Linguistic Research 42(3): 657-684
DOI: 10.17250/khisli.42.3.202512.007

Phonetic aspects of the vowels /o/ and /u/ in Seoul Korean*

Yong-cheol Lee
(Hannam University)

Lee, Yong-cheol. 2025. Phonetic aspects of the vowels /o/ and /u/ in Seoul Korean. *Linguistic Research* 42(3): 657-684. This study investigated the phonetic aspects of the the vowels /o/ and /u/ in Seoul Korean, examining how positional (word-initial vs. word-final), morphological (content vs. function morphemes), and sociolinguistic (gender and age) factors affect the productions of the two vowels. Using an experimental design that compared vowel realizations within matched word positions, the results revealed that overlapping patterns occur more frequently in function morphemes than in content morphemes, particularly along the vowel height dimension (F1). When morphological category was held constant, word-initial positions provided more favorable conditions for vowel convergence than word-final ones. Age-related patterns also emerged, such that the change began with speakers born in the 1950s. Younger speakers exhibited greater acoustic overlap between /o/ and /u/, with female speakers showing consistent /o/-raising, while male speakers displayed more variable and less systematic patterns. Regarding the morphological factor, the merger was most evident in word-final function morphemes, likely due to their high frequency, low semantic weight, and prosodic environments favoring phonetic reduction. Furthermore, results from the Linear Discriminant Analysis (LDA) reliably captured these production realizations, reflecting the observed patterns of vowel convergence across social and linguistic factors. The findings of this study highlight the complex interplay between linguistic structure and sociolinguistic factors in shaping the overlapping patterns observed in the two vowels. **(Hannam University)**

Keywords /o/-/u/ convergence, phonetic variation, positional, morphological, sociolinguistic, Seoul Korean

* I am deeply grateful to the three anonymous reviewers for their constructive feedback and valuable suggestions on this manuscript.

© 2025. Yong-cheol Lee, published by *Linguistic Research* (KHU ISLI). This work is licensed under the Creative Commons Attribution 4.0 International License.

1. Introduction

Language evolves constantly, with changes occurring either abruptly or gradually. One such change is a vowel merger, in which the distinction between two vowel phonemes is lost. This change may reshape a language's vowel system and trigger a chain shift in the vowel inventory. For instance, when a vowel shifts to a new articulatory position, it may push another vowel to move in order to maintain phonemic contrast. A well-known example is the Northern Cities Shift in American English, characterized by a systematic rotation of six short vowels, as exemplified in words like *bat, bot, bought, bet, but*, and *bit* (Labov et al. 2006). While some vowel shifts occur to preserve phonemic contrast to avoid merger (Labov 1994), vowel mergers often spread at the expense of existing distinctions (Herzog 1965; Labov 1994). Vowel mergers are commonly found in a wide range of languages (Yao and Chang 2016), particularly in vowel-rich systems like English, German, French, and Yiddish (Johnson 2010).

Vowel mergers are generally classified into two types: conditioned and unconditioned (Hoenigswald 1965). A conditioned merger occurs when a particular vowel merges with a different one only in certain phonological contexts. A well-known example is the PIN–PEN merger, which has been widespread throughout the American South (Brown 1991). In this merger, the vowel /ɪ/ is replaced by /ɛ/ in pre-nasal contexts, as in *pin–pen* and *him–hem*. Another example of a conditioned merger involves the raising of /æ/ to /ɛ/ before word-final /g/, known as the BAG–BEG merger. This phenomenon has been observed in the Pacific Northwest (Wassink 2015), parts of the Upper Midwest (Purnell 2008), and Western Canada (Boberg 2008), where prevelar raising leads to overlapping realizations of the two vowels, making *bag* and *beg* sound identical. In contrast, an unconditioned merger refers to cases where two phonemes merge in all phonological environments. A prototypical example is the COT–CAUGHT merger, in which /ɑ/ and /ɔ/ are pronounced identically across many North American English dialects. As a result, minimal pairs such as *bot* and *bought* become homophones in approximately half of the United States (Labov et al. 2006). A comparable unconditioned merger is observed in Seoul Korean (hereafter simply "Korean"), where /ɛ/ has merged with /e/, resulting in the consistent realization of both as /e/ (Ko 2009; Lee and Cho 2021). For example, the words /ke/ ('crab') and /kɛ/ ('dog') are now pronounced identically in modern Korean, eliminating the contrast between the two vowels.

1.1 Korean vowel system

Table 1 presents the vowel inventory of Korean, with gray-highlighted cells indicating vowels that have disappeared due to two major sound changes. First, through a process of diphthongization (Cho 2016), the monophthongs /y/ and /ø/ have been replaced by the diphthongs /wi/ and /we/, respectively. Second, the vowel /ɛ/ has merged with /e/, further reducing the vowel inventory. According to Lee and Cho (2021), this merger began among female speakers born in the 1930s, initially affecting the F2 dimension of the vowel space before extending to F1. Although surface realizations of these vowels continue to vary by syllable position (Chung 2022; Lee 2023), it is more plausible to conclude that the phonemic distinction between /ɛ/ and /e/ has disappeared among speakers born after the 1970s (cf. Jang et al. 2015; Ko 2009; Lee and Cho 2021), and that this merger is also observed even in Yanbian Korean (Yu et al. 2022, 2024). Supporting this claim, listeners often report confusion between the two vowels, interpreting them through verbal cues—such as combining /a/ *아* with /i/ *이* to signal /ɛ/ *애*, or /ʌ/ *어* with /i/ *이* to represent /e/ *에*. These patterns suggest that the two vowels are now perceptually indistinguishable in modern Korean. Accordingly, it is more accurate to characterize the vowel system of Korean as having shifted from a 10-vowel to a 7-vowel inventory.

Table 1. The vowel inventory with Hangeul in Korean. Modified from Ko (2009)

	Front		Back	
	Unrounded	Rounded	Unrounded	Rounded
High	/i/ 이	/y/ 위	/ɯ/ 으	/u/ 우
Mid	/e/ 에	/ø/ 외	/ʌ/ 어	/o/ 오
Low	/ɛ/ 애		/a/ 아	

1.2 The ongoing change from /o/ to /u/

As Table 1 illustrates, the vowels /o/ and /u/ are phonologically distinct in Korean, traditionally occupying separate positions in the vowel space. However, a number of studies have consistently demonstrated that /o/ is undergoing a phonetic change toward /u/, particularly along the F1 dimension (cf. Byun 2020; Chae 1995; Kang and Han 2013; Yoon 2020). This suggests that, despite their phonemic distinction,

the acoustic realization of the two vowels is becoming increasingly similar in terms of F1, raising the possibility of a partial overlap in certain contexts. To better understand the mechanisms driving this change, what follows is a review of key linguistic and sociolinguistic factors—such as morphological environment, syllable position, age, and gender—that have been shown to influence the ongoing change from /o/ to /u/ in Korean.

Research by Yoon (2020) confirms that a phonetic change from the mid-back rounded vowel /o/ to the high-back rounded vowel /u/—commonly referred to as /o/-raising—is actively taking place in Korean, particularly in word-final function morphemes. The overall substitution rate of /u/ for /o/ was approximately 50%. Specifically, linking endings, particles, and adverbs ending in /o/ were replaced with /u/ in about half of the stimuli. In contrast, nominal items showed a much lower substitution rate, with replacements occurring in fewer than 5% of cases. This finding is also in line with observations reported by Chae (1995). /o/-raising appears to be more advanced in function morphemes (such as suffixes and particles) than in content morphemes, suggesting that the sound change is morphologically conditioned. For example, 그리고 [geurigo], meaning 'and,' can be produced as [geurigu], whereas 냉장고 [naengjanggo], meaning 'refrigerator,' is rarely pronounced as [naengjanggu]. In Jang et al. (2015), the study analyzed vowels that appeared in the word-initial position of the first content word in each sentence. Since all stimulus sentences began with content words, this effectively meant analyzing the initial vowel of the first word. The results revealed that although /o/ and /u/ were acoustically realized in close proximity, they nevertheless maintained a phonemic distinction.

