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The Effect of Consonants on Vowel Formant in Sudanese

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Abstract: In this study, the formant transition of vowel /a/, /i/ and /u/ following the voiced and voiceless labial, alveolar and velar stops are analyzed, and it is found that for voiced labial stop, whether the preceding vowels are /a/, /i/, or /u/, the formant transitions of F1and F2 are always rising. For the voiced alveolar stop, results show that formant transitions for the first formants of /a/ and /i/ are rising, but that for the first formant of /u/ is a level transition. After voiceless labial stop, formant transition for the first formants of /a/ is rising, that of vowel /u/ is falling, but that for the first formant of vowel /i/ is level. For the voiceless stops, the formant transitions tend to be falling, while when the preceding consonants are voiced, formant transitions tend to be rising. When the preceding consonant is labial, the formant transition tends to be rising.

Keywords: - Formant, vowel, stop consonant

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I. INTRODUCTION

Research has identified two primary types of acoustic cue for the identification of place of articulation of stop consonants. The spectral properties of the aperiodic noise associated with consonant release and frication constitute one type of cue, while the other consists of transitional patterns of formant movement on vowels adjacent to the consonantal constriction. In spectrographic displays, these acoustic properties are clearly separable entities. As such, they may be manipulated for research into the relative perceptual weight of noise vs. transitional cues to consonant place identification and discrimination of place contrasts. Much of the published literature [1-4] on stop place perception has found that formant transitions play a more prominent role than burst noise for place perception.

It is argued that formant transitions are housed in a more robust periodic portion of the speech signal that maintains its perceptual robustness even in noisy listening conditions. One of the studies [5] presents stop place perception data in Korean and English. In their study, formant transitions played a more significant role than noise bursts. The authors attribute this finding to the fact that Korean contains a three-way laryngeal contrast that is cued in part by burst amplitude and aspiration noise. They suggest therefore that the noise cues are somehow reserved for the laryngeal contrast, forcing listeners to rely more heavily on formant transitions for place of identification. The fact that Korean leaves coda stops unreleased, forcing listeners to rely on transitions, is compatible with this interpretation. Thus, the relative weight of burst vs. transitional cues may be related to other aspects of a given language's phonology.

In the production of an oral stop, the vocal tract is initially sealed during which time air-pressure builds up that is then released. At the point of release, the shape of the vocal tract has a marked influence on the acoustic signal and this influence extends at least to the beginning of the formant transitions, if the following segment is a vowel. Since the shape of the vocal tract is quite different for labial, alveolar, and velar places of articulation, the way in which the acoustic signal is influenced following the release differs correspondingly. If the influence extends to the onset of periodicity for the following vowel, then the formant onset frequencies of the same phonetic vowel should be different when it occurs after consonants at different places of articulation [6]. As a study had shown, different places of articulation have their greatest influence on the onset of the second formant frequency. But it was the famous perception experiments using hand-painted spectrograms at the Haskins Laboratories that gave rise to the concept of an F2-locus.

Research shows that the origin of the second formant frequency may influence the perception of the place of articulation of the following consonant. More specifically, if the F2-onset was low and at around 700 Hz, listeners would predominantly hear /b/; if it was roughly in the 1800 Hz region, they would hear /d/, while if the F2-onset began near 3000 Hz, listeners would perceive /g/ before front vowels. The locus frequency was not at the acoustic vowel onset itself, but at some point prior to it during the consonantal closure. More specifically, in synthesizing a CV transition, formants would be painted from the F2-locus somewhere in the consonant closure to the F2-vowel target and then the first part of the transition up the where the voicing for the vowel began would be erased [7]. With these experiments, the researcher and colleagues also demonstrated that the perception of place of articulation was categorical and this finding was interpreted in favor of the famous motor theory of speech perception. In the years following the Haskins Laboratories experiments, various large-scale acoustic studies were concerned with finding evidence for an F2-locus.

The relation of formant transitions to place-of-articulation for stop consonants has been investigated, and a speech production model has been used to generate simulated utterances containing voiced stop consonants, and a perceptual experiment was performed to test their identification by listeners. Based on a model of the vocal tract shape, a theoretical basis for reducing highly variable formant transitions to more invariant formant deflection patterns as a function of constriction location was proposed. A speech production model was used to simulate vowel-consonant-vowel (VCV) utterances for 3 underlying vowel-vowel contexts and for which the constriction location was incrementally moved from the lips toward the velar part of the vocal tract. The simulated VCVs were presented to listeners who were asked to identify the consonant [8]. Listener responses indicated that phonetic boundaries were well aligned with points along the vocal tract length where there was a shift in the deflection polarity of either the 2nd or 3rd formant. The study demonstrated that regions of the vocal tract exist that, when constricted, shift the formant frequencies in a predictable direction. Based on a perceptual experiment, the boundaries of these acoustically defined regions were shown to coincide with phonetic categories for stop consonants.

