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Variation of Vowels when Preceding Voiced And Voiceless Consonant in Sundanese

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Abstract:- In this study the effect of voicing of coda on the values of the first and second formant of the preceding vowel in Sundanese is examined. It is displayed that formant values are normally lower at the offset point for vowel preceding voiced consonant than preceding voiceless ones, because the larynx is comparatively lower when articulating voiced consonants. Formant values are lower when preceding the voiceless labial consonants, so there is no effect of voicing of consonant on the formants values of vowel /a/ in that condition. The formants of vowel /u/ and the first formant value of vowel /i/ are basically low, so there is no significant effect of the two voicing conditions on vowel formants when preceding velar consonants.
Keywords:- Formant, vowel, voicing, consonant

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I. INTRODUCTION

In this study, the acoustic effect of coda voicing on the preceding vowel is investigated. There has been enormous amount of research that documented the correlation between voicing of coda consonants and the duration of the preceding vowel [1-8]. The basic finding is that vowel duration preceding voiced consonants is longer than that before voiceless consonants, which can be called voicing effect. Contrastingly, research on the relationship between the aspiration of coda consonants and the duration of the preceding vowel has led to inconsistent results. Some of the proposed accounts for the voicing effect are production-based, such as those that suggest the shortened vowel duration before voiceless consonants is due to the greater articulatory force needed to produce such consonants, and those that attribute the effect to laryngeal adjustments needed to produce voiced consonants. However, most of these production-based accounts have been criticized based both on the absence of evidence for their empirical consequences and lack of proper justification for many crucial notions. In was found that there is a vowel duration difference before voiced and voiceless consonants coda in Hindi, and vowel durations preceding aspirated coda consonants are longer than those before un-aspirated coda consonants. Closure durations of coda consonants are longer for un-aspirated consonants and voiceless consonants, and when crucial confounds are controlled, there is a slight positive correlation between coda consonant duration and preceding vowel length.

Experiments with synthetic speech have shown that vowel duration is an important cue for the voicing distinction of the following consonant in word-final position. The role of this cue is evaluated for natural speech in [9], which may also contain secondary cues for maintaining this distinction. In their experiment, duration of the vowel nucleus was systematically reduced with a digital gating approach, and recognition rates as a function of vowel duration were obtained. Category change takes place mainly for intrinsically long vowels, as well as for high vowels in combination with final fricatives alone, or in consonant clusters. In other cases, category change cannot be established even after the vowel duration is reduced to 30% of its original duration. The presence of a long voice bar for a final voiced stop will make shortening of the vowel perceptually less effective. A multiple regression analysis of the experimental data indicates that, in natural speech, not only vowel duration, but also voice bar duration, duration of silent closure preceding the final release transient, and duration of the release burst or frication noise, depending on the consonant type, vary in weight as cues for voicing under different vowel and consonant type conditions. The English segment sets /b, d, g/ and /p, t, k/ are phonologically referred to as voiced and voiceless stops respectively. A context in which the stop members of the two phonological sets may be distinguished simply on the basis of voicing, as narrowly defined with respect to stop consonants, is between vowels, as for example in the pair rabid and rapid. Acoustically, however, as many as 16 pattern properties can be counted that may play a role in determining whether a listener reports hearing one of these words rather than the other. In purely acoustic terms these properties are rather disparate, although most of them show variations that can plausibly be considered to be primarily the diverse effects of a relatively simple difference in the management of the larynx together with the closing and opening of the mouth. This diversity makes it difficult to rationalize a purely acoustic account of the rabid-rapid opposition, i.e., one that makes no reference to the articulatory mechanisms and maneuvers by which the common linguistic effect of varying these acoustic properties might be explained [10].

It was proposed that language communities intentionally vary vowel length to enhance auditorily the closure-duration cue for voicing distinctions. By the principle of durational contrast, a long vowel should make a short closure interval seem even shorter and hence more voiced, whereas a short vowel should make a long closure interval appear longer and hence more voiceless. Kluender et al [11] show that, for /aba/ and /apa/ stimuli varying in medial closure duration and for square-wave stimuli that temporally mimic these speech stimuli, a longer initial segment caused a reliable shift in 28 adults' 2-category labeling boundaries toward longer medial gap durations.

