

# Research on the Temporal Variation of Fricatives in Sundanese

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## Abstract

In this study, the effect of position, syllable type and word length on the temporal variation of fricatives in Sundanese is analyzed. It is found that due to the effect of final lengthening, the durations of fricatives at word final position is longer than at word medial position. There is also the effect of initial strengthening, so the duration of the fricative at word initial position is longer than at word medial position. As CVC syllable is phonologically heavier than CV syllable, fricative duration in the CVC syllable is longer than in the CV syllable. Because of the effect of polysyllabic shortening, fricative duration in the two syllable word is longer than those in the three and four syllable words.

**Keywords** —Fricative, duration, syllable

## I. INTRODUCTION

This study deals with the duration of fricatives in Sundanese. Fricatives are consonants produced by forcing air through a narrow channel which is made by placing two articulators close together. The articulators may be the lower lip against the upper teeth, in the case of /f/; the back of the tongue against the soft palate, in the case of German /χ/, the final consonant of ‘bach’. This turbulent airflow is called frication. A specific subset of fricatives is the sibilants. When producing a sibilant, the speaker is still forcing air through a narrow channel, but in addition, the tongue is curled lengthwise to direct the air over the edge of the teeth.

Much research work has been done on the variation of duration of segments and of fricatives [1-9], and acoustic analyses were undertaken to explore the durational characteristics of the fricatives as cues to initial consonant voicing in English [10]. Based on reports on the perception of voiced-voiceless fricatives, it was supposed that there would be clear-cut duration differences distinguishing voiced and voiceless fricatives. Preliminary results for three speakers show that, contrary to expectations, there was a great deal of overlap in the duration distribution of voiced and voiceless fricative tokens, though differences emerged in the overall mean duration of voiced and voiceless ones.

Investigation was also done on the duration of single consonants and two-consonant clusters in

Modern Standard Arabic as produced by Tunisian male subjects [11]. The research data consisted of 105 words of the type CVCVCV and CVCCVCV with stress on the first syllable. The results indicate that in Arabic, a language which contrasts geminate and single consonants, the durations of single stops are considerably shorter than those reported for English or Dutch. The results also demonstrate that the observed duration of a two-consonant cluster exceeds the sum of the durations of each consonant when it occurs as singleton. The lengthening of consonants in clusters, as opposed the compression reported in other languages, is observed in both obstruents and sonorants, and is inversely proportional to the duration of single consonants. The effects of variables such as position within the cluster, voicing and major class features on the duration of simple consonants and clusters were also discussed.

Duration of segments varies with the voice condition of the neighboring segments. Holt et al [12] did an acoustic-phonetic exploration of segmental structure of African American English, and the purpose was to better understand the temporal variation in African American English by analyzing duration. Sixteen male speakers, eight African American English speakers and eight White American English speakers, read a randomized set of words containing 11 vowels followed by either a voiced stop /d/ or a voiceless stop /t/ for a total 896 tokens. It is found that, compared with White American English speakers, African American English speakers significantly prolonged the vowels preceding voiced consonants, but the shorter durations of vowels before voiceless consonants did not differ significantly from those by the White American English speakers. The proportional measure further established that the temporal contrast between vowels before voiced versus voiceless consonants was significantly increased in African American English relative to White American English. Furthermore, the tense-lax vowel distinction was reduced in African American English relative to White American English in both voicing contexts. These findings show that both the extensive vowel lengthening before voiced stops and the smaller temporal contrast between tense and lax vowels are distinctive features of African American English. It may enhance the temporal contrast between vowels, and this contrast may serve as the primary

marker of the consonant voicing distinction even if the consonant itself is devoiced or deleted altogether.

