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Vowel production variation in Korean heritage speakers*

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1 Introduction

Studies in vowel acoustics indicate that in clear speech, talkers increase their acoustic vowel space as well as vowel duration. Ferguson & Kewley-Port (2007) demonstrated this effect for American English speakers recording the same carrier sentences in two different speech styles: conversational speech and "clear speech", in which they were instructed to speak as if talking to a person with hearing loss. More recently, Kuo & Weismer (2016) demonstrated the same effect for male American English speakers recording casual conversation and text passages in addition to sentences in clear and citation styles. Reduction in vowel formants toward the center of the vowel space based on the Euclidean distance of F1 and F2 and the Euclidean distance of F2 and F3 was greater in the more casual registers, with conversation eliciting the greatest reduction, followed by text passages, citation sentences, and clear sentences.

Acoustic vowel space measurements such as Euclidean distance between vowel formants have been used to differentiate between dialects of the same language (Clopper *et al.* 2005, Ruch 2018) and the similar vowel systems of different languages (Chung *et al.* 2012). Vowel space is also considered a stylistic difference between speakers of the same dialect according to gender. Simpson (2002) found that in a comparison of female and male speakers, female speakers tended to have larger vowel spaces than male speakers, although the articulations of their vocal tracts (i.e., tongue movements) also tended to be smaller in magnitude. More recent work relates vowel distance (though not necessarily overall vowel space) to parodic performances of dialects (Pratt & D'Onofrio 2017), specific personae at the intersection of gender, sexuality, class, and region (Podesva 2011), and other styles and stances associated with the linguistic construction of identity (Bucholtz & Hall 2005, Eckert 2008).

Although much of the research on acoustic differences across speech styles has been done on varieties of English, the same general pattern has also been found in many other languages, including Mixtec (DiCanio *et al.* 2015), Spanish of Spanish-English bilinguals (Bradlow 2002), and Finnish of Finnish-Engilsh bilinguals (Granlund *et al.* 2012). Research on the effects of speech style on the acoustic characteristics of the Korean language confirms what Granlund *et al.* call language-independent global enhancements: clear speech results in a slower speech rate and

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greater emphasis on the phonetic parameters that differentiate the unvoiced Korean stops (Kang & Guion 2008, Cho *et al.* 2011) and glides (Chang 2017). Winter & Grawunder (2012) also analyzed the acoustic correlates of different formal and informal registers in Korean, finding that formal or more honorific speech tended to be lower and less variable in f0 level and span.

However, the research on the acoustic correlates of speech style in Korean is limited in two ways. First, the existing research focuses on specific segmental and suprasegmental phenomena in the language, including f0 contours at prosodic boundaries and their effects on the acoustics of phrase-initial consonants, but does not analyze vowel formants or acoustic vowel space. Second, the majority of studies in Korean acoustics use data from native monolingual speakers of the Seoul variety of Korean, while the speech of heritage Korean speakers or other Korean-English bilinguals is quite understudied.

Heritage speakers are bilingual speakers whose exposure to and acquisition of the heritage language most often occur in the home during early childhood, a period which is followed by radically decreased exposure and usage as the speaker adopts the majority language of society (Polinsky & Scontras 2020). They tend to be dominant in the majority language of society and use their heritage language in limited social situations, including with their parents or heritage language community, and may not be literate in their heritage language. Though not all heritage language users are immigrants, it is often the minority languages of recent immigrants that become heritage languages in the context of the United States. Due to the social pressures that favor dominance in English over minority languages in the United States, many heritage language users decline in the proficiency of their heritage language, and within a few generations, native and heritage knowledge of the language is lost (Valdés 2001, Shin 2005).