The influences of phonological representations upon the temporal relations in the production of word-medial VC-sequences were examined in [12]. The parameters under investigation are vowel, closure, and release duration in a selected set of German disyllabic words. The words include systematically varied word-medial vowel length, i.e., /a/ versus /a:/ followed by the contrasting stops /p, b/, /t, d/, and /k, g/. One point of interest is the extent to which the duration of the vowel and of the closure interacts in distinguishing the sets of consonants in intermediate position. Both long and show vowels demonstrate a lengthening effect when preceding voiced stops. Furthermore, closure durations of the voiced stops are shorter than those of voiceless stops, but are not a function of the preceding vowel length. If the stop closures somehow compensate for the greater lengthening of the long vowels, they should show a larger duration difference when preceded by long vowels, which they do not. The results provide evidence for an anticipatory vowel lengthening effect before voiced stops instead of a nearly constant duration of the vowel and closure sequence as claimed in the literature.

This study aims at examining the effect of consonant voicing on the formant of the preceding vowel. It will compare the formant values at the offset point of the vowel before the voiced and the voiceless consonants.Words with three main vowels a/, /i/ and /u/ preceding six consonants /b, d, g/ and /p, t, k/ will be investigated.

II. METHODOLOGY

2.1 Studying materials

The materials used in this study include words with the three basic vowels, /a, i, u/. In Sundanese, a consonant may occur at both the onset position and the coda position. This study investigates the effect of voicing of the subsequent consonant on the formant of vowels, so it focuses on the consonants at the coda position. Words with syllables ending with /b, d, g/ and /p, t, k/ are used in this study. Consonants in the first set, /b, d, g/, are voiced, while those in the second set, /p, t, k/, are voiceless. The six consonants can be divided into three sets according to their place of articulation, with /b, p/ labial, /d, t/ alveolar, and /g, k/ velar.

2.2. Procedure and measurements

This study aims to give an investigation of the effect of consonant voicing on the preceding vowel in Sundanese. Vowel quality is related to the formant values, so the first and the second formant values at the offset point of the vowels are examined, which are extracted using Praat [13]. An ANOVA is conducted for the comparison of the formant values in the two voiced conditions. Statistic is done in SPSS.

III. RESULT

3.1. Vowel /a/

3.1.1. The first formant

Fig. 1 presents the mean values of the first formant of vowel /a/ at the offset point preceding voiced and voiceless stops. Results from ANOVA show that there are significant difference for the formant values of the two voiced condition when the subsequent consonants are alveolar and velar, alveolar: $F(1, 130) = 5.34$, $p = 0.042$; velar: $F(1, 172) = 33.1$, $p < 0.001$, with formant values higher preceding voiceless consonant. However, no significant difference exists between the formant values of the two voiced condition when preceding labial consonants: $F(1, 129) = 2.09$, $p = 0.152$.