In addition to morphological factors, the change from /o/ to /u/ is also influenced by positional factors, as noted in Chae (1995), who found that /o/ is more raised in non-initial syllables than in initial ones. Specifically, vowels in second or later syllables tend to show greater overlap between /o/ and /u/. While the contrast between these vowels remains relatively stable in initial syllables, it becomes considerably less robust in non-initial positions, indicating that syllabic position plays a significant role in the progression of this sound change. In a related study, Kang and Han (2013) conducted a production experiment using bisyllabic pseudowords to examine positional effects on the sound change. Female speakers exhibited /o/-raising in both V1 (first syllable) and V2 (second syllable) positions, with the greatest spectral overlap observed among younger females in V1 (e.g. 90% overlap for Age 20). In contrast,

male speakers showed /o/-raising only in the V2 position, while the V1 contrast remained relatively stable across age groups. These findings suggest that non-initial syllables provide a more favorable environment for vowel convergence.

Furthermore, sociolinguistic factors such as age and gender also influence this change, with younger speakers and females leading the sound change (Byun 2020; Chae 1995; Kang and Han 2013)—a trend consistent with broader patterns of linguistic innovation (Labov 1994). Kang and Han (2013), for example, observed that young female speakers produced /o/ at higher articulatory positions and /u/ at lower ones than their typical realizations, significantly narrowing the acoustic gap between the two vowels, particularly along the F1 (vowel height) dimension. Age played a key role as well. Younger speakers tended to use a more centralized and compact vowel space, which contributed to increased spectral overlap between /o/ and /u/. As Byun (2020) also reports, this overlap was especially observed among younger speakers and was most evident in female speakers, including those born before the 1970s. In contrast, male speakers generally preserved a clearer acoustic distinction between the two vowels. However, Jang et al. (2015) reported no statistically significant differences in the acoustic realization of /o/ and /u/ across age or gender. While speakers of different age and gender groups produced these vowels with similar acoustic patterns, /o/ and /u/ continued to exhibit distinct formant values. This suggests that conventional sociolinguistic factors, such as age and gender, did not meaningfully account for variation in this particular vowel contrast in Jang et al.'s (2015) study.

This type of sound change is not unique to Korean but has also been attested in various other languages, suggesting that it is also typologically common. For example, Arnold (2015) reports that in Youngstown English, /o/ is raised in pre-/l/ contexts, contributing to a potential overlap between /ʊl/ and /ol/, with the change being more advanced among younger speakers. Similarly, Fox (1996) identifies a change from /o/ to /u/ as part of a broader chain shift observed in Semitic languages such as Phoenician, Hebrew, and Aramaic. This change tends to be directional—moving from /o/ to /u/—though not necessarily complete. /o/-raising is also found in Polish, where the vowel /o/ raises to [u] in final syllables before voiced, non-nasal consonants (Kenstowicz 1994). These findings highlight that /o/-raising is a cross-linguistic pattern of vowel change rather than an isolated phenomenon in certain languages.

1.3 The current study

The present study examines the conditions under which the phonetic change from /o/ to /u/—commonly known as /o/-raising—occurs in Korean. Previous research has established that this sound change is more advanced in non-initial syllables and function morphemes, while content exhibit greater resistance to the change (Yoon 2020). These findings, however, are complicated by a critical methodological confound: function morphemes predominantly occur in word-final positions. Consequently, it remains unclear whether the observed patterns genuinely reflect positional conditioning or merely stem from the distributional tendencies of different morpheme types. This interpretive challenge is further compounded by Kang and Han's (2013) research, which suggests that non-initial syllables provide a more favorable environment for vowel convergence. Yet, because their study relied on pseudowords presented in various positions, it remains an open question whether these positional effects extend to content morphemes in natural speech. Jang et al. (2015) limited their analysis to word-initial content morphemes, finding that /o/ and /u/ were acoustically similar yet still phonemically distinct. However, it is still uncertain whether word-final content morphemes exhibit a similar pattern.

While earlier studies have explored /o/-raising from structural or demographic perspectives, methodological issues—especially concerning the interaction between morpheme type and syllable position—remain unresolved. To address these shortcomings, the present study incorporates content morphemes that occur in both word-initial and word-final positions. Additionally, it includes word-final function morphemes to be contrasted with word-final content morphemes, allowing for a direct comparison of morpheme type within the same position. This design enables a controlled examination of positional effects while holding morphological category constant. As a methodological note, because Korean does not allow function morphemes with /u/ in word-final position, content morphemes were used for /u/ instead, serving as a baseline for comparison. Through a systematic analysis of vowel realizations across syllable positions within content words—and by comparing them to patterns found in function morphemes—this study aims to isolate the independent contribution of syllable position to the advancement of /o/-raising. Within this framework, our investigation centers on two primary research questions: (1) which

syllable position—initial or non-initial—shows a more advanced stage of phonetic change, and (2) to what extent does morpheme type (content vs. function) independently influence this progression.

Beyond structural conditioning, this study also explores sociolinguistic dimensions of the change. Prior research suggests that younger female speakers may be leading the ongoing change from /o/ to /u/ in Korean (Byun 2020; Chae 1995; Kang and Han 2013), a pattern consistent with broader trends in linguistic innovation (Labov 1994). Yet, Jang et al. (2015) found no significant effects of age or gender in the realization of /o/ and /u/. To reconcile these conflicting findings, the current study includes both male and female speakers born between the 1930s and 1980s and poses two additional research questions: (3) When did this vowel change begin? and (4) Which gender group has played a leading role in this sound change?

2. Method

2.1 The speech corpus of reading-style standard Korean

This study analyzed speech data sourced from t*he speech corpus of reading-style standard Korean*. This corpus is a collection of read speech produced by 120 native speakers of Korean, developed and released by the National Institute of the Korean Language in 2005. The corpus contains 19 short stories that include traditional folktales and personal essays, comprising 930 sentences in total. The speakers were all born and raised in or near Seoul, with ages ranging from 19 to 71 at the time of recording in 2003. The dataset includes an equal number of male and female speakers (60 each), whose parents were also native speakers of Korean and resided in Seoul or its metropolitan area. Notably, speakers aged 50 and older read only 11 of the 19 stories, resulting in a reduced dataset of 404 sentences for this age group.

2.2 Our data

From the corpus, we extracted data from 117 speakers—59 females and 58 males—born between the 1930s and 1980s. Recordings from three speakers were unavailable due to technical issues in the corpus. Table 2 shows the distribution by gender and

10-year age group, following the classification method used by Kang (2014).

Table 2. Speakers classified by 10-year age groups and gender

Gender	10-year age groups					
	1930s	1940s	1950s	1960s	1970s	1980s
Female	2	9	25	3	11	9
Male	4	12	4	8	25	5

However, this 10-year grouping resulted in an uneven speaker distribution across birth years, limiting the objectivity of group comparisons. To overcome this issue, we created a custom categorization that ensured a more balanced and structured distribution across birth years. Speakers were grouped in chronological order into five evenly distributed groups per gender. As shown in Table 3, Groups 1 to 4 for female speakers include 12 individuals, while Group 5 includes 11. For male speakers, Groups 1 to 3 include 12 individuals, with Groups 4 and 5 each consisting of 11. Some overlap in birth years was necessary to maintain group balance—for instance, individuals born in 1972 appear in both Groups 3 and 4. Although the range of birth years varies somewhat, especially for males, this grouping better supports the comparative analyses presented in this study.