The grammatical properties of the bilingualism of heritage speakers are still not well known, as many conflicting studies characterize heritage bilingualism as "incomplete acquisition" of one language (Montrul 2016), while others theorize it as a microcosm of language contact within an individual (Muysken 2020). The common thread in all studies of heritage bilingualism, however, is that interspeaker variation within the speaker community of any given heritage language, in terms of variables such as language background and experience, proficiency, and grammatical organization, is very high. Despite this, recent studies on the phonetics of heritage language users' speech has found, for example, that heritage speakers' use of prosody differs substantially from native and L2 speakers (Chang & Yao 2016), that heritage speakers can maintain language-internal and cross-linguistic phonetic contrasts in stops and vowels (Chang *et al.* 2011), and that acoustic characteristics of consonants such as Voice Onset Time (VOT) can be affected by intereference from the phonetic attributes of the majority language (Hrycyna *et al.* 2011, Kang *et al.* 2016, Kang & Nagy 2016, Asherov *et al.* 2016).

Thus, the current study investigates the pattern of stylistic differentiation in acoustic vowel space in heritage speakers. If heritage speakers behave more like the aforementioned native speakers of Korean or other langauges, then they will show large vowel spaces in more careful speech styles and smaller vowel spaces in more casual speech styles. If, however, heritage speakers differ from both native and L2 speakers, then they may not demonstrate the pattern of stylistic differentiation. In this study, the acoustic vowel space and vowel duration of heritage Korean speakers was investigated, with the hypothesis that they will demonstrate the same pattern of stylistic vowel space differentiation that has been demonstrated for monolingual American English speakers and other speaker communities whereby more casual speech is correlated with smaller acoustic vowel space.

2 Methods

The data collected for this study were collected from thirty-one heritage speakers of Korean who were bilingual in Korean and English and dominant in English. Twenty-one identified as cisgender female, and ten as cisgender male. They ranged in age from 18 to 55 (median age=23 years). Eighteen speakers (female=11) had been born and raised in the United States, while thirteen (female=10) had been born in South Korea but moved to the United States prior to the age of 16 (median age of arrival=9 years). Korean Americans who are born and raised in the United States are called "second generation" Korean Americans, while those who immigrate during childhood with their families are called "1.5 generation" Korean Americans. (Their parents, the adult immigrants, are called first generation Korean Americans, regardless of citizenship status.) A summary of the speakers' demographic characteristics can be found in Table 1.

Generation	male	female	total	age range of immigration
1.5	3	10	13	3 to 16 yrs
2	7	11	18	–

Table 1: Demographic data for the 31 study participants.

Each speaker participated in a bilingual sociolinguistic interview with a trained interviewer. First, they conversed in Korean, following a short script with guided questions about the speaker's childhood, family, and hobbies. Then, the speaker was given a series of passages written in the Korean script, *hangul*, to read aloud at their own pace. The final part of the bilingual interview was conducted in English, but the English data is not used in the current study, which only compares measurements from the Korean interview section (henceforth, the "interview") and the passage reading section (henceforth, "reading"). The average duration of the Korean-language portions of the interview was 11 minutes.

The bilingual sociolingustic interview was part of a larger study of heritage Korean speakers, in which a total of forty speakers participated. Three independent native and heritage speakers of Korean listened to randomized one-minute samples of the participants' speech from both the interview and the reading sections, then rated the samples in both native-like accent and native-like proficiency on a five-point Likert scale. Of the forty participants, seven participants were removed from the current analysis because their average accent and proficiency scores were both below 3. Two participants were removed due to recording or data processing errors. This left thirty-one speakers to be analyzed in the current study.

The content of each interview was transcribed by hand and automatically aligned using a Korean version of the Penn Forced Aligner (Yoon & Kang 2014). Formant data for the eight monophthongs of Korean, /i, e, ɛ, a, ʌ, o, u, ɯ/, were extracted using `ifcformant` (Watanabe 2001) and compared across groups and speech styles. The vowels in question are listed in Table 2.

IPA	ARPABET
i	I
e	E
ɛ	AE
a	A
ʌ	EO
o	O
u	U
ɯ	EU

Table 2: Korean monophthongs and ARPABET equivalents (for coding and visualization).

Vowel formant data was subjected to several rounds of data processing and cleanup. The `ifcformant` tool extracts formant frequency measurements at ten millisecond intervals throughout the entire duration of an audio signal. During automatic alignment and formant extraction, each vowel was divided into ten equally-spaced timepoints, and a smoothing function was called over all of the data, per subject, to reduce the effects of errors during alignment or formant extraction (Garcia 2010). Each vowel's duration in seconds was recorded and then log-transformed across speakers in order to normalize them. After normalization, any vowels whose duration was deemed an outlier[1] were removed. Finally, only the midpoint of each monophthong (i.e., the fourth timepoint out of ten) was kept, and all values in Hertz were transformed to the Bark auditory scale[2].