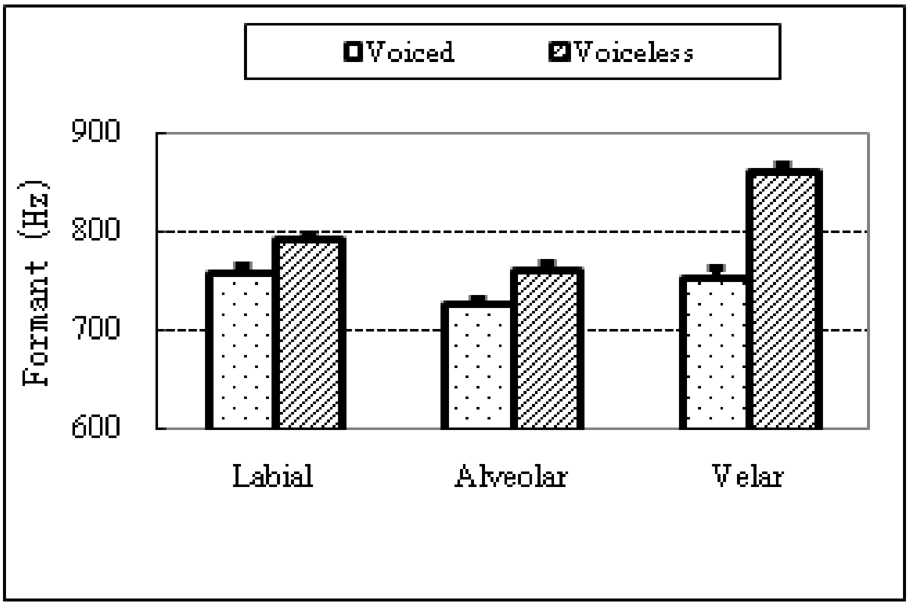

Fig. 1. The F1 values of vowel /a/ at the two voiced conditions

3.1.2. The second formant

In Fig. 2, the average values of the second formant of vowel /a/ preceding the two voiced conditions displayed, and ANOVA result demonstrates that significant difference exists for the formant values when preceding velar consonants: $F(1, 172) = 9.28$, $p = 0.003$, with formant values higher when preceding voiceless consonants. However, there are no significant differences between the values of the two voiced conditions when preceding labial or alveolar consonants, labial: $F(1, 129) = 2.44$, $p = 0.121$; alveolar: $F(1, 130) = 0.814$, $p = 0.389$.

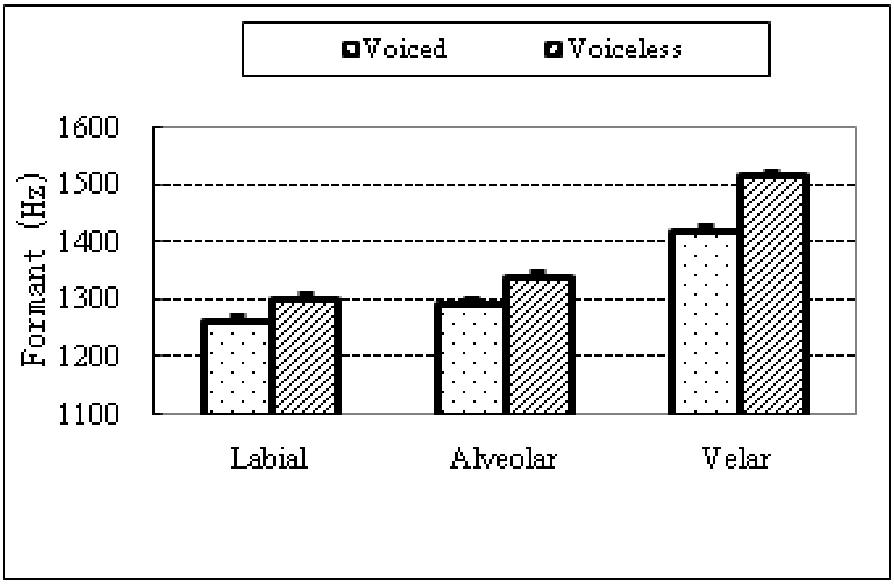

Fig. 2. The F2 values of vowel /a/ at the two voiced conditions

3.2. Vowel /i/

3.2.1. The first formant

The formant values of vowel /i/ are analyzed in this section. Fig. 3 displays the mean values of the first formant in the two voiced conditions, and ANOVA results show that there are significant differences for the formant values of vowel /i/ in the two voiced conditions when the vowel precedes labial and alveolar consonants, labial: $F(1, 65) = 7.81$, $p = 0.008$; alveolar: $F(1, 76) = 16.1$, $p < 0.001$, with formant values higher when preceding voiceless consonants. However, there is no significant difference between the formant values when preceding velar consonants: $F(1, 70) = 0.563$, $p = 0.456$.