Consonants of different place or manner of articulation have their unique temporal pattern. Van Tasell et al [13] evaluated the effects of practice and of multiple speakers on the identification of temporal consonant information. Naturally produced /Ca/ disyllables were used to create ‘temporal-only’ stimuli with instantaneous amplitudes identical to natural speech stimuli, but flat spectra. Practice improved normal-hearing subjects’ identification of temporal-only stimuli from a single speaker over that reported earlier for a different group of unpracticed subjects. When the number of speakers was increased to six, however, performance was poorer than that observed for one speaking, indicating that subjects had been able to learn the individual stimulus items derived from the speech of the single speaker. Even after practice, subjects varied greatly in their performance to extract temporal information related to consonant voicing and manner. Identification of consonant place was uniformly poor in the multiple-speaker situation, demonstrating that for these stimuli consonant place is cued via spectral information. Comparison of consonant identification by users of multi-channel implants indicated that the implant users’ identification of consonant duration was largely within the range predicted from the normal data. In the instances where the implant users were performing especially well, they were identifying consonant place information at levels well beyond those predicted by the normal-speaker data. Comparison of implant-user performance with the temporal-only data reported here can help determine whether the speech information available to the implant user consists of entirely temporal cues, or is augmented by spectral cues.

Fricatives are normally un-aspirated, and aspirated fricatives are typologically uncommon sounds, only found in a handful of languages. Jacques [14] explores the diachronic pathways leading to the creation of aspirated fricatives. A review of the literature brings out seven such historical pathways. An eighth, heretofore unreported pattern of change is revealed by Shuiluo Pumi, a Sino-Tibetan language spoken in China. These diachronic pathways have non-trivial implications for phonological modelling as well as for the synchronic typology of sound patterns. First, they provide new evidence for the debate concerning the definition of the feature [+spread glottis]. Second, they explain some of the typological properties of aspirated fricatives, in particular the absence of aspirated fricatives in consonant clusters and the rarity of non-coronal aspirated fricatives.

There are both voiced and voiceless fricatives in Greek. Nurgianaki et al [15] examined the temporal and spectral characteristics of Greek fricatives, including duration and spectral moments, i.e. mean,

variance, skewness and kurtosis. The effects of voicing, speaker’s gender and post-fricative vowel on both duration and spectral moments were also investigated. The results show that noise duration does not distinguish fricatives in terms of place of articulation. However, voiceless fricatives have longer durations than voiced ones. Spectral moments distinguish fricatives in terms of place of articulation, except for the labio-dental from dental place. They also examined the temporal characteristics of Greek fricatives as distinctive cues for their place of articulation. The effects of voicing, voiced vs. voiceless, speaker gender, female vs. male, and post-fricative vowel, [a], [e], [i], [o], [u], on fricative duration are investigated. The results show that fricative duration does not distinguish fricatives in terms of place of articulation. However, it clearly differentiates voiced from voiceless fricatives, with voiceless fricatives having significantly longer durations than voiced ones. It is also demonstrated that females produce significantly longer fricatives than males.

## II. METHODOLOGY

### A. Studying materials

There are two fricatives in Sundanese, /s/ and /h/. They may occur in the initial, medial or final positions of a word. The words studies are taken from a database of Sundanese vocabulary, and the materials used in this study include the two fricatives, occurring in the three positions. The two common syllable types in Sundanese are CV and CVC syllables, and the words investigated in this study includes these two syllable types. In Sundanese, there are monosyllabic words, and there are also two and multi-syllabic words.

### B. Procedure and measurements

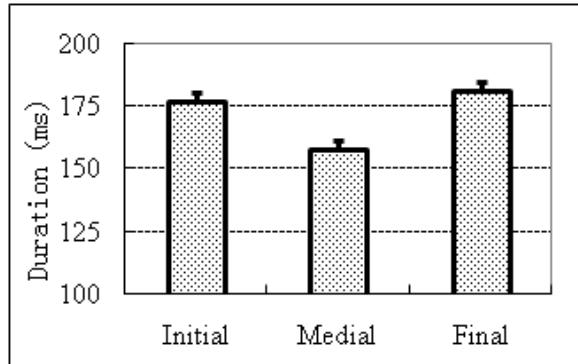
This study aims to give an investigation on the effect of position, syllable type and word lengthen on the duration of fricatives in Sundanese. Fricative duration is annotated in the Praat [16]. As for the factors, there are two conditions of word positions, word initial, word medial and word final positions. For syllable type, it includes CV and CVC syllables, where only fricatives in the onset position are concerned. Regarding word length, fricative duration of two, three and four syllable word will be compared. An ANOVA is conducted for the analysis of the effect of the three factors on the duration values, and a Post Hoc test is done for further analysis. Statistic is done in SPSS.