Table 3. Speakers assigned to each group in chronological order within each gender

Gender	Group	Speakers	Min Year	Max Year	Median Year
Female	1	12	1935	1951	1946
	2	12	1952	1955	1953
	3	12	1956	1959	1957
	4	12	1960	1978	1975.5
	5	11	1979	1984	1980
Male	1	12	1932	1947	1941
	2	12	1948	1967	1951
	3	12	1968	1972	1970
	4	11	1972	1977	1976
	5	11	1977	1984	1979

In this study, we selected two folktales—*The Sun and the Moon* and *The Old Lady of the Gwanghwamun Underpass*—to analyze two target vowels. These stories were chosen because they contained a relatively high number of tokens for the target vowels, and sorting initial and final target syllables manually was time-intensive. As

stated previously, the research questions were to determine when the sound change involving these vowels began, which gender led the change, which syllable within a word underwent the change first, and whether this sound change depended on morpheme type (content vs. function). In this study, target words were selected for each vowel according to syllable position and morpheme type: for example, /o/ in *오*누이와 [onuiwa] (word-initial content), 나*온* [naon] (word-final content), and *살*고 [salgo] (word-final function); and /u/ in *물*건을 [mulgeoneul] (word-initial content) and 나*무* [namu] (word-final content).

To address these questions, we categorized the vowels by gender (male, female), chronological age group (Groups 1–5), and vowel position within a word (initial, final). Since word-initial positions in Korean do not host function morphemes for /o/ and /u/, only word-final positions—where morphemes typically appear as suffixes or particles—were further divided into content and function morphemes. As noted earlier, because Korean does not allow function morphemes with /u/ in word-final position, content morphemes in this environment were used instead as baseline data. For simplicity, 'chronological age group' and 'vowel position within a word' will hereafter be referred to as 'age group' and 'position,' respectively.

The vowel tokens were filtered for each speaker and vowel category using a 95% confidence interval (CI) method to remove outliers. Values exceeding ±1.96 standard deviations from the mean within each group were defined as outliers and removed. Filtering was applied separately to F1 and F2 before merging the results, eliminating approximately 1.09% of the total dataset. This independent approach was chosen because F1 and F2 represent distinct acoustic characteristics, allowing for more precise outlier detection while minimizing data loss. The final removal rate (1.09%) was lower than the theoretical 5%, likely due to the data's distributional properties and the group-wise filtering method. Table 4 provides a detailed breakdown of the number of filtered target vowels across gender, age group, and morpheme type. In Table 4, NA indicates that the vowel /u/ from function morphemes cannot occur in this position. Therefore, the vowel /u/ from content morphemes was used instead.

Table 4. Number of vowel tokens categorized by gender, group, position, and morpheme type

Gender	Group	Vowel	Initial Position (Content Morpheme)	Final Position (Content Morpheme)	Final Position (Function Morpheme)
Female	1	/o/	646	81	393
		/u/	296	80	NA
	2	/o/	631	82	393
		/u/	295	83	NA
	3	/o/	638	80	395
		/u/	293	82	NA
	4	/o/	640	81	394
		/u/	293	83	NA
	5	/o/	589	76	357
		/u/	268	76	NA
Male	1	/o/	622	65	383
		/u/	291	91	NA
	2	/o/	645	70	387
		/u/	292	93	NA
	3	/o/	618	81	388
		/u/	278	84	NA
	4	/o/	582	75	360
		/u/	254	77	NA
	5	/o/	579	76	355
		/u/	255	77	NA

2.3 Measurements

In this study, we employed a Korean forced aligner (Yoon and Kang 2012) to automatically label individual segments within each sentence. This method is widely recognized for its efficiency, particularly in the analysis of large-scale speech corpora (Reddy and Stanford 2015). For implementation, the recordings were first downsampled to a 16 kHz sample rate, after which the forced aligner automatically aligned the onset and offset of each labeled segment.

While automatic measurements provide a significant advantage in analyzing vowel formant frequencies, especially when processing large datasets (Escudero et al. 2009; Reddy and Stanford 2015), they are not without limitations. Automated methods can

sometimes introduce tracking errors, such as formant omissions, misalignments, or incorrect detections (Yao et al. 2010). To address this issue, we carefully reviewed and manually adjusted each target vowel's labeling, ensuring greater accuracy and control over the formant measurements.

To optimize our acoustic analysis, we determined the ideal formant ceiling for each speaker. Values were adjusted within a range of 4000 Hz to 6500 Hz, and the setting that yielded the lowest variance in F1 and F2 measurements was chosen as the optimal threshold (Escudero et al. 2009). Additionally, to reduce coarticulation effects, F1 and F2 values were extracted from the midpoint of each vowel using a Praat script.

2.4 Analyses

To analyze the ongoing change from /o/ to /u/, we employed a series Linear Mixed-Effects Models using the lme4 package (Bates et al. 2015). The dependent variables were the formant frequencies F1 and F2, each analyzed separately. The main effect was vowel, representing the target vowel category (/o/ vs. /u/), while sentences and speakers were included as random effects to account for repeated measures and the nested structure of the speech data. These models were fitted separately for each combination of gender and age group to explore group-specific patterns. To evaluate the significance of the main effect, we performed Type III ANOVA with Satterthwaite's approximation for degrees of freedom. This allowed us to compute F-statistics, degrees of freedom, and p-values, testing whether vowel category significantly predicted F1 or F2 values. Additionally, marginal R^2 values were calculated to estimate the proportion of variance explained by the main effect, providing an effect size measure for the influence of vowel category on the formant values. These values were computed using the performance package in R (Lüdecke et al. 2021), based on the method proposed by Nakagawa and Schielzeth (2013). Because the vowel /u/ from content morphemes in word-final position was compared with the vowel /o/ from word-final function morphemes, morpheme type was included as a fixed effect in the linear mixed-effects model to control for its effect.

Furthermore, to assess the classification accuracy of the two vowels, we trained separate Linear Discriminant Analysis (LDA) models for each gender using formant

frequencies (F1 and F2) as predictors, employing the *MASS* package in R (Venables and Ripley 2002). LDA identifies a linear combination of acoustic features that best separates vowel categories. The classification results offer insight into vowel distinctiveness: high rates of misclassification between /o/ and /u/ suggest overlapping acoustic characteristics, whereas clearer separability reflects more distinct production. Crucially, by analyzing the direction of misclassification (i.e., which vowel is more often confused with the other), we were able to infer the directionality of the ongoing vowel merger.

As shown in Table 4 above, the distribution of vowel tokens was uneven across birth years, with some groups contributing substantially more tokens than others. For example, the female speakers in Group 1 produced 646 tokens for the vowel /o/ in word-initial position, whereas the male speakers in Group 1 produced only 65 tokens for /u/ in word-final position with content morphemes only. This imbalance poses potential challenges when comparing age groups, as larger sample sizes increase statistical power, potentially leading to statistical significance even when effect sizes are small. Consequently, differences detected between groups with substantially different token counts require careful interpretation. To mitigate this issue, we employed bootstrap resampling, repeatedly drawing 65 tokens (matching our smallest sample size) with replacement from each larger set across gender and age groups. This process was repeated 1,000 times to conduct multiple analyses when comparing target vowels, including linear mixed-effects models, marginal R^2 values, and LDA model training—thereby enhancing reliability and accounting for sampling variability.

3. Results

3.1 Descriptive statistics and visual observations

Before turning to the visual inspection, we first examine the overall descriptive statistics of F1 and F2 across vowels, gender, and age groups. On average, the vowel /o/ shows a higher mean F1 (about 420 Hz) and a lower mean F2 (about 1,050 Hz) than /u/, which generally exhibits F1 values around 350 Hz and F2 values around 1,380 Hz. Female speakers consistently produce higher F2 values than males, reflecting their shorter vocal tracts and correspondingly more fronted acoustic space. Across age

groups, the F1 difference between /o/ and /u/ tends to decrease in younger speakers, suggesting gradual vowel raising and a possible /o/–/u/ merger in progress. These tendencies are further illustrated in Figures 1–3 below, which display the F1–F2 distributions segmented by position, morpheme type, gender, and age group.