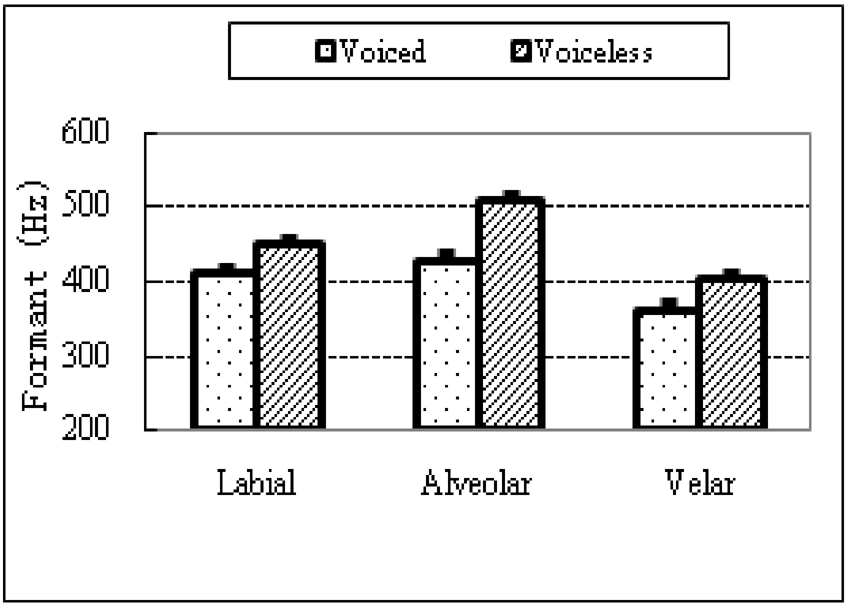

Fig. 3. The F1 values of vowel /i/ in the two voiced conditions

3.2.2. The second formant

The average formant values of the second formant of vowel /i/ in the two voiced conditions are presented in Fig. 4. Results from ANOVA show that there is significant difference for the formant values of the vowel in the two voiced conditions when it precedes velar consonants: $F(1, 70) = 8.25$, $p = 0.005$, with formant values higher when preceding voiceless consonants. However, there are no significant differences between formant values in the two voiced conditions when preceding labial or alveolar consonants, labial: $F(1, 65) = 0.014$, $p = 0.906$; alveolar: $F(1, 76) = 0.933$, $p = 0.337$.

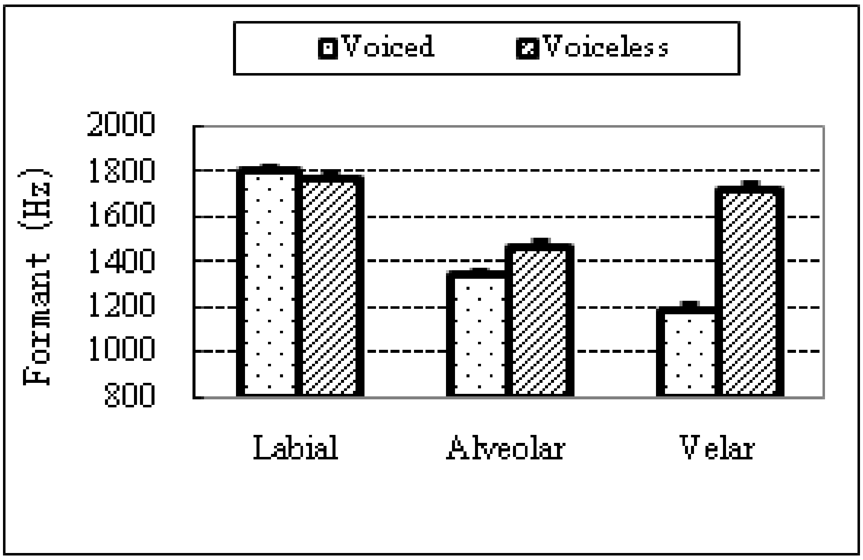

Fig. 4. The F2 values of vowel /i/ at the two voiced conditions

3.3. Vowel /u/

3.3.1. The first formant

In Fig. 5, the average values of the first formant of vowel /u/ in the two voiced conditions are shown, and ANOVA result displays that significant difference exists for the formant values of the vowels when they precede labial and alveolar consonants, labial: $F(1, 61) = 5.83$, $p = 0.022$; alveolar: $F(1, 82) = 24.1$, $p < 0.001$, with formant higher when preceding voiceless consonants. However, there is no significant difference between formant values of vowel /u/ when preceding velar consonants: $F(1, 96) = 0.029$, $p = 0.866$.

