The timing of Seoul Korean fricative identification and vowel anticipation

Background This study investigates the temporal aspect of the identification of Korean fricatives and the anticipation of the following vowel. Studies have reported that the coarticulatory information in English fricatives can be used to anticipate the following vowel (Rysling & Kingston, 2019) even when the fricative is not accurately identified (Nittrouer & Whalen, 1989; Schreiber & McMurray, 2019). This study explores the relative timing of these two processes in Korean non-fortis /s/ and fortis /s*/.

For Seoul Korean fricatives, identification of the laryngeal category involves various cues that unfold asynchronously during the initial frication, aspiration, and the following vowel. During frication, fortis /s*/ have higher CoG (center of gravity) than non-fortis /s/. After frication, aspiration is observed for non-fortis fricatives, especially before /a/ (Yoon, 1999; 2002), while fortis fricatives have extended frication instead. Moreover, vocalic cues have been suggested to be primary in identifying Seoul Korean fricatives (Park, 1999; Chang, 2013). Additionally, cues relating to the following vowel are present in the initial frication, such as lower CoG from rounding before /u/ and palatalization before /i/. Given that cues for fricatives and vowels are available at different times, this study investigates the time course of the identification of Seoul Korean fricatives and the anticipation of the following vowel using a gating task.

Experiment The stimuli were made from recordings of CV syllables produced by a female Seoul Korean speaker, where C was either /s, s*/ and V was one of /a, i, u/. Gates were established based on the different sections of the non-fortis fricatives to form a total of seven gates. Frication was divided into three parts (gates 1, 2, 3), and aspiration was divided into two (gates 4, 5). In addition to the fricative, the first initial 50ms of the vowel was used for gate 6, and the entire syllable was used as the last gate (gate 7). Since /si/ and fortis fricatives lack clear aspiration, the mean proportion of aspiration to the total fricative duration of the /sa/ and /su/ recordings was applied to create comparable gates.

The participants were instructed that they would hear parts of the syllables /sa/, /s*a/, /su/, /s*u/, /si/, and /s*i/and that they were to guess which syllable the stimulus was extracted from. The gated stimuli were randomly presented in different vowel pair blocks (/a/-/u/, /a/-/i/, /u/-/i/) along with the fricative contrast, resulting in each block having four syllables (e.g. /sa/, /s*a/, /su/, /s*u/) as possible choices. The four-alternative forced-choice task was used to investigate both fricative identification and vowel anticipation in one response. Responses that matched the stimulus fricative identity were coded as correct fricative responses, regardless of the vowel identity. Responses matching the stimulus vowel identity, separate from the fricative category, were also marked as correct for vowels. These correct responses were counted as a measure of accuracy.

Results Results from a mixed-effects logistic regression model with 9 Seoul Korean participants found significant effects of gate on the fricative response. As shown in Figure 2a, fricative responses were different in three parts, the frication section (gates 1, 2, 3), the aspiration section (gates 4, 5), and the vowel section (gates 6, 7). Fricatives were unidentifiable during the frication gates, with mean accuracy remaining at chance level (M = 47.9, 48.4, 53.7%). As shown in Figure 1, there were more non-fortis fricative responses during the frication, regardless of the stimulus. This suggests that listeners did not use the cues in the frication for fricative

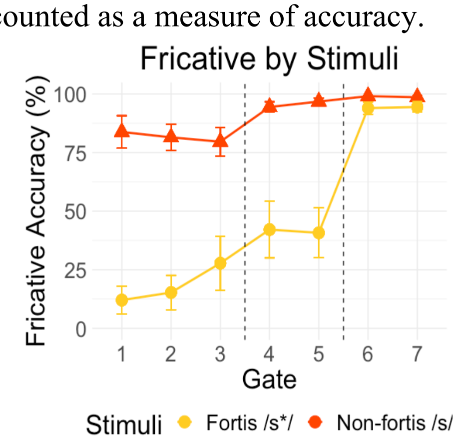

Figure 1. Accuracy rate by fricative

identification and possibly relied on the frequency bias in the lexicon. Moreover, accuracy for non-fortis fricatives increased to 94.4% at gate 4, suggesting that accurate non-fortis identification occurs after aspiration onset. For fortis fricatives, accuracy sharply increased from 40.7% at gate 5 to 94% at gate 6, suggesting that fortis identification occurs after vowel onset.

On the other hand, a mixed-effects logistic regression model for vowel accuracy did not find any significant main effect of gate, suggesting that vowels were similarly identifiable across gates. As shown in Figure 2, mean vowel accuracy started from 71.3% at gate 1 and 84.5% at gate 2, much higher than those of fricatives (47.9%, 48.4%). Paired t-tests showed that at gate 1 the difference between fricatives and vowels was significantly different from zero ($t(8) = 4.7053$, $p < .05$), and vowel accuracy remained higher during the consonant gates (gate 1-5).

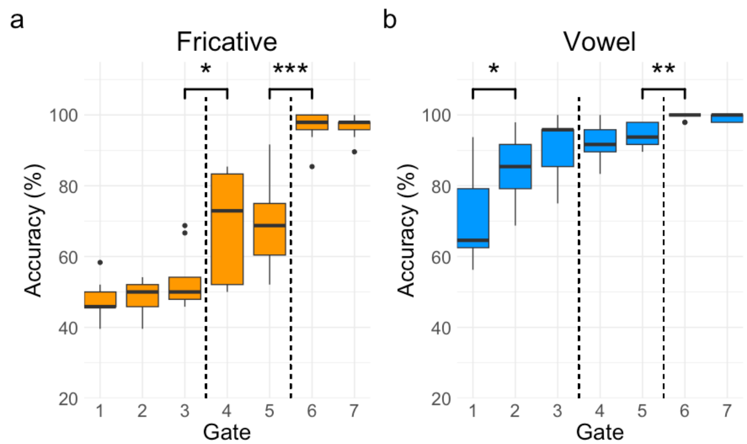

Figure 2. Mean accuracy for (a) fricatives and (b) vowels

Conclusion Results suggest that Korean fricative identification cannot occur during the initial frication and depends on the later arriving aspiration and vocalic cues, much in line with previous literature on Korean fricative perception. Furthermore, vowel anticipation can occur during the initial frication of Korean fricatives, even before aspiration and vowel onset, which is in line with previous studies on English fricatives. The different cues involved in Korean fricatives and vowels and their asynchronous timing suggest that anticipation of the following vowel precedes the identification of the fricative in Korean. The results of this study clearly demonstrate the nonlinear, dynamic nature of speech perception, where processing is not limited to the linear order of segments but rather utilizes all cues available at each time point.

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