The resulting dataset had about 40,000 observations of eight vowels from thirty-one participants, or about 1300 vowel tokens per speaker. Each observation had smoothed Bark measurements for the first and second formants (F1 and F2), which were used in the calculation of acoustic vowel space using the `phonR` package in R (McCloy 2012). The `vowelMeansPolygonArea` function calculates the area of the polygon defined by the mean values for each of the eight monophthongs, grouped by speaker and section (interview or reading). Thus, each speaker had two vowel space area measurements, one per section, as well as a value that calculated the difference between reading and interview. A higher value for vowel space area

[1]That is to say, greater or less than the values of the 95% Confidence Interval, calculated by the R function `boxplot.stats` according to the formula:

$$median \pm \frac{1.58 * IQR}{\sqrt{n}}$$

[2]Bark transformation was calculated using the formula:

$$Bark = \frac{(26.81 \times formant)}{(1960 + formant)} - 0.53$$

indicates a larger vowel space (and, consequently, less reduction), while a lower value indicates a smaller vowel space.

3 Results

Results showed that overall, speakers had a larger vowel space during the reading section compared to the interview section. This is visualized in Figure 1, a standard F1×F2 plot with Bark-normalized axes. The vowel formant means for the reading section are in orange, and the interview section vowels are in green. Upon visual analysis, it can be seen that the orange vowels are more widely dispersed than the green vowels, although the effect appears to be larger for female speakers than for male speakers, and mostly due to formant differences between styles found in high vowels such as /i/ and back vowels such as /o/ and /u/.

Figure 2 demonstrates the same group comparison using a boxplot; here, it is clear that for both female and male speakers, the median vowel space area for the reading section was higher than the median area for the interview section. However, there is a significantly larger difference between sections for female speakers compared to male speakers. In addition, the vowel space area for female speakers tended to be greater than the vowel space area for male speakers, regardless of section.

A linear mixed effects regression model fit to the data showed that speaker gender and section significantly affected vowel space area. In addition, there was an interaction between gender and section, such that female speakers showed a significant difference between reading and interview, while male speakers did not. The model results are summarized in Table 3.

	Dependent variable:
	area
sectionreading	1.227***
	(0.209)
GenderMale	-1.160^{***}
	(0.351)
sectionreading:GenderMale	-0.896^{**}
	(0.369)
Constant	1.779***
	(0.199)
Observations	62
Log Likelihood	-79.149
Akaike Inf. Crit.	170.297
Bayesian Inf. Crit.	183.060
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 3: Linear mixed effects regression model results for vowel space area by section, speaker gender, and section*gender.