It is shown from researches that initial CV transitions tend to be a good deal more salient than VC transitions: compatibly, there are many more sound changes in which the vowel and syllable-final consonant merge resulting in consonant loss than is the case for initial CV syllables. This would suggest that synchronically a consonant and vowel are more sharply delineated from each other in CV than in VC syllables and again there are numerous aerodynamic and acoustic experiments to support this view. There are various investigations which show that in V1CV2 sequences where C is an alveolar, the carry-over influence of V1 on V2 is greater than the anticipatory influence of V2 on V1. This suggests that the alveolar resists coarticulatory influences of the following V2, so the alveolar has a blocking effect on the coarticulatory influences of a following vowel, but is more transparent to the coarticulatory influences of the preceding V2, so the alveolar does not block the coarticulatory influences of a preceding vowel to the same extent [9].

Formant transitions reflect the overall change in shape of the vocal tract during speech production. Vocal tract movements from one vowel to another tend to produce slowly varying and continuous transitions of the formant frequencies, whereas the onset and offset of the vocal tract movements needed to impose and release consonantal constrictions result in rapidly changing transitions. Although formant transitions are thought to play a role in specification of constriction location, the coarticulation of vowels and consonants causes their contributions to the formant transitions to be superimposed, thus creating highly context-dependent acoustic characteristics [10]. Thus, the actual formant transitions produced by imposing a consonantal constriction at a particular location in the vocal tract depend on the vowel context. The relative perceptual significance of bursts and formant transitions as cues for place of articulation has been a frequent topic of investigation. Early experiments in speech perception demonstrated the importance of direction and slope of the second and third formant transitions (F2 and F3).

A widely cited result of the studies was that a rising F2 transition in the syllable /di/ could evoke the same perceptual response for the initial consonant as a falling F2 transition in the syllable /du/. Context dependence of this sort has often been used as an example of the presumed lack of acoustic invariance in the speech signal and has been taken as evidence that perception of speech is referent to the speech production system [11]. A competing view is that place of articulation is invariantly specified by the gross characteristics of a short-time spectrum sampled to include the burst and the initial portion of the formant transitions. This spectral representation is intended to integrate the consonant release and the initial vocalic portions that follow into a single invariant event rather than a sequence of events separated in time, perhaps in a manner similar to that of the auditory system. The formant transitions are thought to smoothly link the integrated onset spectrum with the following vowel such that discontinuities are minimized.

A number of studies that have investigated the role of the release burst and formant transitions in signaling place of stop consonant articulation in CV syllables have indicated that these acoustic features vary as a function of the identity of the following vowel [12]. For example, the second formant transition, which has been thought by some investigators to be important in carrying information about place of articulation, falls following consonantal release in /du/，but rises in /di/, and the starting frequencies of the second-formant transition differ between the two syllables. Indeed, the relative importance of burst and transition information in specifying place of articulation may also vary in a context-dependent manner. The contextual variability of the burst and formant transitions associated with different places of articulation would seem to require the postulation of active perceptual mechanisms capable of using higher-level linguistic knowledge to interpret the speech waveform in a contextually appropriate manner.

With respect to place of articulation, it has been argued that the burst and transition information in the first 10-30 ms of the CV syllable, which are the result of one articulatory gesture, provide a single, integrated cue to consonantal identity that is independent of the following vowel context. As have been pointed out, although bursts and formant transitions are visually distinctive in spectrographic displays, the auditory system does not necessarily process these features independently of one another. Rather, these acoustic segments might, in the early stages of auditory analysis, combine in such a way that they provide the basis for the constancy of the place percept. During the initial and final portions of the syllable, formant transitions are characterized by short duration and usually rapid movement across large frequency ranges. Vowel nucleus dynamics are characterized by longer durations and slower changes across smaller frequency ranges. Perhaps because of the more limited movement in non-diphthongized vowels, the nucleus dynamics have often been characterized as quasi-steady state. However, it has been shown that systematic movement does occur. The dynamic cues in syllables available in either the consonantal transitions alone or the nucleus region alone has been shown sufficient to produce high vowel identification rates [13]. A complete theory of vowel perception must explain the roles of both types of formant movement in vowel identification.

Attempts to model the initial stages of speech processing, which employ more sophisticated methods of analysis than traditional spectrographic ones, have, in fact, met with some success in identifying invariant acoustic correlates of place of articulation. The work of Stevens and Blumstein has been particularly influential in promoting the notion that such correlates exist in the speech waveform and that these properties mediate the perception of place. They have proposed that the relative slope and diffuseness of energy in the short-term spectrum sampled at consonantal release in a stop-vowel syllable specify place in a context-independent manner, labials may be characterized by a diffuse flat or falling spectrum, alveolar by a diffuse-rising spectrum, and velars by a prominent mid-frequency spectral peak. Within Stevens and Blumstein’s model, the onset spectrum of a stop CV syllable is obtained by integrating energy over the first 25.6 ms of the syllable and using linear prediction analysis.