Figures 1–3 illustrate the F1–F2 formant distributions of the vowels /o/ (red) and /u/ (blue) in Korean, segmented by position (word-initial vs. word-final), morpheme type (content vs. function), gender, and age group. Figure 1 presents vowel data extracted from word-initial content morphemes, while Figures 2 shows data from word-final content morphemes. Figure 3 includes the vowel /o/ from function morphemes and the vowel /u/ from content morphemes, since Korean does not allow /u/ in word-final function morphemes.

Figure 1, across both genders, /o/ generally exhibits a higher F1 (lower vowel height) and a lower F2 (more back articulation) than /u/. Female speakers consistently display higher F2 values, which may partly reflect anatomical differences in vocal tract length. In particular, women's shorter oral cavity reduces the length of the front resonating cavity, contributing to more fronted acoustic realizations. Older speakers (Groups 1 and 2) maintain a clear acoustic separation between the vowels, while younger speakers (Groups 3–5) show increased overlap, particularly in F1. This indicates a potential vowel change across generations.

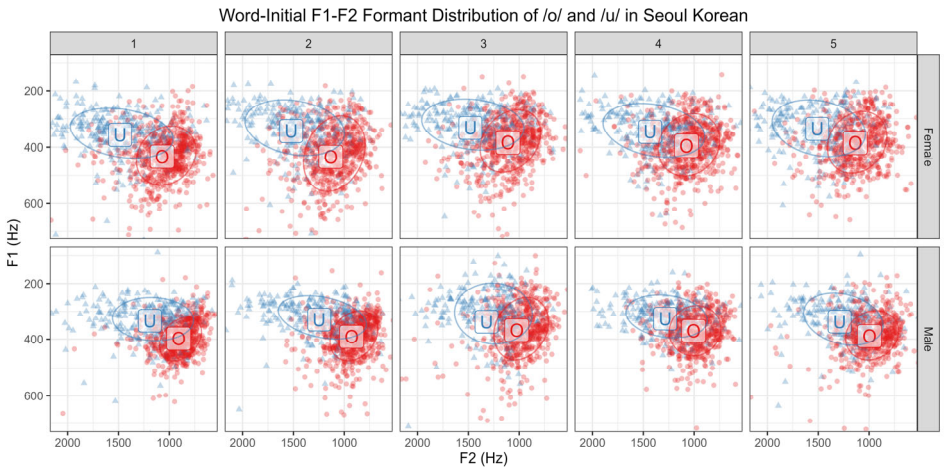

Figure 1. Word-initial F1-F2 formant distribution of /o/ and /u/ in Korean, divided by gender and age groups, focusing exclusively on content morphemes

Figure 2 demonstrates that the contrast between /o/ and /u/ remains robust across all age and gender groups in word-final content morphemes. While female speakers again show slightly higher F2 values, the vowels remain acoustically distinct in both formant dimensions, indicating stability in this morphological environment.

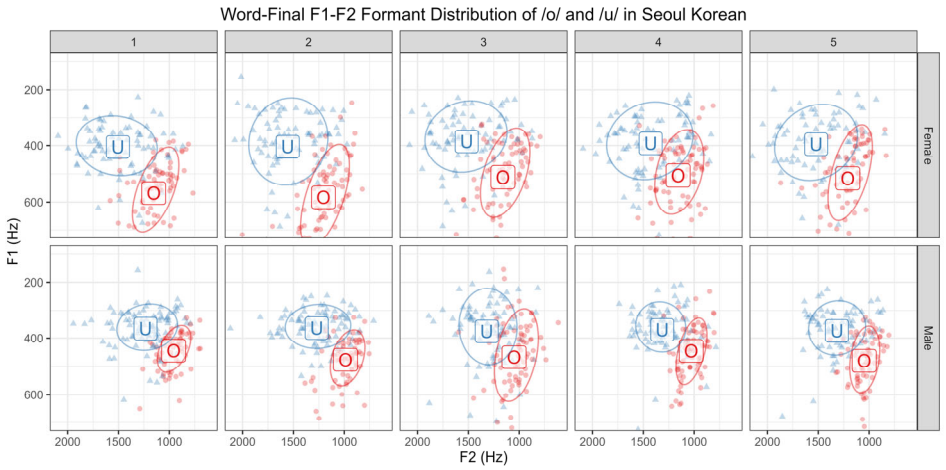

Figure 2. Word-final F1-F2 formant distribution of /o/ and /u/ in Korean, divided by gender and age groups, focusing exclusively on content morphemes

In contrast, Figure 3 reveals increased vowel overlap in this comparison, particularly in F1. With the exception of female speakers in Group 1, most groups show convergence between /o/ and /u/. Notably, younger males (Groups 3–5) exhibit greater overlap between the two vowels. This pattern indicates an ongoing change from /o/ toward /u/ among younger male speakers, particularly when /o/ occurs in word-final function morphemes.

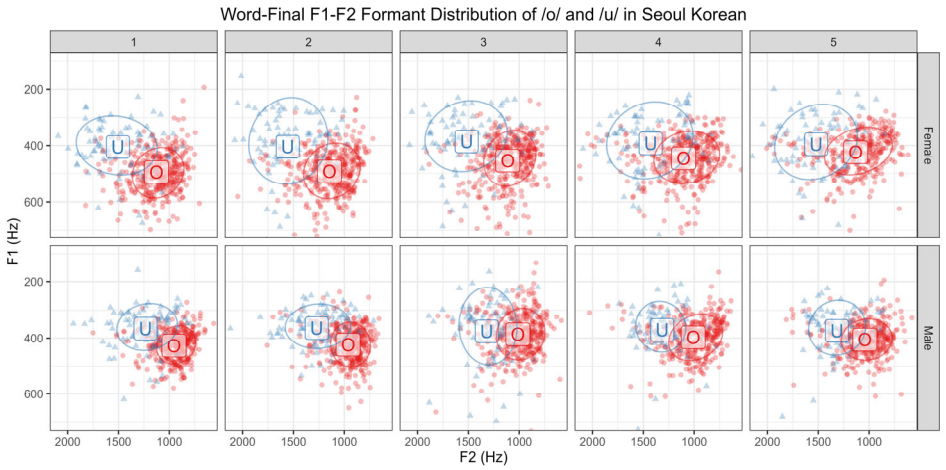

Figure 3. Word-final F1-F2 formant distribution of /o/ and /u/ in Korean, divided by gender and age groups, containing the vowel /o/ from function morphemes and the vowel /u/ from content morphemes

3.2 Statistical results

Tables 5 through 7 below report statistical analyses of the vowels /o/ and /u/, broken down by segmental position, morpheme type, gender, and age group. Specifically, Table 5 focuses on word-initial content morphemes, while Table 6 provides results for word-final content morphemes. Table 7 includes the vowel /o/ from function morphemes and the vowel /u/ from content morphemes.

Table 5 presents the statistical results comparing /o/ and /u/ in word-initial content morphemes in Korean, broken down by gender (female and male) and five age groups (Groups 1 to 5). Most comparisons reveal significant differences between the vowels, except for the F1 contrast in male Group 3 (p = .218). A general trend emerges. Higher F-values tend to align with stronger effect sizes (marginal R^2). F2 consistently produces higher F-values than F1, with minimum R^2_m values above 0.185, indicating robust vowel separation in the front-back dimension. In contrast, F1 effect sizes vary considerably. For example, higher F1 F-values (33.859 for Female Group 1 and 44.799 for Male Group 1) correspond to relatively strong effect sizes (R^2_m = 0.190 and 0.192, respectively), while lower F-values (e.g., 5.661 for Male Group 3) yield much weaker effects (R^2_m = 0.020). The R^2_m value of 0.020 for male Group 3 indicates that only

2% of the variance in F1 is explained by the model's main effect (i.e., vowel category). These lower values are more common among younger speakers (Groups 3–5), regardless of gender. Overall, the table demonstrates a clear acoustic distinction between /o/ and /u/ in word-initial content morphemes, particularly along the F2 dimension, while their F1 values tend to show increased convergence among younger speakers.