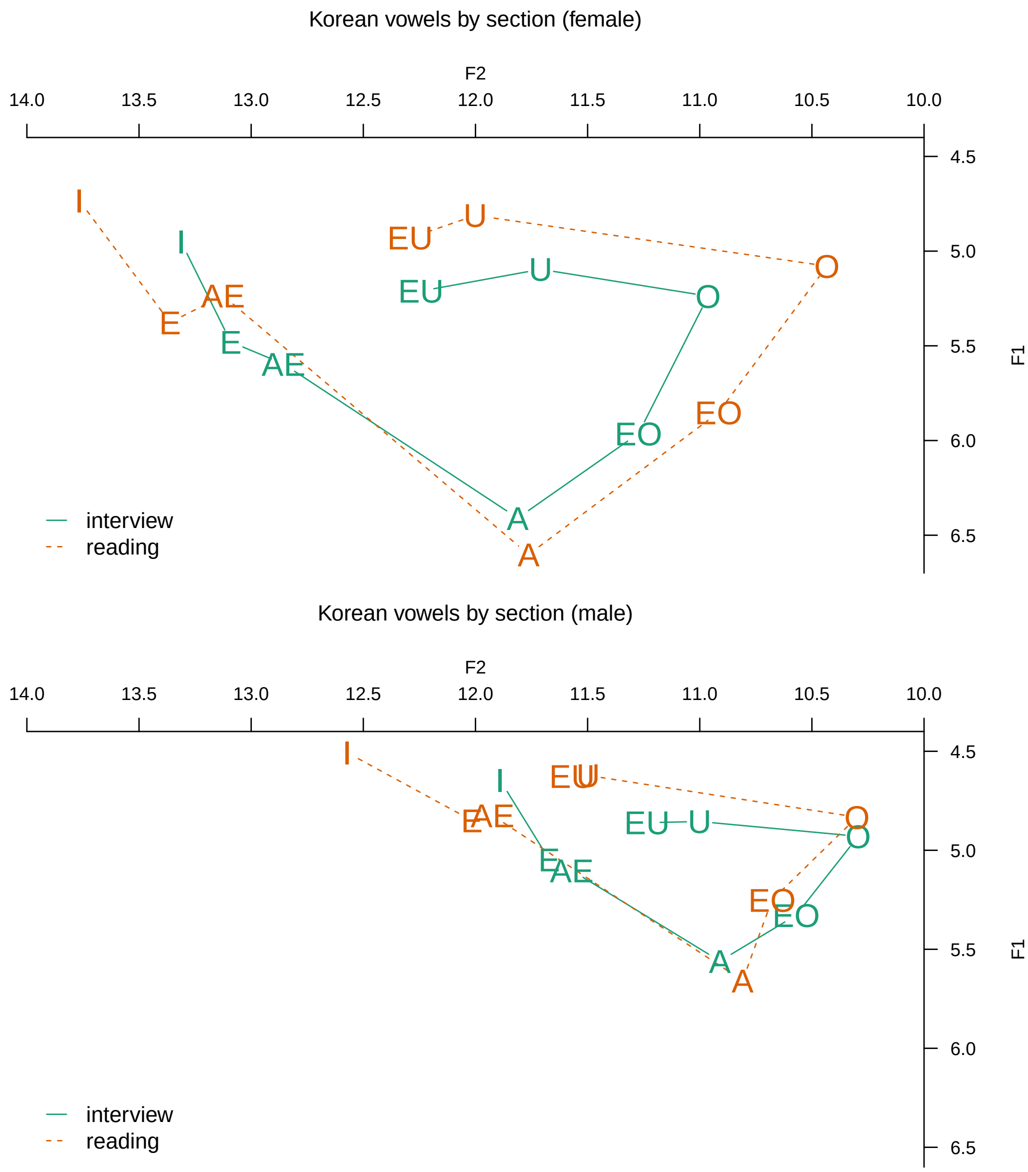

Figure 1: F1 and F2 (Bark) of the vowels of all speakers, split by speech style and gender.

However, even with the speakers who scored below average in perceived Korean proficiency and perceived Korean accent removed from the dataset, there was lots of variability in the spoken Korean of the thirty-one speakers. Each speaker received two perceived proficiency scores, one for the interview (i.e., proficiency in communicating in casual spoken Korean), and one for the reading section (i.e., proficiency in reading Korean). The perceived accent ratings were not used in the analysis. Female speakers, on average, scored higher in interview proficiency (W=157.5, p=0.025), but there was no significant difference between male and female speakers for reading proficiency ratings (W=138.5, p=0.16).

Figure 3 illustrates the vowel space area for speakers plotted against each speaker's