Several perceptual studies have investigated human listeners’ ability to identify stop consonant place of articulation from the release burst, presented either in isolation or followed by some vocalic context with or without formant transitions. Some of these studies used synthetic speech in which the bursts had a single spectral peak and therefore may not have approximated the information content of natural release bursts. Classic research at Haskins Laboratories has shown that such synthetic noise bursts provide sufficient cues for some stop consonants preceding some steady-state vowels, but also that identical bursts often lead to different place of articulation percepts in the context of different vowels. Blumstein and Stevens compared place of articulation perception in synthetic CV syllables with and without bursts intended to be optimal for /b, d, g/, and found that the burst enhanced identification accuracy. Their study included stimuli consisting only of the burst plus a single glottal pulse, whose identification was almost as good as that of full synthetic syllables.

Some researchers employed released VC syllables, so that the burst occurred in utterance-final position and essentially in the context of a neutral following vowel. Listeners’ identification of place of articulation from such release segments presented in isolation was in the vicinity of 80% correct. The releases were also found to provide important cue to place identification in full VC syllables. Other researchers presented listeners with natural-speech bursts that, according to a liberal definition, included both the release burst proper and all the following aspiration of initial voiceless aspirated stops. Intelligibility of these fairly long stimuli ranged from about 90% correct when cross-spliced onto different vowels to about 75% correct in isolation or with 100 ms of the original vowel following to 83% correct in combination with steady-state vowels. When the aspiration was replaced with silence, listeners’ performance fell to 61% correct.

Formant transitions have been considered important context-dependent acoustic cues to place of articulation in stop-vowel syllables. The acoustic correlates of place of articulation in the voiced formant transitions from natural speech have been examined. Linear prediction analysis was used to provide detailed temporal and spectral measurements of the formant transitions for /b, d, g/ paired with eight vowels. Measurements of the transition onset and steady state frequencies, durations, and derived formant loci for F1, F2, and F3 are examined. Analysis of the measures showed little evidence of context invariant acoustic correlates of place. When vowel context was known, most transition parameters were not reliable acoustic correlates of place except for the F2 transition and a two-dimensional representation of F2 X F3 onset frequencies. The results indicated that the information contained in the formant transitions in these natural stop-vowel syllables was not sufficient to distinguish place across all the vowel contexts studied.

The present study will investigate the formant pattern of vowels /a, i, u/ following stop consonants /b, d, g/ and /p, t, k/ in Sundanese. It is aimed to present the formants values at the onset and middle point of the vowels, and analysis will be done in SPSS.

II. METHODOLOGY

2.1. Studying materials

In Sundanese, there are voiced stops /b, d, g/ and voiceless stops /p, t, k/. As for vowel, three basic vowels /a, i, u/ are analyzed, and there formant values will be examined. Figure 1 to 3 show the waveform and spectrogram of words 'bata' (brick), 'bitu' (blast) and 'bulu'(hair). From the figures, it can be seen that there is rising transition of F1 for /a/ after /b/, rising transition of F2 for /i/, and level transition of formants for /u/.

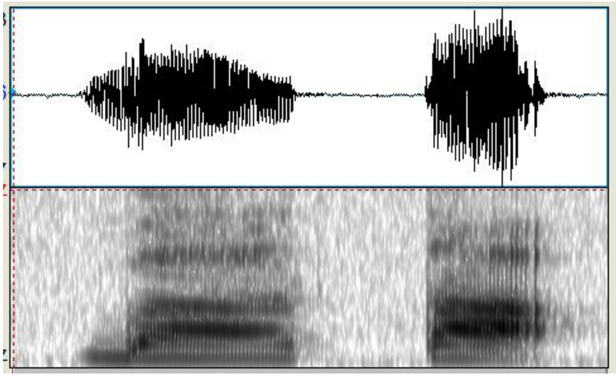


Fig. 1 The waveform and spectrogram of 'bata' (brick)

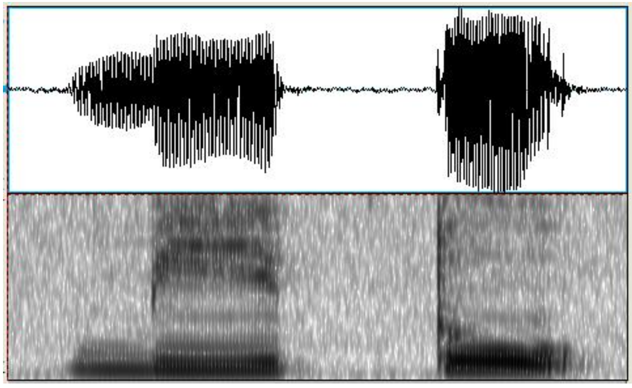


Fig. 2 The waveform and spectrogram of 'bitu' (blast)

