	S6	Sum
S1	N/A	14	8	10	10	10	52
S2	5	N/A	7	9	8	10	39
S3	9	11	N/A	10	7	11	48
S4	8	11	6	N/A	9	8	42
S5	8	11	6	9	N/A	12	46
S6	6	12	7	11	10	N/A	46
Sum	36	69	34	49	54	51	N/A

One subject performs well on the perception experiment, but most of the rest are merely better than chances, leading to the conclusion that both native and nonnative speakers had equal trouble distinguishing /e/ and /ɛ/. Figure 10 is the bar plot comparing accuracy of /e/ and /ɛ/ between native and nonnative speakers, along with error bar of one standard deviation.

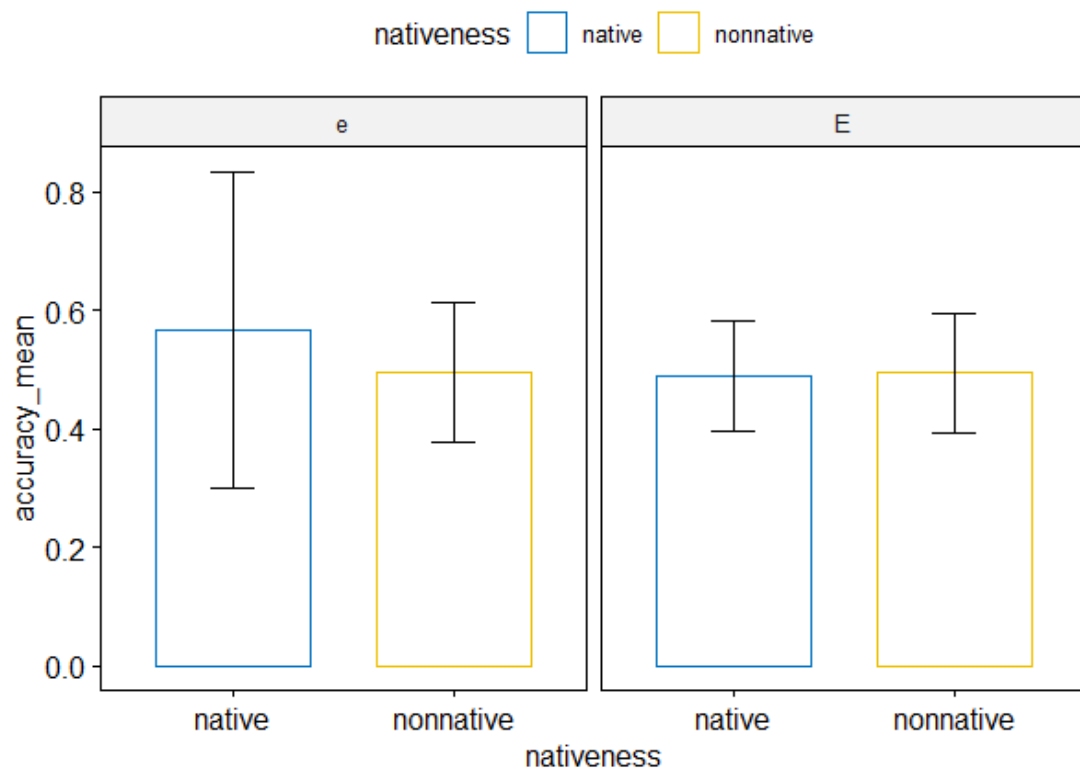


Figure 10. Accuracy bar plot comparing /e/ vs. /ɛ/ and native vs. nonnative speakers

(E stands for /ɛ/)

## 6. Conclusions

In summary, this paper aims to examine the production and perception

differences in two Korean mid front vowels /e/ and /ɛ/. The findings are:

1. in production, the two vowels are indeed merged, regardless of gender and native language. But individual difference exists.
2. in perception, the two vowels cannot be distinguished by either native or nonnative speakers.

To be more accurate, the merger proceeded from two phonemes, /e/ and /ɛ/, toward only one phoneme, /ɛ/.

This current study does not look at regional accent differences, which could be influential to the vowel productions as the merger develops slower in rural areas. Age is also a considerable factor, since this /e/ and /ɛ/ distinction still exist in some areas that have higher elderly populations. Thus, more native Korean speakers from different regions and age groups is the synchronic direction of future studies on this merger phenomenon.

Besides synchronically examining the vowels' relationship, diachronic studies could be conducted by follow-up collections of /e/ and /ɛ/ formant data in order to compare how this merger evolves from past to future.

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## 8. Appendix

Table 12. Two-sided paired t-test comparing subjects' /e/ and /ɛ/ F3

Subject 1	F3	8	-209.9342	265.0036	0.7959384
Subject 2	F3	8	-134.1032	398.0613	0.2857766
Subject 3	F3	8	-100.6123	207.6807	0.4463422
Subject 4	F3	8	-144.2557	157.9753	0.9192071
Subject 5	F3	8	-440.45571	88.61423	0.1636862
Subject 6	F3	8	-322.1663	325.7102	0.9902446