Table 5. Statistical results of the vowels /o/ and /u/ in word-initial content morphemes in Korean, categorized by gender and age groups (Numerator df = 1). The cell with non-significant results is shaded in gray for clarity.

Gender	Age Group	Formants	*F*-Value	*P*-Value	R^2_m
Female	Group 1	F1	33.859	0.001	0.190
		F2	62.919	<.001	0.299
	Group 2	F1	26.806	<.01	0.157
		F2	54.388	<.001	0.299
	Group 3	F1	14.280	<.05	0.076
		F2	48.733	<.001	0.299
	Group 4	F1	14.569	<.05	0.084
		F2	44.321	<.001	0.301
	Group 5	F1	14.649	<.05	0.081
		F2	55.861	<.001	0.349
Male	Group 1	F1	44.799	<.001	0.192
		F2	46.831	<.001	0.255
	Group 2	F1	32.357	<.01	0.151
		F2	52.904	<.001	0.267
	Group 3	F1	5.661	=.218	0.020
		F2	33.303	<.01	0.185
	Group 4	F1	19.897	<.05	0.086
		F2	39.778	<.001	0.260
	Group 5	F1	17.094	<.05	0.102
		F2	39.712	<.001	0.293

Table 6 exhibits the statistical comparison of the vowels /o/ and /u/ in word-final content morphemes position in Korean, categorized by gender and age group. Across most groups, both F1 and F2 show significant differences between the vowels, with F2 consistently producing higher *F*-values and marginal R^2 values, indicating that vowel distinction is stronger along the front-back (F2) dimension. Female speakers in Group 1 show the strongest F1 effect (F = 60.855, R^2_m = 0.413), while male Group 4 exhibits the highest F2 effect (F = 70.552, R^2_m = 0.455). In contrast, younger male

groups display the weakest F1 distinction, suggesting a potential weakening of the /o/–/u/ contrast in vowel height among younger male speakers. Overall, the results demonstrate a robust acoustic separation between /o/ and /u/ in word-final content morphemes across both F1 and F2 dimensions; however, younger speakers exhibit a weaker contrast between the two vowels along the F1 dimension.

Table 6. Statistical results of the vowels /o/ and /u/ in word-final content morphemes in Korean, focusing exclusively on content morphemes, divided by gender and age groups (Numerator df= 1).

Gender	Age Group	Formants	*F*-Value	*P*-Value	R^2_m
Female	Group 1	F1	60.855	<.001	0.413
		F2	48.780	<.001	0.344
	Group 2	F1	40.321	<.001	0.325
		F2	50.555	<.001	0.396
	Group 3	F1	27.388	<.001	0.198
		F2	49.604	<.001	0.368
	Group 4	F1	27.925	<.001	0.200
		F2	26.269	<.001	0.559
	Group 5	F1	21.653	<.001	0.201
		F2	34.906	<.001	0.319
Male	Group 1	F1	46.819	<.001	0.278
		F2	52.380	<.001	0.363
	Group 2	F1	69.384	<.001	0.377
		F2	46.152	<.001	0.336
	Group 3	F1	12.728	<.01	0.248
		F2	33.065	<.001	0.598
	Group 4	F1	18.451	<.01	0.144
		F2	70.552	<.001	0.455
	Group 5	F1	32.357	<.001	0.243
		F2	53.696	<.001	0.418

In contrast, Table 7 presents the statistical comparison of /o/ and /u/ in word-final positions, by age group and gender. The vowel /o/ was extracted from word-final function morphemes and the vowel /u/ from word-final content morphemes. The results show a consistent asymmetry between F1 and F2. F2 exhibits strong and statistically significant differences between the vowels in all groups ($p < .001$), with large effect sizes (e.g., $R^2_m = 0.501$ for male Group 5), whereas F1 differences are generally weak or non-significant, especially among younger speakers. For example, F1 comparisons are non-significant in female Groups 5 and in male Groups 3-5, with

marginal R^2_m values often below 0.05. These patterns suggest that the vowel /o/ from word-final function morphemes is raised toward /u/ in terms of vowel height (F1), while their distinction is primarily maintained in backness (F2). This tendency appears more advanced among younger speakers, with both genders showing signs of an ongoing sound change.

Table 7. Statistical results of the vowels /o/ and /u/ in word-final position in Korean, divided by gender and age groups, containing the vowel /o/ from function morphemes and the vowel /u/ from content morphemes (Numerator df= 1). The cells with non-significant results are shaded in gray for clarity.

Gender	Age Group	Formants	*F*-Value	*P*-Value	R^2_m
Female	Group 1	F1	61.292	<.001	0.271
		F2	75.168	<.001	0.364
	Group 2	F1	29.523	<.01	0.157
		F2	91.204	<.001	0.423
	Group 3	F1	22.943	<.05	0.103
		F2	89.903	<.001	0.436
	Group 4	F1	14.373	<.01	0.062
		F2	50.173	<.001	0.408
	Group 5	F1	3.417	=.275	0.014
		F2	68.29	<.001	0.417
Male	Group 1	F1	57.187	<.001	0.210
		F2	87.588	<.001	0.366
	Group 2	F1	49.285	<.001	0.173
		F2	75.608	<.001	0.378
	Group 3	F1	3.94	=.366	0.010
		F2	72.917	<.001	0.458
	Group 4	F1	13.686	=.134	0.033
		F2	78.034	<.001	0.480
	Group 5	F1	15.618	=.110	0.047
		F2	75.088	<.001	0.501

3.3 LDA analysis

LDA analyses were conducted by position (word-initial vs. word-final), morpheme type (content vs. function), gender, and age group. Tables 8 to 10 present the confusion matrices showing classification results for distinguishing between the vowels /o/ and /u/ based on F1 and F2 formant values across different gender and age groups. Specifically, Table 8 presents results from word-initial content morphemes, and Table

9 presents results from word-final content morphemes. Table 10 presents results for the vowel /o/ from word-final function morphemes and for the vowel /u/ from word-final content morphemes.

Table 8 (word-initial content morphemes) shows that the overall classification accuracy for /o/ ranges from 60.4% to 83.0%, and for /u/, from 57.4% to 76.6%. F2 generally yields higher classification rates for /o/ (78.7% to 83.0%), while /u/ remains less accurately classified (57.4% to 67.4%). Older speakers tend to show higher classification accuracy than younger ones, particularly in F1. The confusion between /o/ and /u/ is asymmetrical in F2, with /u/ more often misclassified as /o/ than the reverse. For example, the accuracy for /o/ using F2 ranges from 78.7% to 83.0%, whereas that for /u/ declines from 67.4% to 57.4%. These asymmetrical patterns suggest that the vowel /u/ is produced in a way that partially overlaps with the phonetic space of /o/ in terms of F2, particularly among younger male speakers.

Table 8. Confusion matrices of the vowels /o/ and /u/ in word-initial content morphemes in Korean, categorized by gender and age groups.