## III.RESULT

### A. The effect of position

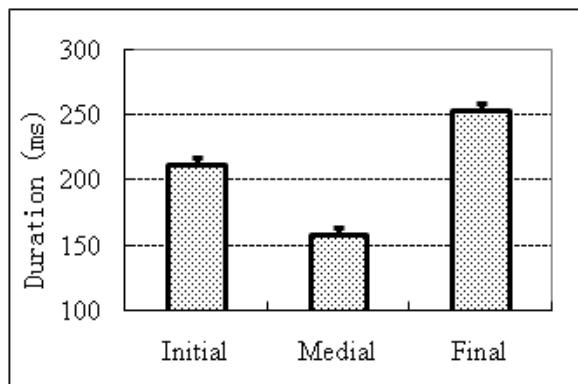
1) *At syllable initial position:* Fig. 1 presents the mean values of the durations of fricatives at initial, medial and final position of word. Results from ANOVA show that there is significant difference for the duration values at the three positions:  $F(2, 548) =$

6.15,  $p = 0.002$ . Post Hoc results show that the durations of fricatives at word final and initial positions are longer than those at word medial position, final vs. medial:  $p = 0.002$ ; initial vs. medial:  $p = 0.005$ . However, no significant difference is found between durations at word initial and word final position:  $p = 0.624$ .



**Fig. 1. Fricative duration at syllable initial position**

2) **At syllable final position:** In Fig. 2, the average values of fricative durations at the three positions are displayed, and ANOVA result demonstrates that significant difference exists for the duration values:  $F(2, 285) = 12.2$ ,  $p < 0.001$ . It is revealed from further Post Hoc test results that the durations of fricatives at word final position are longer than those at word medial or initial positions, final vs. medial:  $p < 0.001$ ; final vs. initial:  $p = 0.008$ . However, there is no significant difference between durations at word initial and word medial position:  $p = 0.102$ .

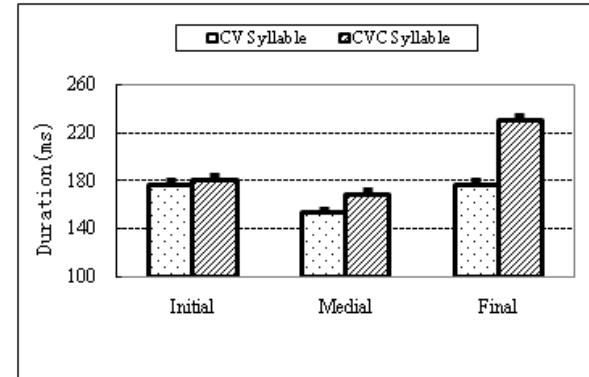


**Fig. 2. Fricative duration at syllable final position**

#### B. The effect of syllable type

The fricative durations CV and CVC syllable types are analyzed in this subsection. Fig. 3 displays the mean values of fricative durations of the two syllable types at the three positions, and ANOVA results show that, at word medial and word final positions, there are significant difference for the fricative duration, medial position:  $F(1, 256) = 6.31$ ,  $p = 0.035$ ; final position:  $F(1, 359) = 26.7$ ,  $p < 0.001$ , with fricative duration in the CVC syllable longer than

that in the CV syllable. However, there is no significant difference between fricative duration of the CV and CVC syllables at the initial position of the word:  $F(1, 313) = 0.307$ ,  $p = 0.581$ .