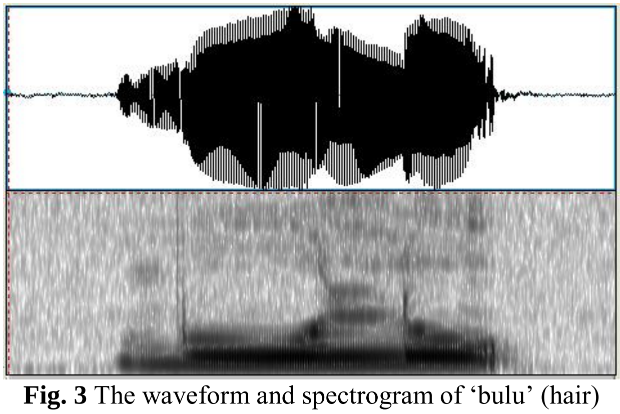


Fig. 3 The waveform and spectrogram of 'bulu' (hair)

There are usually formant changes at the beginning of vowels after consonants. At the onset point of the vowel, the vocal shape may be affected by the articulation of the consonant, so the formant will be a little different from that at the middle point. Therefore, the formant values of vowels /a, i, u/ at the onset and middle points, in adjacent to voiced and voiceless labial, alveolar and velar stops will be examined, and the formant transition pattern will be analyzed.

2.2. Procedure and measurements

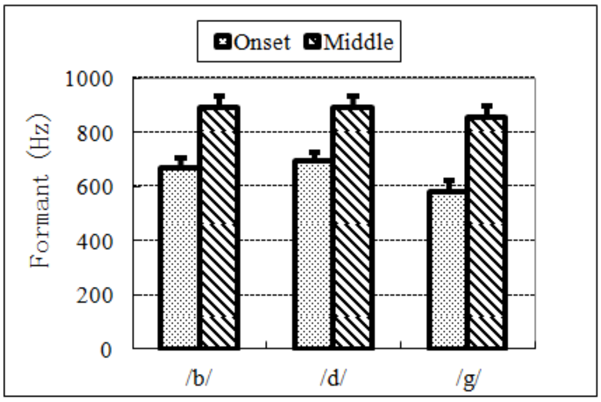
This study aims to investigate the intensity pattern of nasals of two-syllable words in Madurese, so intensity values of nasals of various syllable position and various syllable types are investigated. The intensity value of each nasal is extracted using the software of Praat [16]. The intensity values of nasals at different word positions and different syllable structures are compared.

III. RESULTS

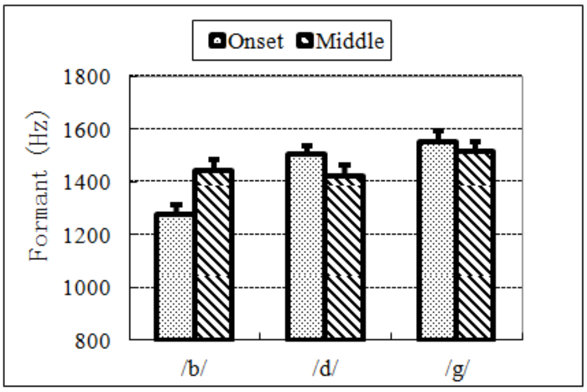
3.1. Vowel /a/

1) Following voiced stops

Figure 4-a displays the first formant values at the onset and middle points of vowel /a/ following the three voiced stop consonants. Repeated ANOVA results show that formant values at the middle points are higher than at the onset points, following /b/: $F(1, 122) = 635$, $p < 0.001$; /d/: $F(1, 90) = 202$, $p < 0.001$; /g/: $F(1, 73) = 302$, $p < 0.001$. As for the second formant values, which is shown in Figure 4-b, it is demonstrated that value at the middle point is higher than onset when following consonant /b/: $F(1, 122) = 114$, $p < 0.001$. However, when the preceding consonants are alveolar and velar, there is no significant difference between the onset and the middle points, following /d/: $F(1, 90) = 2.59$, $p = 0.101$; /g/: $F(1, 73) = 0.947$, $p = 0.334$.