Formant	Gender	Vowel	Group1		Group2		Group3		Group4		Group5	
			/o/	/u/	/o/	/u/	/o/	/u/	/o/	/u/	/o/	/u/
F1	Female	/o/	68.8	31.2	66.0	34.0	62.1	37.9	61.7	38.3	62.5	37.5
		/u/	23.9	76.1	23.1	76.9	29.8	70.2	32.6	67.4	34.8	65.2
	Male	/o/	70.2	29.8	64.6	35.4	60.4	39.6	63.0	37.0	66.7	33.3
		/u/	23.4	76.6	25.5	74.5	34.0	66.0	30.4	69.6	31.6	68.4
F2	Female	/o/	82.3	16.7	81.2	18.8	81.2	18.8	79.2	20.8	83.0	17.0
		/u/	32.6	67.4	32.6	67.4	31.9	68.1	36.2	63.8	34.0	66.0
	Male	/o/	83.0	17.0	83.0	17.0	83.0	17.0	78.7	21.3	79.2	20.8
		/u/	36.2	63.8	38.3	61.7	42.6	57.4	34.0	66.0	38.3	61.7

Table 9 (word-final content morphemes) shows that both formants contribute to distinguishing /o/ and /u/, though F2 provides more robust separation. Using F1, classification accuracy for /o/ ranges from 60.4% to 78.7%, and for /u/ from 72.3% to 85.1%. F2 offers stronger discrimination, especially for /o/, with accuracies ranging from 74.5% to 91.5%, while /u/ remains less accurately classified (66.0% to 76.6%). Males in Group 4 show the highest /o/ classification rate (91.5%) using F2, indicating strong backness contrast. As in Table 9, the confusion is also asymmetrical in F2: /u/ is more frequently misclassified as /o/ than the reverse. A subtle age-related pattern also emerges: younger speakers tend to exhibit weaker differentiation along the F1

dimension, with both genders showing this tendency.

Table 9. Confusion matrices of the vowels /o/ and /u/ in word-final content morphemes in Korean, focusing exclusively on content morphemes, divided by gender and age groups.

Formant	Gender	Vowel	Group1		Group2		Group3		Group4		Group5	
			/o/	/u/	/o/	/u/	/o/	/u/	/o/	/u/	/o/	/u/
F1	Female	/o/	78.7	21.3	74.5	25.5	64.6	35.4	63.8	36.2	60.4	39.6
		/u/	14.9	85.1	16.7	83.3	17.0	83.0	25.5	74.5	27.7	72.3
	Male	/o/	70.2	29.8	74.5	25.5	61.7	38.3	66.7	33.3	68.8	31.2
		/u/	23.4	76.6	14.9	85.1	25.5	74.5	23.4	76.6	19.1	80.9
F2	Female	/o/	83.0	17.0	83.3	16.7	81.2	18.8	74.5	25.5	80.9	19.1
		/u/	30.8	69.2	29.6	70.4	29.8	70.2	34.0	66.0	32.6	67.4
	Male	/o/	87.2	12.8	87.2	12.8	81.2	18.8	91.5	8.5	89.4	10.6
		/u/	27.7	72.3	27.7	72.3	27.7	72.3	23.4	76.6	25.5	74.5

Table 10 indicates that both formants contribute to distinguishing /o/ and /u/, though F2 provides a more reliable basis for separation. Using F1, classification accuracy for /o/ ranges from 58.3% to 74.5%, and for /u/ from 55.3% to 76.6%. F2 produces higher accuracy overall, with /o/ classified between 78.7% and 85.4%, while /u/ classification remains comparatively lower (61.5% to 78.7%). Male speakers in Group 2 show the strongest separation, achieving an 85.4% rate for /o/ using F2, suggesting a robust backness distinction. As shown in Table 10, misclassification is asymmetrical in F2: /u/ is more often identified as /o/ than the reverse. An age-related trend is also evident, as younger speakers show less consistent separation along the F1 dimension across both genders (e.g., Female Group 1: /o/ 74.5%, /u/ 76.6% vs. Female Group 5: /o/ 60.4%, /u/ 55.3%; Male Group 1: /o/ 70.2%, /u/ 71.7% vs. Male Group 4: /o/ 59.6%, /u/ 58.7%). These findings suggest a potential ongoing change, with the /o/–/u/ contrast appearing less stable, especially when /o/ appears in word-final function morphemes.

Table 10. Confusion matrices of the vowels /o/ and /u/ in word-final position in Korean, focusing on /o/ from function morphemes and /u/ from content morphemes, divided by gender and age group.

Formant	Gender	Vowel	Group1		Group2		Group3		Group4		Group5	
			/o/	/u/	/o/	/u/	/o/	/u/	/o/	/u/	/o/	/u/
F1	Female	/o/	74.5	25.5	74.5	25.5	66.0	34.0	63.8	36.2	60.4	39.6
		/u/	23.4	76.6	23.4	76.6	25.0	75.0	34.0	66.0	44.7	55.3
	Male	/o/	70.2	29.8	68.1	31.9	58.3	41.7	59.6	40.4	64.6	35.4

		/u/	28.3	71.7	25.5	74.5	45.7	54.3	41.3	58.7	36.2	63.8
F2	Female	/o/	83.0	17.0	83.3	16.7	85.1	14.9	78.7	21.3	79.2	20.8
		/u/	38.5	61.5	34.6	65.4	27.7	72.3	34.0	66.0	29.8	70.2
	Male	/o/	83.0	17.0	85.4	14.6	81.2	18.8	81.2	18.8	78.7	21.3
		/u/	27.1	72.9	26.1	73.9	23.4	76.6	21.3	78.7	25.5	74.5

3.4 /o/-raising

As demonstrated in our data, compared to F1, F2 values consistently revealed a significant difference between the target vowels. However, the results for F1 values showed variation depending on the data set. For example, when the vowel /o/ was produced in word-final function morphemes, several cases—especially among younger speakers—showed no significant difference in F1 between /o/ and /u/. This pattern suggests a tendency toward /o/-raising among younger speakers in this specific morphological context. To investigate this pattern more systematically, we employed a Linear Mixed-Effects Model. The analysis was based on the word-final function morphemes for /o/ and word-final content morphemes for /u/. The objective was to examine how the F1 values (associated with /o/-raising) of /o/ and /u/ vary across age groups, and to determine whether the patterns of change differ between the two vowels. The model included main effects for vowel, age group, and their interaction, along with random effects for sentences (sentence-level variability) and speakers (individual differences). Morpheme type was included as a fixed effect to control for its potential influence.

The results yield distinct patterns of F1 change by gender. Among female speakers, the vowel /o/ exhibits a consistent raising trend, characterized by a gradual decrease in mean F1 values over time, as illustrated in Figure 4. Statistical analysis confirms significant F1 lowering for /o/ across age groups, particularly from age group 3 to 5 (Group 3: $\beta = -40.80$, $p < .05$; Group 4: $\beta = -49.48$, $p < .01$; Group 5: $\beta = -71.66$, $p < .001$), while the /u/ vowel remains relatively stable with no significant change. Consequently, the F1 difference between /o/ and /u/ progressively narrows across age groups, suggesting an increasing acoustic overlap between the two vowels.

Male speakers, on the other hand, exhibit a weaker /o/-raising pattern. Although a slight raising of F1 for /o/ is observed in Group 3 ($\beta = -42.02$, $p < .05$), the magnitude of change is generally smaller than that observed among females. Furthermore, a clear gender difference is observed in the progression of the change: female speakers show

more consistent evidence of /o/ being raised, while male speakers show only weak and irregular patterns for /o/. This suggests that the change from /o/ to /u/ is more advanced among women, with men lagging behind in this phonetic change.

These patterns are also reflected in the interaction effects. For female speakers, a significant interaction between vowel and age group is observed (Group 4: β = 37.42, p < .01; Group 5: β = 62.43, p < .001), indicating that the narrowing of the F1 difference between /o/ and /u/ is statistically robust. Similarly, male speakers exhibit significant interactions in three age groups (Group 3: β = 52.72, p < .001; Group 4: β = 35.92, p < .001; Group 5: β = 31.29, p < .01). These results indicate that the F1 distance between the two vowels is smaller across male groups, although the overall pattern is characterized by greater variability and less consistency.