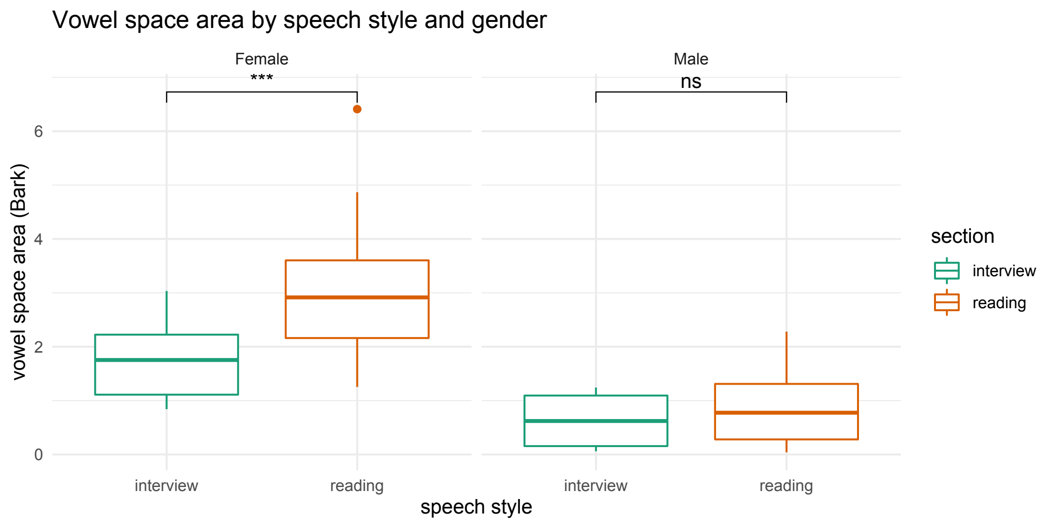

Figure 2: Vowel space area for speakers, split by gender and speech style (section). Female speakers' vowel space area was greater during the reading section than during the interview section.

proficiency scores for the interview and reading sections. Although the slopes of the smoothing lines in Figure 3 and the overall shapes of the patterns are the same in subfigures A and B, the strengths of the associations differ.

A second linear mixed effects regression model was fit to the data and included fixed effects for perceived proficiency ratings of the interview and reading sections. The model results are displayed in Table 4. Interview proficiency was not found to be a significant predictor of vowel space area[3], but reading proficiency was. As can be seen in Figure 3B, speakers with a higher reading proficiency rating tended to have smaller vowel spaces during the reading section. However, once again, the effect only holds for female speakers, while male speakers appeared to show no relationship between proficiency rating and vowel space area.

With the demonstrated effect of perceived reading proficiency on vowel space during reading, the next step was to determine a cause. It has long been known that speech rate affects the acoustic characteristics of vowels such that a faster speech rate causes vowel reduction and a smaller overall vowel space (Fourakis 1991; Tsao *et al.* 2006). Thus, to test the effect of speech rate, the correlation between mean log vowel duration and vowel space area was investigated.

Figure 4 illustrates the relationship between vowel space area for each section and mean log vowel duration, calculated per section for each gender. As can be seen in the figure, for female speakers, there is a strong positive correlation between vowel space area and mean log vowel duration: the longer the vowels, the larger the vowel space. The correlation exists for female speakers for both interview and reading sections, and is particularly strong for the reading section. For male speakers, the same positive trends exist, but they do not appear to be as statis-

[3]Note that these results are likely skewed by the significant difference between genders in interview proficiency rating.