(a) F1 values

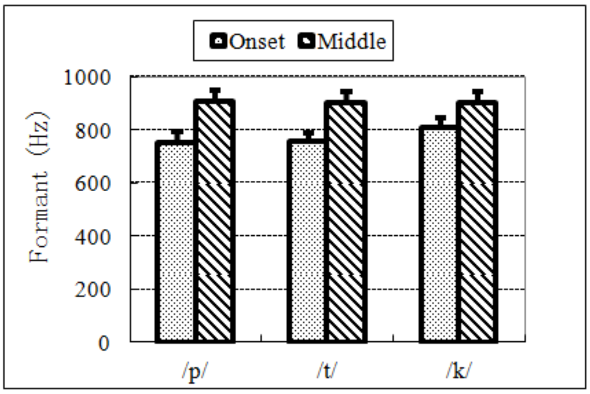


(b) F2 values

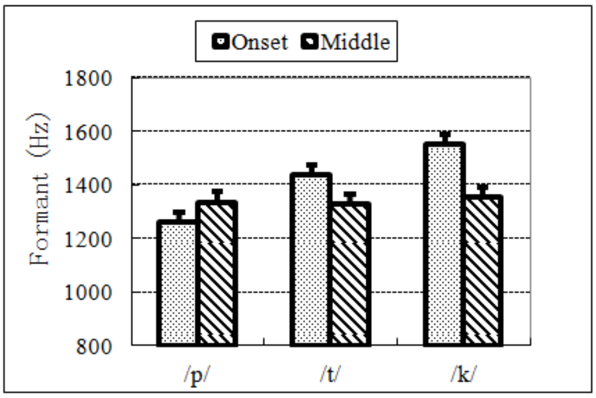
Fig. 4 Formant values of vowel /a/ following the voiced stops

2) Following voiceless stops

When the preceding consonants are voiceless, the transition pattern is different, as is displayed in Figure 5, with Figure 5-a for the first formant values, and Figure 5-b for the second formant values. For the first formant values, repeated ANOVA results show that the formant values at the middle point is higher than that at the onset point, following /p/: $F(1, 184) = 119$, $p < 0.001$; /t/: $F(1, 129) = 65.5$, $p < 0.001$; /k/: $F(1, 201) = 48.5$, $p < 0.001$. Regarding the second formant values, it is shown that, following the labial consonant, the formant value is higher at the middle point, $F(1, 184) = 15.4$, $p < 0.001$. However, when following the alveolar and the velar consonants, the values at the onset point are higher than those at the middle points, following /t/: $F(1, 129) = 15.9$, $p < 0.001$; /k/: $F(1, 73) = 302$, $p < 0.001$.



(a) F1 values



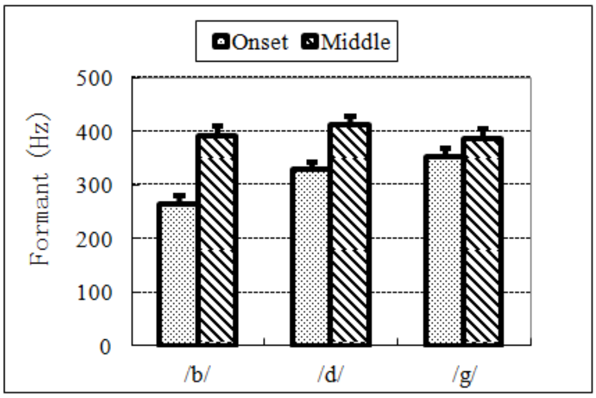
(b) F2 values

Fig. 5 Formant values of vowel /a/ following the voiceless stops

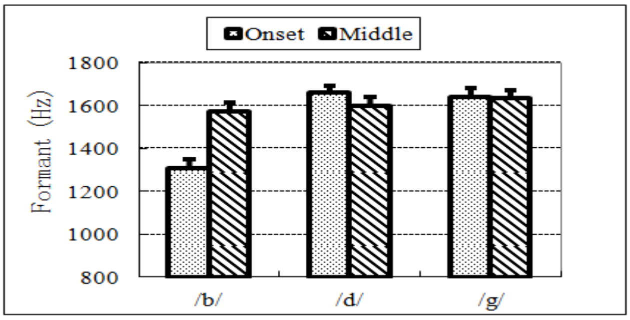
3.2. Vowel /i/

1) Following voiced stops

In Figure 6, the displays the formant values at the onset and middle points of vowel /i/ following the three voiced stop consonants, with Figure 6-a the first formant and Figure 6-b the second formant. It is shown from repeated ANOVA results that, following the labial and alveolar consonants, formant values at the middle points are higher than at the onset points, following /b/: $F(1, 42) = 320$, $p < 0.001$; /d/: $F(1, 45) = 16.8$, $p < 0.001$. However, after the velar consonant, there is no significant difference between the formant values at the onset and the middle points: $F(1, 32) = 0.634$, $p = 0.426$. As for the second formant values, it is demonstrated that value at the middle point is larger than onset when following consonant /b/: $F(1, 42) = 6.32$, $p = 0.016$. However, when the preceding consonants are alveolar and velar, there is no significant difference between the onset and the middle points, following /d/: $F(1, 45) = 0.692$, $p = 0.412$; /g/: $F(1, 32) = 0.002$, $p = 0.964$.