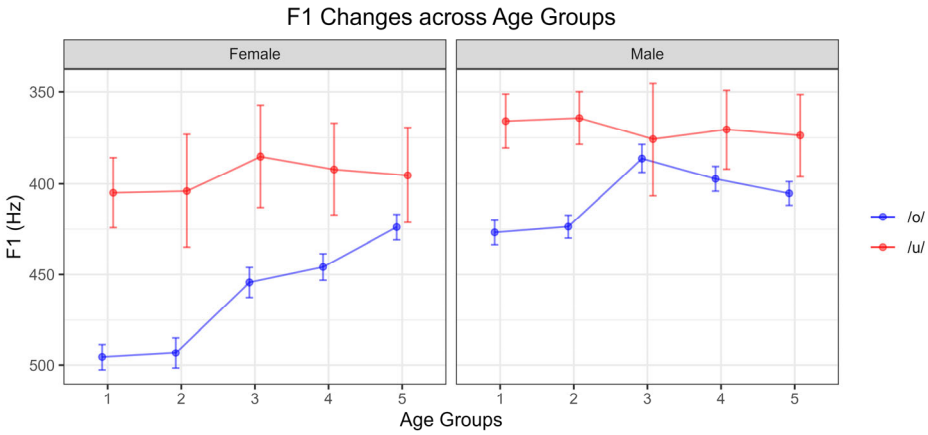

Figure 4. F1 Formant trajectories of /o/ and /u/ across age groups, separated by gender. Error bars indicate 95% confidence intervals

Table 11. Results from linear mixed-effects models for F1: Age and gender Effects on /o/ and /u/, with vowel–age group interactions[1]

Gender	Vowel	Group	Coefficient	p-value
Female	/o/ (F1)	Baseline	495.23	-
		Group 2	-1.95	=.912
		Group 3	-40.80	<.05
		Group 4	-49.48	<.01

1 This table is not intended for comparing model fit indices such as R^2. Instead, it focuses on assessing the statistical significance of vowel changes across age groups.

		Group 5	-71.66	<.001
	/u/ (F1)	Baseline	404.90	-
		Group 2	-0.56	=.983
		Group 3	-20.49	=.438
		Group 4	-12.42	=.637
		Group 5	-10.22	=.704
	/o/ vs /u/ (Interaction)	Baseline	495.27	-
		Group 2	1.45	=.911
		Group 3	20.91	=.107
		Group 4	37.42	<.01
		Group 5	62.43	<.001
Male	/o/ (F1)	Baseline	427.54	-
		Group 2	-4.38	=.795
		Group 3	-42.02	<.005
		Group 4	-30.37	=.082
		Group 5	-22.44	=.197
	/u/ (F1)	Baseline	365.56	-
		Group 2	-1.16	=.950
		Group 3	10.25	=.581
		Group 4	5.01	=.792
		Group 5	8.22	=.665
	/o/ vs /u/ (Interaction)	Baseline	427.70	-
		Group 2	3.87	=.711
		Group 3	52.72	<.001
		Group 4	35.92	<.001
		Group 5	31.29	<.01

4. Discussion

This study investigated the production of the vowels /o/ and /u/, focusing on positional (word-initial vs. word-final), morphological (content vs. functional morphemes), and sociolinguistic (gender and age) factors. By employing an experimental design that directly compared morpheme types within the same word position, this study provided a clearer understanding of the patterns underlying this vowel change. What follows is to revisit the four research questions in turn and discuss the main findings.

To begin, the first research question asked which syllable position—word-initial or word-final—shows a more advanced stage of the phonetic change. The results

indicated that, all else being equal, the word-initial position was more susceptible to phonetic convergence between the two vowels. Specifically, when the vowel data were extracted from word-initial content morphemes, younger speakers (Groups 3–5) showed increased overlap—particularly in F1—while older speakers maintained a clear distinction between the two vowels. In contrast, when the vowels were extracted from word-final content morphemes, they were clearly distinguished by both F1 and F2, regardless of age and gender. This suggests that the contrast between /o/ and /u/ remains more robust in word-final position, whereas it is less distinct in word-initial position.

An immediate question arises as to why the vowel /o/ in word-final content morphemes resisted the change to /u/. We speculate that this resistance can be explained primarily by prosodic factors. First, the word-final position is often associated with final lengthening—a universal phenomenon involving increased segmental duration at the right edge of prosodic domains (Paschen 2022). Furthermore, the word-final position serves as a prosodic boundary, which generally limits coarticulatory influence from adjacent segments. For instance, in the word *창고* [changgo] meaning 'storage,' the second vowel /o/ occurs in word-final position, where the absence of a following segment minimizes the possibility of anticipatory coarticulation. This prosodic boundary effect thus contributes to the relative stability of /o/ in such environments. In contrast, vowels in word-initial position are more susceptible to contextual influence. For example, in *조식* [josik] meaning 'breakfast,' the first vowel /o/ occurs before the high vowel /i/, which may exert a coarticulatory raising effect due to the [+high] feature of the following vowel. Therefore, we anticipate that the vowels /o/ and /u/ in Korean will continue to be distinguished by both F1 and F2 when they occur in word-final content morphemes. This explanation, albeit indefinite, provides a reasonable account of why the vowel /o/ resists the change in word-final position but not in word-initial position, underscoring the positional asymmetry regarding the change from /o/ to /u/.

The second research question asked: to what extent does morpheme type (content vs. function) influence the progression of the vowel change? The results raise important questions about why the phonetic change from /o/ to /u/ appears more advanced in function morphemes than in content morphemes. Although the vowels extracted from word-initial content morphemes were realized quite similarly, the change was notably more advanced in word-final function morphemes. One possible explanation

relates to frequency and predictability. Function morphemes are typically high-frequency items with lower semantic weight, which may promote greater phonetic reduction or lenition. For instance, as stated before, 그리고 [geurigo], meaning 'and,' is often produced as [geurigu], whereas 냉장고 [naengjanggo], meaning 'refrigerator,' is rarely realized as [naengjanggu]. In addition, the functional load of the /o/–/u/ contrast may be lower in function morphemes, making the distinction less critical for comprehension. Taken together, these factors suggest that function morphemes may serve as natural sites for vowel convergence, offering insight into the phonetic pathways of sound change in Korean—and potentially in other languages as well.

Regarding the third research question, while this study cannot pinpoint the exact onset of the vowel change, the findings broadly suggest that the change may have begun among speakers born in and after the late 1950s (Group 3 in this study). The vowels /o/ and /u/ appear to be undergoing a partial overlap in vowel height (F1) in word-final function morphemes. This pattern was more noticeable among younger speakers, with both genders showing increased overlap between the two vowels. Similar patterns emerged in word-initial content morphemes, where younger speakers also demonstrated increased F1 convergence between /o/ and /u/. That is, although the precise timing remains unclear, a distinct age-related pattern emerged. Older speakers tended to maintain acoustic distinction between /o/ and /u/, while younger speakers showed greater overlap in F1, as indicated by smaller effect sizes across datasets. This generational difference is consistent with the interpretation of an ongoing change occurring primarily along the vowel height dimension (F1).

Our final research question addressed which gender group appears to lead the ongoing vowel change. The results revealed gender-differentiated patterns. Female speakers exhibited relatively consistent /o/-raising, with a gradual decrease in F1 values from Group 1 to Group 5, while /u/ remained comparatively stable. This pattern resulted in a progressive narrowing of the F1 distance between /o/ and /u/ among younger females, suggesting increased acoustic overlap. In contrast, male speakers displayed greater variability. /o/-raising was less consistent and fluctuated across groups, whereas /u/ remained stable throughout. Taken together, these results indicate that both genders participate in the change in distinct ways, yet their formant trajectories overlap among younger groups, consistent with the findings of Jang et al. (2015). In other words, the female pattern is more consistent and systematic, suggesting that women may be leading the ongoing change, whereas men show greater

variability and appear to participate in a less systematic manner.