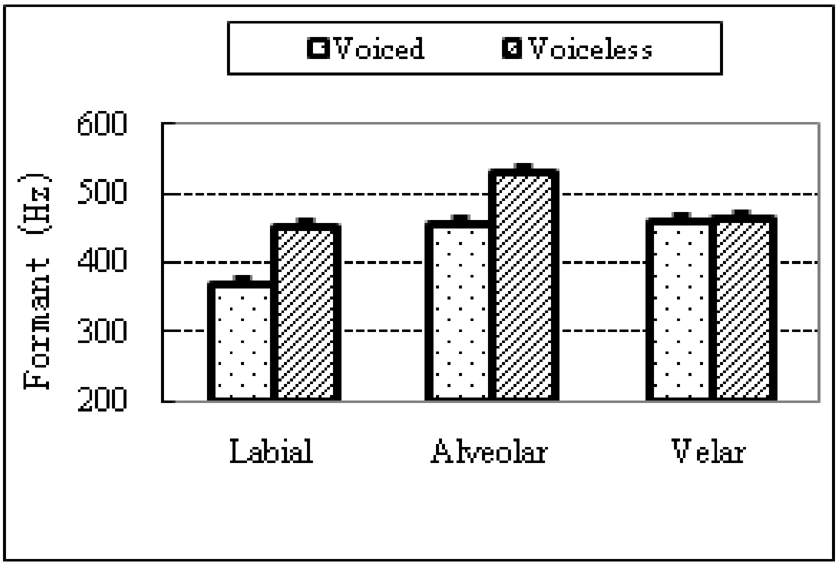

Fig. 5. The F1 values of vowel /u/ in the two voiced conditions

3.3.2. The second formant

Fig. 6 displays the mean values of second formant of vowel /u/ in the two voiced conditions, and ANOVA results show that there are significant differences for the formant values in the two voiced conditions when the vowel precedes labial and alveolar consonants, labial: $F(1, 61) = 10.4$, $p = 0.003$; alveolar: $F(1, 82) = 4.01$, $p = 0.048$, with formant value higher when preceding voiceless consonants. However, there is no significant difference between formant values of the two voiced conditions when preceding velar consonants: $F(1, 96) = 0.513$, $p = 0.476$.