(a) F1 values

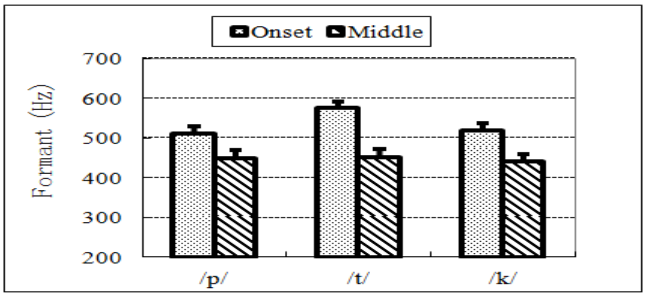


(b) F2 values

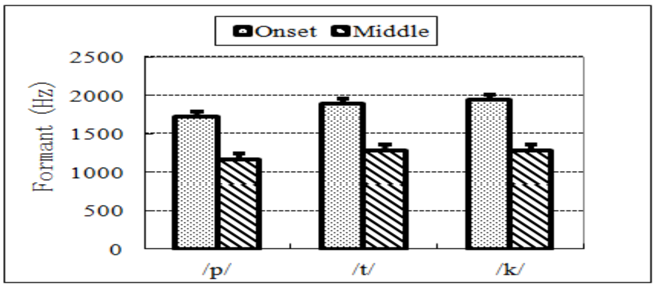
Fig. 6 Formant values of vowel /i/ following the voiced stops

2) Following voiceless stops

The transition pattern of the vowel is displayed in Figure 7 when the preceding consonants are voiceless, with Figure 7-a for the first formant values, and Figure 7-b for the second formant values. For the first formant values, repeated ANOVA results show that the formant values at the onset point are higher than that at the middle point after the alveolar and velar consonants, following /t/: $F(1, 58) = 105$, $p < 0.001$; /k/: $F(1, 50) = 8.08$, $p = 0.006$. However, when following the labial consonant, there is no significant difference between the values at the onset and the middle points: $F(1, 50) = 3.53$, $p = 0.651$. As for the second formant values, ANOVA results show that, following the labial consonant, the formant values at the onset point are higher than those at the middle points, following /p/: $F(1, 50) = 43.1$, $p < 0.001$; /t/: $F(1, 58) = 62.3$, $p < 0.001$; /k/: $F(1, 50) = 47.8$, $p < 0.001$.



(a) F1 values



(b) F2 values

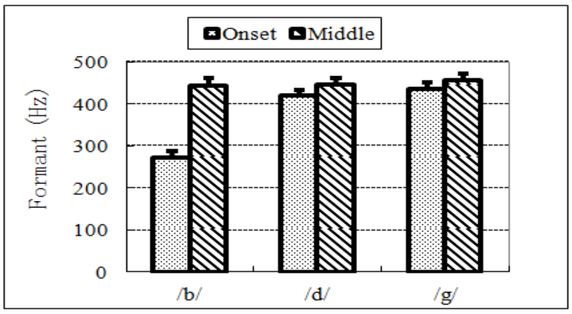
Fig. 7 Formant values of vowel /i/ following the voiceless stops

3.3. Vowel /u/

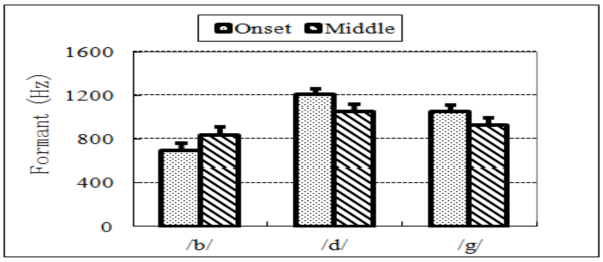
1) Following voiced stops

Figure 8-a displays the first formant values at the onset and middle points of vowel /a/ following the three voiced stop consonants. Repeated ANOVA results show that formant values at the middle points are higher than at the onset points when following consonant /b/: $F(1, 69) = 580$, $p < 0.001$. However, there is no significant difference between the onset values and the middle values when the preceding consonants are alveolar and velar, /d/: $F(1, 54) = 1.273$, $p = 0.257$; /g/: $F(1, 31) = 0.362$, $p = 0.551$. As for the second formant values, which is shown in Figure 8-b, it is demonstrated that value at the middle point is higher than the onset when following consonant /b/: $F(1, 69) = 80.8$, $p < 0.001$. However, when the preceding consonants are alveolar

and velar, the formant values at the onset point are higher than at the middle points, following /d/: $F(1, 54) = 70.9$, $p < 0.001$; /g/: $F(1, 31) = 6.486$, $p = 0.016$.