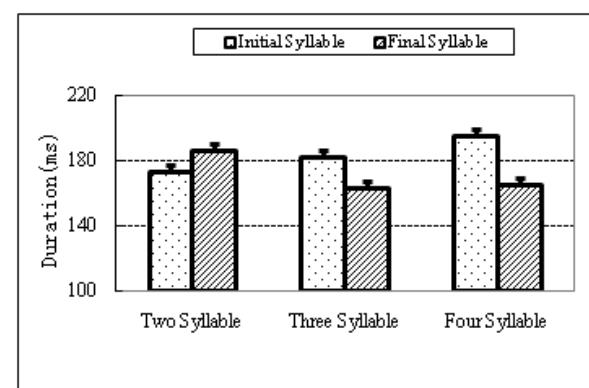


**Fig. 3. Fricative duration of CV and CVC syllables**

#### C. The effect of word length

In this section, fricative durations in the onset position in two, three and four syllable words are compared. In Fig. 4, the average duration values of fricatives of the initial and final syllable in two, three and four syllable word are shown, and ANOVA result displays that significant difference exists for fricative durations of various word length of the final syllable:  $F(2, 165) = 8.75$ ,  $p < 0.001$ .

It is demonstrated from further Post Hoc test result that, fricative duration in the two syllable word is longer than that in three syllable words:  $p = 0.001$ , and it is also longer than that in four syllable word:  $p = 0.029$ . However, no significant difference is found between fricative durations in three and four syllable words:  $p = 0.971$ .



**Fig. 4. Fricative duration in two, three and four syllable word**

#### IV.DISCUSION

In this study, the effect of position, syllable type and word length on the temporal variation of fricatives in Sundanese is analyzed. It is found that the durations of fricatives at word final position is longer than that at word medial position, which is due to the final lengthening effect. Final lengthening is a cross-

linguistic phenomenon that occurs at the right edge of the word, the phrase, and the utterance. The increased duration at the right edge of the word means that a final syllable is significantly longer than a non-final one. It has been shown that final lengthening affects the rhyme of the syllable preceding the prosodic boundary, where the final segment is lengthened more than other segments in the final rhyme. As for the reason for the mechanism of final lengthening, there is evidence that final lengthening helps in syntactically parsing an utterance to help people better understand the meaning of the utterance. Because of the effect of final lengthening, the durations of fricatives at word final position is longer than that at word medial position.

Detailed analysis reveals that, for onset, the duration of the fricative at word initial position is longer than at that at word medial position, which is due to the initial strengthening effect. It is known that in a CVC word, the initial consonant can be pronounced differently than the final consonant, i.e., the initial consonant is longer and have greater articulatory magnitude. Some acoustic studies have extended this line of research above the syllable and word level to phrasal levels. For example, Pierrehumbert & Talkin presented a study in which they used acoustic measures of breathiness to show that /h/ is more consonant-like when it is phrase-initial than when it is phrase-medial. Similarly, the VOT of /t/ is longer phrase-initially. This pattern is called ‘domain-initial strengthening’, because the lingual articulations appeared to be stronger for consonants at the beginning of each prosodic domain. Fougeron & Keating discussed the mechanisms, including articulatory undershoot of shorter segments, overshoot of consonants after lengthened domain-final vowels, coarticulatory resistance by segments in initial positions, and overall greater articulatory effort for initial segments. All in all, because of the effect of initial strengthening, the duration of the fricative at word initial position is longer than at that at word medial position. The durations of fricatives in CV and CVC syllables are compared in this research, and it is found that, at word medial and word final positions, fricative duration in the CVC syllable is longer than that in the CV syllable, which is due to the fact that CVC syllable is phonologically heavier than the CV syllable.