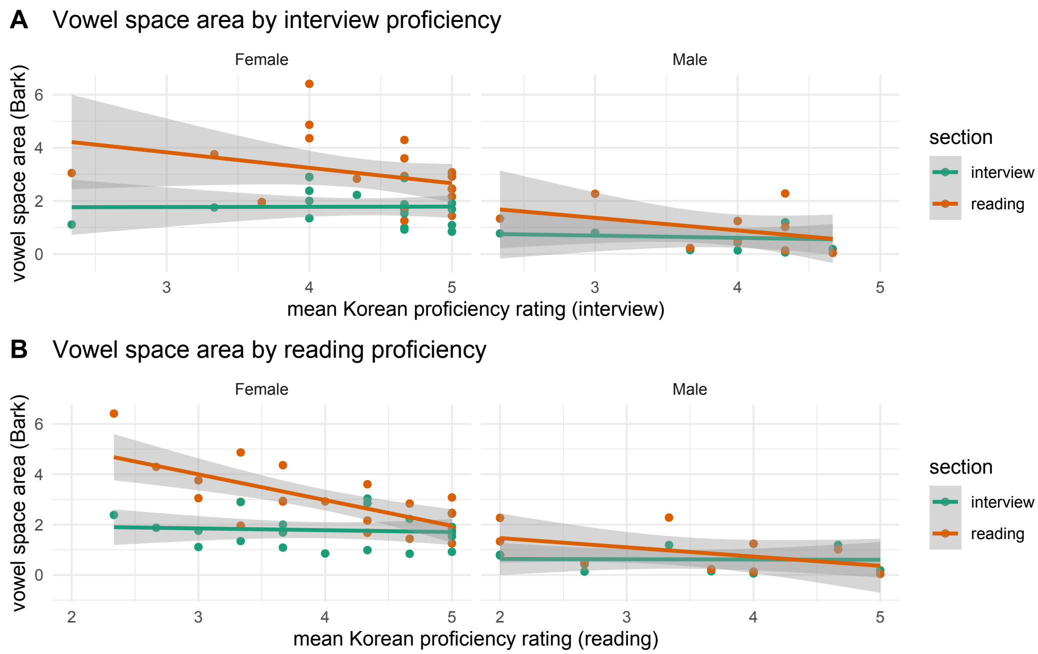

Figure 3: Speakers' vowel space area and mean rating in Korean proficiency (interview and reading).

	Dependent variable:
	area
sectionreading	1.227***
	(0.209)
GenderMale	−1.351***
	(0.344)
mean.proficiency.i	0.148
	(0.259)
mean.proficiency.r	−0.478**
	(0.197)
sectionreading:GenderMale	−0.896**
	(0.369)
Constant	3.022***
	(0.852)
Observations	62
Log Likelihood	−76.797
Akaike Inf. Crit.	169.594
Bayesian Inf. Crit.	186.611
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 4: Linear mixed effects regression model results for vowel space area by section, gender, section*gender, and Korean proficiency during interview (i) and reading (r).

tically significant.

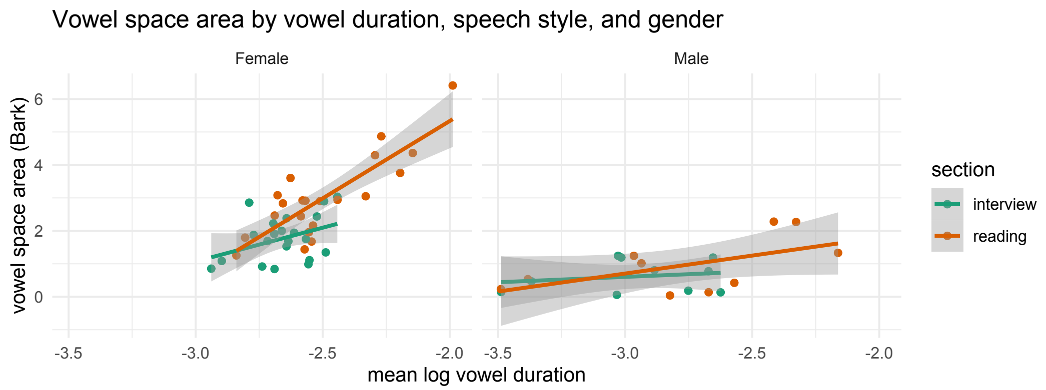

Figure 4: Speakers' vowel space area and mean log vowel duration.

A third and final linear mixed effects regression model was fit to this data to determine the effects of mean log vowel duration on vowel space area. The model results can be seen in Table 5. In this model, section did not significantly affect vowel space area at all, but speaker gender and mean log vowel duration were significant effects. There was also an interaction effect between speaker gender and mean log vowel duration, in that the effect of vowel duration on vowel space area was significant for female speakers, but not for male speakers (who also tended to have shorter mean log vowel durations overall).

An Akaike's An Information Comparison (AIC) estimate of model quality was run on the three models (area by section*gender, area by section*gender and interview and reading proficiency, and area by section*gender*duration). The first model had an AIC value of 170.2972 (df=6). The second model had an AIC value of 169.5936 (df=8). The final model had an AIC value of 120.3368 (df=10), which is a significant decrease that represents a better quality model. Thus, although the addition of more fixed effects and interaction affects decreases the power of a linear model, the model that incorporated the effect of log vowel duration and left out perceived proficiency ratings proved to be the most accurate one.