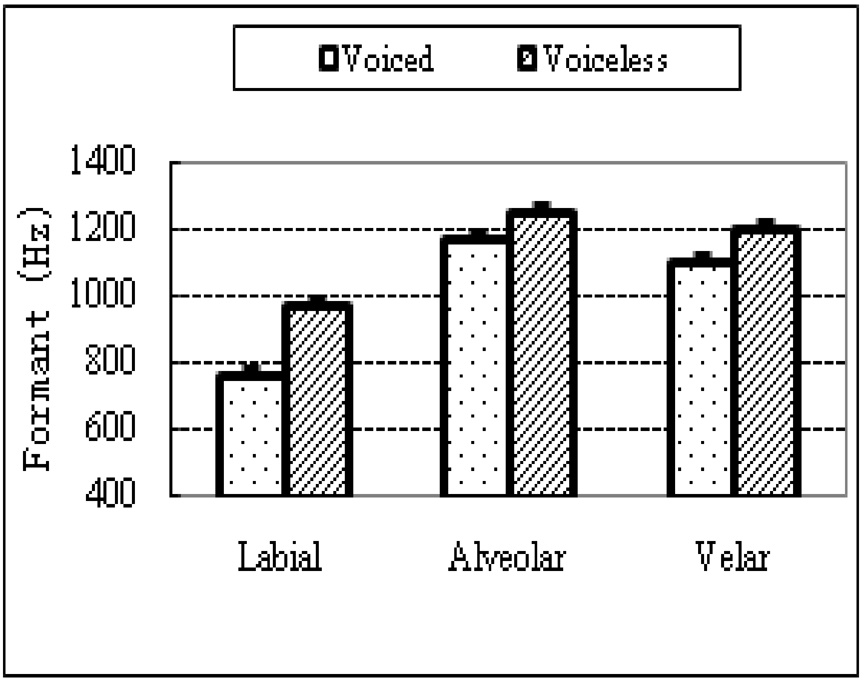

Fig. 6. The F2 values of vowel /u/ in the two voiced conditions

IV. DISCUSSION

In this study, the effect of voicing on the formant value of vowels in Sundanese is analyzed, and it is found that, in most cases, formant values at the offset point are higher for voiceless vowel than the voiced ones. Voicing is the result of the vibration of the vocal cords. In acoustic analysis, the most important thing with regards to voicing is the low frequency area at the bottom of the spectrogram in the frequency range from 0 to approximately 200 Hz. This greater darkness is referred to as a voicing bar, and is a primary indicator of voicing in the spectrogram. A formant is a range of frequencies of a complex sound in which there is an absolute or relative maximum in the sound spectrum. In speech science and phonetics, however, a formant is also sometimes used to mean acoustic resonance of the human vocal tract. Thus formant can mean either a resonance or the spectral maximum that the resonance produces. Formants are often measured as amplitude peaks in the frequency spectrum of the sound, using a spectrogram or a spectrum analyzer. In the case of voice, this gives an estimate of the vocal tract resonances. Formants are distinctive frequency components of the acoustic signal produced by speech.

The information that humans require to distinguish between speech sounds can be represented purely quantitatively by specifying peaks in the amplitude spectrum. Most of these formants are produced by tube and chamber resonance, but a few whistle tones derive from periodic collapse of Venturi effect low-pressure zones. The formant with the lowest frequency is called F1, the second F2, and the third F3. Most often the two first formants, F1 and F2, are enough to disambiguate the vowel. The relationship between the perceived vowel quality and the first two formant frequencies can be appreciated by listening to artificial vowels that are generated by passing a click train through a pair of band-pass filters to simulate vocal tract resonances.

Acoustic analysis showed a number of effects of consonant environment on vowel formant frequencies. The most important of these effects included a general tendency toward centralization for vowels produced in non-null environments, and large upward shifts in F2 of 500–600 Hz for /u/ and 200–300 Hz for the centralized /u/ in initial-position alveolar environments. There is an upward shift of about 100 Hz in F2 for /a/ and the raised /a/ in initial-position alveolar environments, and an upward shift of about 100 Hz in F2 for back vowels in initial-position velar environments. There is a downward shift of about 85–100 Hz in F2 for front vowels in initial-position labial environments, and a tendency toward somewhat lower F1 values for vowels in the environment of voiced consonants.

Furthermore, systematic effects were seen for the manner, voicing, and place of articulation of the flanking consonants. The effects of place on F1 values tended to be small and rather consistent in magnitude from one vowel to another. Place effects on F2, on the other hand, were sometimes quite large and varied considerably in magnitude from one vowel to the other. The largest effect was an upward shift averaging about 350 Hz in F2 for /u/ in the environment of post-dental consonants, and a shift averaging about 200 Hz was also seen for the centralized /u/ in the environment of post-dentals. There were also downward shifts in F2 of some 100–200 Hz for front vowels, with the exception of /i/ in the environment of labial and post-dental consonants. The effects of manner class and voicing were typically rather small. Vowels flanked by voiced consonants tended to be produced with slightly lower F1 values as compared to the same vowels in the context of unvoiced consonants. Manner class had little effect on F1 values, but vowels in stop consonant environments tended to have slightly higher F2 values.

There is an effect of voicing on formant frequency. For normal vowels, the most consistent effect appears to be a tendency for the F1 values of vowels flanked by voiced stops to be slightly lower than those in unvoiced consonant environments. Results indicate that the difference in F1 between voiced and unvoiced environments is approximately 75 Hz, while for the back vowels and central vowels the difference is quite small, typically averaging no more than 15–20 Hz. For the front vowels, the largest voicing-related differences are downward shifts in F1 in voiced environments averaging about 90 Hz. We assume that these shifts in F1 values are due at least in part to the slightly lower position of the larynx for voiced as compared to unvoiced consonants, with this difference carrying over into the vowel in the case of initial consonants and being anticipated in the case of final consonants [14].