Many languages exhibit heavy and light syllable contrast, with CVC and CVV syllables heavier than CV syllable. A theory of weight is advanced in which a syllable shape in a given position is only heavy if it is sufficiently longer than a light syllable in the same position. A syllable should be extra-long word-finally in order to be categorized as heavy, because a final CV is notably longer than a non-final CV due to final lengthening effect. Analyzing weight as requiring a minimum

proportional increase reflects human perception of differences: the same raw increase has less of a perceptual effect when added to a relatively long stimulus. Using the results of a production study, it is shown that heavy syllables in Norwegian are at least 60% greater than unstressed CV syllables in the same position. The regular stress patterns in the language are shown to include not only the predominant stress pattern of the language but also several minor patterns, predictable exceptions to the basic pattern. As CVC syllable is phonologically heavier than CV syllable, fricative duration in the CVC syllable is longer than that in the CV syllable.

However, it is indicated that there is no significant difference between fricative duration of the CV and CVC syllables at the initial position of the word. This is because that in Sundanese, the first syllable tends to be stressed. One of the reliable cues of stress is the increase of duration. When the syllable is stressed, the durations of the segments in the CV syllable would be prolonged. As for the segments in the CVC syllable, their durations are basically longer than those in the CV syllable. At the initial position of the word, although the syllable is stress, the extend of increase for the segment is limited. The segments of the CV syllable are increased, while those in the CVC syllable are not increased much. As a result, there is no significant difference between the fricative duration of the CV and CVC syllables.

Regarding to the effect of word length, it is found that fricative duration in the two syllable word is longer than those in three and four syllable words, which is due to the polysyllabic shortening effect. Polysyllabic shortening refers to the property of syllable or segment duration to be inversely related to the number of syllables in a word. For example, it is found that /i/ is shorter in ‘speedy’ than in ‘speed’, and shorter still in ‘speedier’. These effects seem to suggest a tendency on part of speakers to keep durations of larger prosodic units constant. In particular, polysyllabic shortening in the interval between the onsets of two consecutive stressed syllables is predicted by the isochrony hypothesis for ‘stressed’ languages, which were claimed by this hypothesis to place stressed syllables at temporally regular intervals. Subsequent research has proposed the strong form of this hypothesis, showing for various languages that Inter-Stress Interval duration is a linear function of the number of component syllables.

Some studies have found that polysyllabic shortening at the Inter-Stress Interval level in English is compatible with weak versions of the isochrony hypothesis. Results suggest that this correlation only holds as long as word boundary locations are not taken into account. Van Santen [17] reports that the duration of stressed vowels in accented words is not a function of the number of syllables in the word or in the Inter-

Stress Interval, but of the number of syllables in the interval between the stressed syllable onset and the right boundary of the word. This interval has been termed word rhyme [18], and it is proposed as the domain of a temporal equalization process. Because of the effect of polysyllabic shortening, fricative duration in the two syllable word is longer than those in three and four syllable words.

## V. CONCLUSION

This study investigated the effect of position, syllable type and word length on the temporal variation of fricatives in Sundanese. It is shown that there is the effect of final lengthening in the language. Final lengthening is a cross-linguistic phenomenon that occurs at the right edge of the word, the phrase, and the utterance. The increased duration at the right edge of the word means that a final syllable is significantly longer than a non-final one. In a CVC word, the initial consonant can be pronounced differently than the final consonant, i.e., the initial consonant is longer and has greater articulatory magnitude. This pattern is called ‘domain-initial strengthening’, because the lingual articulations appeared to be stronger for consonants at the beginning of each prosodic domain.

There are any languages exhibiting heavy and light syllable contrast, with CVC and CVV syllables heavier than CV syllable. Analyzing weight as requiring a minimum proportional increase reflects human perception of differences: the same raw increase has less of a perceptual effect when added to a relatively long stimulus. The effect of polysyllabic shortening seems to suggest a tendency on part of speakers to keep durations of larger prosodic units constant. In particular, polysyllabic shortening in the interval between the onsets of two consecutive stressed syllables is predicted by the isochrony hypothesis for ‘stresstimed’ languages.

## ACKNOWLEDGMENT

The research reported here is partially supported by China National Social Science Fund, No. 16ZDA211.

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