4 Discussion

Heritage speakers of Korean show the familiar pattern of producing a larger vowel space when reading passages in Korean compared to when speaking conversationally in Korean. However, the pattern only holds for female Koran American speakers, not male Korean American speakers. Overall, female speakers had larger vowel spaces than male speakers.

Korean reading proficiency also significantly affected vowel space, whereby female speakers whose read speech was rated as highly proficient tended to have smaller vowel spaces. The effect did not hold true for male speakers, even though male and female speakers had roughly equivalent means and spans for reading proficiency scores.

The effect of perceived proficiency on vowel space appears to be driven mostly

	Dependent variable:
	area
sectionreading	3.202
	(2.269)
GenderMale	-8.363^{***}
	(2.931)
duration	3.442^{***}
	(0.812)
sectionreading:GenderMale	-1.544
	(2.738)
sectionreading:duration	1.010
	(0.865)
GenderMale:duration	-2.787^{***}
	(1.051)
sectionreading:GenderMale:duration	-0.490
	(1.007)
Constant	10.915^{***}
	(2.162)
Observations	62
Log Likelihood	-50.168
Akaike Inf. Crit.	120.337
Bayesian Inf. Crit.	141.608
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 5: Linear mixed effects regression model results for vowel space area by section, speaker gender, mean log vowel duration, and interactions of all three.

by the effect of speech rate on vowel space. For female speakers, vowel duration was strongly positively correlated with vowel space area, regardless of the speech style. It may be that slower speakers were more careful in their speech and reading, resulting in slightly more peripheral articulations, or that faster speakers simply demonstrated lots of reduction in their speech.

Interestingly, every significant effect demonstrated by the data only held true for the female speakers in the sample. Male speakers in the sample tended to show no significant relationship between speech rate and vowel space size, no significant relationship between reading or interview proficiency and vowel space size, and no significant overall change in vowel space size from interview style to reading style. To the extent that overall acoustic vowel space can be considered part of a speaker's linguistic style or sociolinguistic repertoire (Foulkes & Docherty 2006, Eckert 2008), it would seem that only the female speakers in this study employ speech, reading, and the differentiation between them on an acoustic level for the purposes of sociolinguistic variation, or that intraspeaker vowel production variation itself is a marker of gender identity, style, and language proficiency among Korean heritage speakers.

On the other hand, the lack of significant effects for male speakers could also be due to the small sample size and/or an inherent problem in cross-gender comparisons of phonetic phenomena. Although the formant data were normalized for gender by converting the Hertz values to Bark, the male speakers still had overall smaller values for F1 and F2 and a smaller vowel space compared to the female speakers. This means that a proportional change in, for example, mean vowel space area that is significant for female speakers may not appear significant for male speakers. Again, increasing the sample size to increase the power and validity of the statistical testing could be a way to resolve this issue.

5 Conclusion

The hypothesis that heritage Korean speakers would demonstrate the common pattern of stylistic vowel space differentiation was found to be true, albeit only for female speakers in the study. In more casual speech, female heritage speakers decreased their acoustic vowel space and shortened their vowels (i.e., spoke at a faster speech rate). This accords with the rest of the literature on the acoustic characteristics of clear versus casual speech in Korean with respect to consonants and suprasegmental phenomena. Although the male speakers in the sample did not demonstrate the same effects to a statistically significant degree, their data trended in the same direction, and it does not amount to evidence for the alternative hypothesis, that heritage speakers of Korean substantially differ from native speakers of Korean by not decreasing their vowel space in casual speech.

Future research will look more closely at specific vowels and vowel combinations in the Korean inventory, including the mid-front vowels which have recently undergone a merger in the Seoul variety of Korean, to investigate the effects of speech style on a sound change. In addition, a cross-linguistic analysis of the vowel spaces of both languages of heritage bilingual speakers, Korean and English, is another potential avenue for investigation. Because the vowel inventories of each language have some similarities, an analysis of their differences would reveal more about the potential underlying causes of cross-linguistic differences within the bilingual speaker.

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Supplementary materials

A Reading passages

P32
저녁은 또 뭘 해 먹지? 라면이 있긴 한데. 일주일에 두 세번 해 먹네. 비빔밥이나 뭐 좀 제대로 된 걸 먹고 싶은데. 아, 그냥 중국집에 시켜 먹어야 되겠다.