Detailed analysis shows that in some cases there is no significant effect of subsequent consonant voicing on formant value. The relationship between formant and vowel is as follow: The first formant is correlated with tongue height, which affects pharyngeal space, i.e., the area of the back or pharyngeal cavity. The more the pharyngeal space is, the lower F1 value is. As the tongue moves from a higher to a lower position, the pharyngeal cavity decreases in volume. High vowels have more pharyngeal space which resonates at lower frequencies. Raising the tongue will pull the tongue out of the pharyngeal space and increase the pharyngeal space, thereby producing a lower F1. Lowering the tongue pushes the tongue into the pharyngeal space and produces a higher F1.

The second formant is correlated with changes within the oral cavity, primarily tongue retraction, with more retracted tongue producing a lower F2. The shorter oral cavity with the forward tongue position resonates at a higher F2 frequency. As the tongue is retracted, the oral cavity gets longer. The longer the oral cavity becomes, the lower the frequency that will be resonated. The more retracted the tongue is, the longer the front cavity is. The shorter the front cavity is, the higher the F2 is. Therefore, front vowels have higher F2, and back vowels have lower F2. Lip rounding supplements the retraction of the tongue by elongating the oral cavity in the anterior dimension for most of the back vowels. Vowel /u/ has a lower F2 because it is retracted and has lip rounding. For vowel /a/, when followed by labial consonant, there is no significant difference between the values of the two voiced conditions. It is known that labials tend to lower the adjacent formant values. When this effect happens, the formant will lower more when preceding the voiceless consonants. Therefore, there is no significant difference between the voiced and voiceless consonant conditions. When vowel /a/ is followed by alveolar, no significant difference exists between the F2 values. This is because alveolar tends to raise the adjacent formant values, and this effect is more prominent in the voiced consonant condition. As a result, there is no significant difference of F2 when preceding alveolar consonant.

The first formant is basically low while the second formant is basically high for vowel /i/. As for vowel /u/, both the first and the second formants are basically low. As is mentioned above, the voiced consonants tend to lower the formant as the larynx is slightly lowered when producing voiced sound. Velars tend to lower the F1 value of low vowels. The first formant of vowel /i/ is basically low. When the lowering effect of the subsequent velar happens, the formant value gets even lower. Since the F1 value of vowel /i/ is already very low, the lowering effect of voicing will not happen on it. Therefore, there is no effect of consonant voicing on the first formant of vowel /i/. The first and the second formants of vowel /u/ are also very low. Due to the same reason, there is

no effect of the consonant voicing on the formants of vowel /u/ when preceding velar.

When the subsequent consonants are labial or alveolar, there is no significant difference between the F2 values of vowel /i/ preceding the voiced and voiceless consonants. The labial and alveolar consonants tend to raise the adjacent F2 value of a vowel. The second formant of vowel /i/ is basically high. When the raising effect happens, its value gets even higher. The voiceless consonants usually raise the adjacent formant of a vowel. However, as the F2 values of vowel /i/ preceding labial and alveolar consonants are already very high, this effect will not happen. Therefore, no significant effect exists between F2 values of vowel /i/ of the two voicing condition when the subsequent consonants are labial and alveolar.

V. CONCLUSION

Voicing is the result of the vibration of the vocal cords. In acoustic analysis, the most important thing with regards to voicing is the low frequency area at the bottom of the spectrogram in the frequency range from 0 to approximately 200 Hz. Formants are often measured as amplitude peaks in the frequency spectrum of the sound, using a spectrogram or a spectrum analyzer. Most often the two first formants, F1 and F2, are enough to disambiguate the vowel. Acoustic analysis showed a number of effects of consonant environment on vowel formant frequencies. There is an upward shift of about 100 Hz in F2 for /a/ and the raised /a/ in initial-position alveolar environments, and an upward shift of about 100 Hz in F2 for back vowels in initial-position velar environments. The first formant is correlated with tongue height, which affects pharyngeal space, i.e., the area of the back or pharyngeal cavity. The second formant is correlated with changes within the oral cavity, primarily tongue retraction, with more retracted tongue producing a lower F2. Front vowels have higher F2, and back vowels have lower F2. The first formant is basically low while the second formant is basically high for vowel /i/. As for vowel /u/, both the first and the second formants are basically low. Alveolar tends to raise the adjacent formant values, and this effect is more prominent in the voiced consonant condition. As a result, there is no significant difference of F2 when preceding alveolar consonant.

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