Inconclusion, this study examined the production of the Korean vowels /o/ and /u/ by analyzing the effects of positional context (word-initial vs. word-final), morphological status (content vs. functional morphemes), and sociolinguistic variables (gender and age). The findings showed that the distinction between /o/ and /u/ was less clear in word-initial position than in word-final position, and in functional morphemes than in content morphemes, particularly along the F1 dimension (vowel height), and that the patterning differed by age and gender. Younger speakers, especially females, exhibited greater F1 overlap in word-final function morphemes due to systematic /o/-raising, while males displayed the change in less consistent ways. The tendency for /o/ to approximate /u/ appears among speakers born in the late 1950s and later, and it is most evident in word-final function morphemes, where frequency and predictability appear to promote greater acoustic overlap. While this study offers important insights into the dynamics of the /o/–/u/ contrast, further research is warranted. In particular, larger and more balanced datasets will be essential for tracing the complexity of these sociophonetic patterns and understanding the mechanisms that drive the sound change. Moreover, because spontaneous and natural speech often reveals such variation more clearly, future studies should compare the present results with data derived from naturalistic speech.

References

Arnold, Lacey R. 2015. Multiple mergers: Production and perception of three pre-/l/ mergers in Youngstown, Ohio. *University of Pennsylvania Working Papers in Linguistics* 21(2): Article 4.

Bates, Douglas M., Martin Mächler, Ben Bolker, and Steven Walker. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67(1): 1–48.

Boberg, Charles. 2008. Regional phonetic differentiation in Standard Canadian English. *Journal of English Linguistics* 36(2): 129–154.

Brown, Vivian R. 1991. Evolution of the merger of /ɪ/ and /ɛ/ before nasals in Tennessee. *American Speech* 66(3): 303–315.

Byun, Hi-Gyung. 2020. Perceptual cues for /o/ and /u/ in Seoul Korean. *Phonetics and Speech Sciences* 12(3): 1–14.

Chae, Seo-Young. 1995. *External constraints on sound change: The raising of /o/ in Seoul Korean.*

PhD Dissertation. University of Pennsylvania.

Cho, Young-mee Yu. 2016. Korean phonetics and phonology. In Mark Aronoff (ed.), *Oxford research encyclopedia of linguistics*. Oxford: Oxford University Press.

Chung, Inkie. 2022. Hyeondae Seoul bangeon "ㅖ" /e/ wa "ㅐ" /ɛ/ ui eumsojagyeok gwa hamru-e daehayeo [On the phonemic status of the vowels /e/ ㅖ and /ɛ/ ㅐ and their merger in Modern Seoul Korean]. *Korean Journal of Linguistics* 47(4): 857–877.

Escudero, Paola, Paul Boersma, André M. R. Almeida, and Rinus E. Van Leussen. 2009. A cross-dialect acoustic description of vowels: Brazilian and European Portuguese. *Journal of the Acoustical Society of America* 126(3): 1379–1393.

Fox, Joshua. 1996. A sequence of vowel shifts in Phoenician and other languages. *Journal of Near Eastern Studies* 55(1): 37–47.

Herzog, Marvin. 1965. *The Yiddish language in Northern Poland: Its geography and history*. Bloomington, IL: Indiana University Press.

Hoenigswald, Henry. 1960. *Language change and linguistic reconstruction*. Chicago, IL: University of Chicago Press.

Jang, Hyejin, Jiwon Hwang, and Jaeyeol Kim. 2015. Seoul bangeon danmoeum-ui yeonryeong-byeol silhyeon yangsang [Aspects of vowels by ages in Seoul dialect]. *Studies in Phonetics, Phonology and Morphology* 21(2): 341–358.

Johnson, Daniel Ezra. 1997. *Stability and change along a dialect boundary: The low vowels of Southeastern New England*. Durham, NC: Duke University Press.

Kang, Hyunsook and Jeong-Im Han. 2013. Cross-generational change of /o/ and /u/ in Seoul Korean II: Spectral interactions in normalized vowel space. *Phonetics and Speech Sciences* 5(2): 33–41.

Kang, Yoonjung. 2014. Voice onset time merger and development of tonal contrast in Seoul Korean stops: A corpus study. *Journal of Phonetics* 45: 76–90.

Kenstowicz, Michael J. 1994. *Phonology in generative grammar*. Cambridge: Blackwell.

Ko, Insung. 2009. The merger ey /e/ and ay /e/ of Seoul Korean. *Language Information* 10: 73–89.

Labov, William. 1994. *Principles of linguistic change. Volume 1: Internal factors*. Oxford: Blackwell.

Labov, William, Sharon Ash, and Charles Boberg. 2006.*The atlas of North American English: Phonetics, phonology and sound change: A multimedia reference tool*. Berlin: De Gruyter Mouton.

Lee, Yong-cheol. 2023. Revisiting the merger of mid front vowels in Seoul Korean. *Studies in Phonetics, Phonology and Morphology* 29(2): 193–209.

Lee, Yong-cheol and Sunghye Cho. 2021. The merger of /e/ and /ɛ/ in Seoul Korean tracing speakers born from the 1930s to the 1960s. *Studies in Linguistics* 61: 1–16.

Lüdecke, Daniel, Mattan S. Ben-Shachar, Indrajeet Patil, Philip Waggoner, and Dominique Makowski. 2021. Performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software* 6(60): 3139.

Nakagawa, Shinichi and Holger Schielzeth. 2013. A general and simple method for obtaining R^2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution* 4(2): 133–142.

Purnell, Thomas C. 2008. Prevelar raising and phonetic conditioning: Role of labial and anterior tongue gestures. *American Speech* 83(4): 373–402.

Reddy, Sravana and James N. Stanford. 2015. Toward completely automated vowel extraction: Introducing DARLA. *Linguistics Vanguard* 1(1): 15–28.

Venables, William N. and Brian D. Ripley. 2002. *Modern applied statistics with S*. 4th ed. New York, NY: Springer.

Wassink, Alicia B. 2015. Sociolinguistic patterns in Seattle English. *Language Variation and Change* 27(1): 31–58.

Yao, Yao and Charles B. Chang. 2016 .On the cognitive basis of contact-induced sound change: Vowel merger reversal in Shanghainese. *Language* 92(2): 433–467.

Yao, Yao, Morgan Sonderegger, Alan C. L. Yu, and Charles B. Chang. 2010. Automated measurement of vowel formants in the Buckeye Corpus. *Gengo Kenkyu* 138: 99–113.

Yoon, Eunkyung. 2020. Frequency of grammar items for Korean substitution of /u/ for /o/ in the word-final position. *Phonetics and Speech Sciences* 12(1): 33–42.

Yoon, Tae-Jin and Yoonjung Kang. 2012. A forced-alignment-based study of declarative sentence-ending "da" in Korean. In Qiuwu Ma, Hongwei Ding, and Daniel Hirst (eds.), *Proceedings of the 6th International Conference on Speech Prosody 2012*, 559–562.

Yu, Xiaohua, Sunghye Cho, and Yong-cheol Lee. 2022. Individual variability in the production of /e/ and /ɛ/ in Yanbian Korean. *Studies in Linguistics* 65: 1-19.

Yu, Xiaohua, Sunghye Cho, and Yong-cheol Lee. 2024. Yanbian Korean speakers tend to merge /e/ and /ɛ/ when exposed to Seoul Korean. *Speech Communication* 164: 103111.

Yong-cheol Lee
Associate Professor
Department of English Language and Literature
Hannam University
70 Hannamro, Daedeok-gu,
Daejeon 34430, Korea
E-mail: soongdora@gmail.com

Received: 2025. 08. 29.
Revised: 2025. 10. 10.
Accepted: 2025. 10. 16.