(a) F1 values

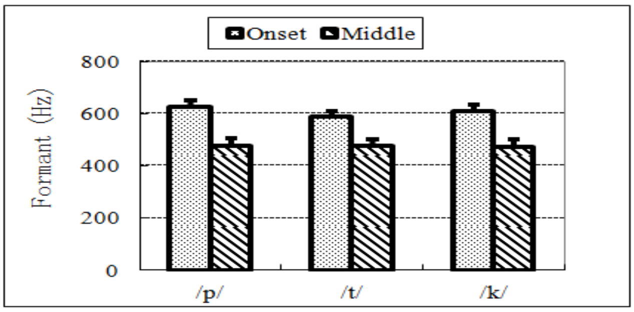


(b) F2 values

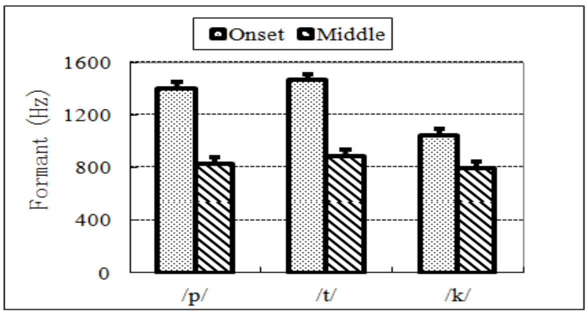
Fig. 8 Formant values of vowel /u/ following the voiced stops

2) Following voiceless stops

When the preceding consonants are voiceless, the transition pattern is different, as is displayed in Figure 9, with Figure 9-a for the first formant values, and Figure 9-b for the second formant values. For the first formant values, repeated ANOVA results show that the formant values at the onset point is higher than that at the middle point, following /p/: $F(1, 36) = 34.6$, $p < 0.001$; /t/: $F(1, 97) = 122$, $p < 0.001$; /k/: $F(1, 62) = 274$, $p < 0.001$. Regarding the second formant values, it is shown from ANOVA results that formant values at the onset point are higher than those at the middle points after the three stop consonants, following /p/: $F(1, 36) = 159$, $p < 0.001$; /t/: $F(1, 97) = 598$, $p < 0.001$; /k/: $F(1, 62) = 72.6$, $p < 0.001$.



(a) F1 values



(b) F2 values

Fig. 9 Formant values of vowel /u/ following the voiceless stops

IV. DISCUSSION

Results from the previous section show that the transition patterns for consonants of different places of articulation are different. For formant transition, during the closure interval for a stop consonant, the vocal tract is completely closed, and no sound escapes through the mouth. However, at the moment of release of the stop constriction the resonances of the vocal tract change rapidly. These changes are traditionally called formant transitions. The first formant exhibits a rising transition after the release of a stop closure. The direction of the second and third formant transitions depend on the particular constrictor producing the stop (lips, tongue tip, tongue body), and also on the overlapping vowel.

The burst spectrum and formant transitions have been found to be major cues to stop-place of articulation. The effect of noise on these place cues, however, is not clear and has not been investigated. It is not known, for instance, how noise affects the tilt of the burst spectrum, and consequently whether a change in the spectral tilt would be accompanied by a shift in phonetic category. Similarly, it is also not known whether a change in burst frequency will be associated with low identification scores. It should be noted that for some of their vowels, as Fl transition extent increased, F2 transition extent decreased. It is possible that these extent cues could interact and thus increase the variance of the boundary locations when identification functions are plotted against transition rate. Since the change in transition rate for the two formants was not consistent across vowels, the relative contributions of duration and rate could not be determined unequivocally.

It was found that an increase in transition rate reduced the frequency extent required to perceive a stop. A detailed examination indicates that an increase in transition rate was accompanied by a decrease in transition duration. Thus, the results could also be indicating that a decrease in Fl transition duration reduces the frequency extent required to perceive a stop. In part of the study, subjects identified stimuli that varied in F2 frequency extent before a variety of vowels. A relationship was found between frequency extent and the perception of semivowels. When the F2 transition was in the appropriate direction they found that a decrease in the extent of the F2 transition resulted in a decrease in semivowel responses. Since transition duration was held constant, a decrease in transition extent resulted in a concurrent decrease in transition rate. The studies indicate that the extent, duration, and rate of consonant transitions are major cues to place of articulation.

In the previous section, it is shown that, for voiced labial stop, whether the preceding vowels are /a/, /i/, or /u/, the formant transitions of F1and F2 are always rising. When producing a labial consonant, the locus of the first and the second formants are both very low. For vowel formants, the first formants of vowel /i/ and vowel /u/ are very low, and the formant transitions for them are still rising, which means that the consistent rising formant transition is a reliable cue for voiced labial stop. It has been shown that voiced consonants may lower the pitch value. From this study, it is shown that voiced consonants can also lower the formant frequency.

For the voiced alveolar stop, results show that formant transitions for the first formants of /a/ and /i/ are rising, but that for the first formant of /u/ is a level transition. For the second formant, transition of vowel /u/ is falling, while those of /a/ and /i/ are level. The formants of vowel /u/ are basically very low, therefore, there is a falling transition for it. Regarding the voiced velar stop, it is shown that formant transition for the first formant of /a/ is rising, but those for the first formants of /i/ and /u/ are level. As for the second formant, transition of vowel /u/ is falling, while those of /a/ and /i/ are level. The reason for this result is also that the formants of vowel /u/ are basically low.