P33
여보세요? 통신판매부조 업무에 착오가 있으신 것 같네요. 카탈로그에 나온 테디베어를 주문했는데 카드대금에는 웬 잔디깎는 기계가 청구되어 있네요. 우리 집에는 정원도 없거든요. 소비자불만센터로 연결해 주시길 바랍니다.

P21
지난 주말 저녁 약속에 못 가서 죄송합니다. 정말 뵙고 싶었는데 그날 갑자기 사고가 좀 났어요. 막 출발하려고 하다가 갑자기 포도주 한 병 가져가고 싶은 생각이 들어서 급하게 불도 안켜고 지하실로 뛰어 내려가다가 계단에서 넘어져서 발목을 접지렀지 뭡니까.

P23
엄마, 여기 강원도는 너무 좋아요. 날씨가 쨍쨍하고 햇빛이 내리쬐는 바닷가는 무슨 딴 세상 같아요. 어제는 바닷가 절벽길을 따라 산책을 했는데요, 바람이 꽤 불어서 날아가는 줄 알았어요. 볕에 글려 피부는 예쁘게 탔는데, 하도 아이스크림을 먹어대서 몸무게는 두 배로 늘었답니다.

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나는 월요일 아침에 비 오는 게 제일 싫어. 길바닥이 온통 질척해져서 지하철 내려서 회사까지 걸어오는 일이 장난이 아니야. 택시를 타고 싶지만 그게 또 쉽지가 않잖아? 적은 월급으로 신발 사 신을 돈도 없는 마당에. 아, 어디 누가 차 한 대 사줄 사람 없나?

Figure 5: The paragraphs in Korean script (*hangul*) that were used during the reading section of the bilingual interview.

B Vowel space area by speech style: Individual results

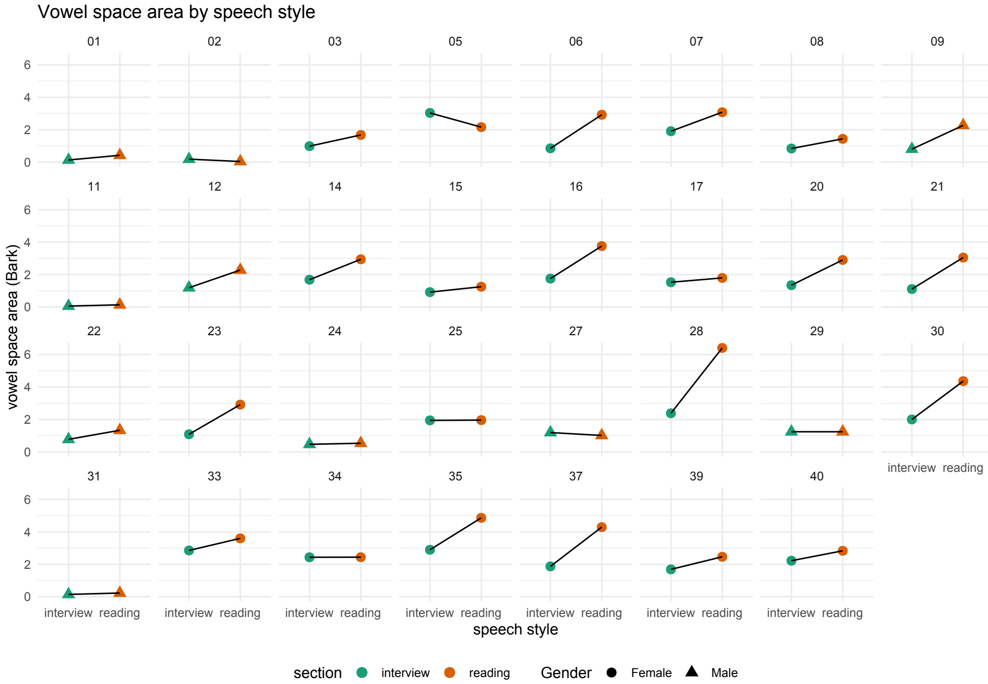

Figure 6: Vowel space area by speech style, showing each of the thirty-one speakers separately.