Formant transitions of vowels following voiceless stops are also analyzed, and it is shown that after voiceless labial stop, formant transition for the first formants of /a/ is rising, that of vowel /u/ is falling, but that for the first formant of vowel /i/ is level. For the second formant, transition of vowel /a/ is rising, while those of /i/ and /u/ are falling. The transition of the first formant of vowel /a/ is rising, so that of the second formant is also rising.

As for the voiceless alveolar stop, results show that formant transitions for the first formant of /a/ is rising, but those for the first formants of /i/ and /u/ are falling. Regarding the second formant, for the three vowels of /a/, /i/ and /u/, the transitions are always falling. When the preceding consonant is the voiceless velar stop, it is shown that the result is the same as that of alveolar, that is, formant transitions for the first formant of /a/ is rising, but those for the first formants of /i/ and /u/ are falling. In regard to the second formant, for the three vowels of /a/, /i/ and /u/, the transitions are always falling. Results show that for the voiceless stops, the formant transitions tend to be falling, while when the preceding consonants are voiced, formant transitions tend to be rising. When the preceding consonant is labial, the formant transition tends to be rising.

V. CONCLUSION

For vowel formants, the first formants of vowel /i/ and vowel /u/ are very low, and the formant transitions for them are still rising, which means that the consistent rising formant transition is a reliable cue for voiced labial stop. It has been shown that voiced consonants may lower the pitch value. From this study, it is shown that voiced consonants can also lower the formant frequency. For the second formant, transition of vowel /u/ is falling, while those of /a/ and /i/ are level. The formants of vowel /u/ are basically very low, therefore, there is a falling transition for it. Regarding the voiced velar stop, it is shown that formant transition for the first formant of /a/ is rising, but those for the first formants of /i/ and /u/ are level. As for the voiceless alveolar stop, results show that formant transitions for the first formant of /a/ is rising, but those for the first formants of /i/ and /u/ are falling. Regarding the second formant, for the three vowels of /a/, /i/ and /u/, the transitions are always falling. For the second formant, transition of vowel /a/ is rising, while those of /i/ and /u/ are falling. The transition of the first formant of vowel /a/ is rising, so that of the second formant is also rising.

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REFERENCES

[1] Kewley-Port, D., Pisoni, D.B., Studdert-Kennedy, M. 1983. Perception of static and dynamic acoustic cues to place of articulation in initial stop consonants. J. Acoust. Soc. Am. 73, 1779–1793.
[2] Walley, A.C., Carrell, T.D. 1983. Onset spectra and formant transitions in the adult's and child's perception of place. J. Acoust. Soc. Am. 73, 1011- 1022.
[3] Wright, R. 2001. Perceptual cues in contrast maintenance. In: Hume, E., Johnson, K. (eds), The role of speech perception in phonology. San Diego: Academic Press, 251-277.
[4] Wright, R. 2004. Perceptual cue robustness and phonotactic constraints. In Hayes, B. Kirchner, R., Steriade, D. (eds), Phonetically based phonology. Cambridge: Cambridge University Press, 34-5.
[5] Hume, E., Johnson, K, Seo, M., Tsardenelis, G. 1999. A cross-linguistic study of stop place perception. Proc. 14th ICPhS San Francisco, 2069-2072.
[6] Żygis, M., Hamann, S. 2003. Perceptual and acoustic cues of Polish coronal fricatives. Proc. 15th ICPhS, Barcelona, 395-398.
[7] Nowak, P., 2006. The role of vowel transition and frication noise in the perception of Polish sibilants. Journal of Phonetics 34, 139-152.
[8] Żygis, M., Padgett, J., 2010. A perceptual study of Polish fricatives, and its implications for historical sound change. Journal of Phonetics 38, 207-226.
[9] Lisker, L. 2001. Hearing the Polish sibilants [s ś s]: phonetic and auditory judments. In: Grønnum, N., Rischel, J. (eds.), To honour Eli Fischer-Jørgensen. Travaux du cercle linguistique de Copenhague XXXI. Copenhagen: Reitzel, 226-238.
[10] Schwartz, G., Aperliński, G., 2014. The phonology of CV transitions. In Cyran, E., Szpyra-Kozłowska, J., (eds), Crossing phonetics-phonology lines. Newcastle: Cambridge Scholars Publishing, 277-29.
[11] Nowak, P., 2006. Vowel reduction in Polish. Ph.D. dissertation. University of California at Berkeley.
[12] Cooke, M., Barker, J., Garcia-Lecumberri, M.L. 2013. Crowdsourcing in speech perception. In: Eskanazi, M. et al. (eds), Crowdsourcing for speech processing. Sussex: Wiley, 137-172.
[13] Lindblom, B. 1990. Explaining phonetic variation: a sketch of the H&H theory. In Hardcastle, W. Marchal, A. (eds), Speech Production and Speech Modelling. The Netherlands: Kluwer Academic, 403-439.

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