An exploration of intrinsic F0 in Hainan Cham tones

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Abstract

In this study, the correlations in Hainan Cham between IF0 and tones are analyzed. The study shows that, while for five speakers it is possible to suggest that this correlation is an automatic consequence of vowel production, one subject shows an especially exaggerated IF0 effect that suggests a deliberate auditory enhancement. The study also shows a non-mechanical enhancement of IF0 to enhance a vowel contrast but one that does not put the tonal contrasts at risk.

1. Introduction

The tendency for high vowels to have higher fundamental frequencies (F0) than low vowels, often referred to as the intrinsic pitch of vowels (IF0), has been well established. Tentative explanations for the existence of IF0 have been given from different points of view [1]. Ohala [2, p. 6], for example, suggests "a high position of the tongue creates a slight pull on the larynx which is translated into increased vocal cord tension [resulting in] the widely-noted slightly higher average pitch for high vowels [i, u] and slightly lower pitch for low vowels [æ, a, ə] [...]." There is disagreement as to whether IF0 is a deliberate enhancement of the speech signal [3, 4] or not [5]. An enhancement of high vowels beyond the typical intrinsically produced enhancement would increase the salience of vowel contrasts and point to the possibility of IF0 becoming phonological; non deliberate enhancement not beyond what typically occurs with intrinsic enhancement would point to a purely phonetic IF0, i.e., "a direct [and universal] result of vowel articulation" [5, p. 363].

It has been shown that the intrinsic pitch effect on vowels occurs not only in nontone languages but also in register languages [6] and in tone languages [7]. For tone languages, the difference in F0 between high and low vowels is robust for high tones and very small (or not present at all) for low tones [5, 8]. The existence of IF0 in tone languages adds a new dimension to the discussion of whether IF0 is a deliberate or non deliberate enhancement of a vowel contrast. Should the IF0 be used to enhance a vowel contrast, would it put a tonal contrast at risk?

In this study, the correlations between IF0 and tones are analyzed in Hainan Cham, an endangered Austronesian language spoken on the island of Hainan in China. The correlation is examined with two questions in mind. The first question is to what extent there is a correlation between the IF0 and the Hainan Cham tones. The second question is whether there is inter-speaker variation. The findings of this research are discussed and a connection with more general issues is made.

2. Hainan Cham tones and IF0

Hainan Cham has five phonemic tones [9-13]: three level tones (tones 55, 33, 11) and two contour tones (tones 43 and 24). Pitch shapes for each tone are analyzed in detail in [13]. In our data, tone 55 is often more a 45 phonetically, tone 11 is more a 21 phonetically, and, tone 43 is often more a 42 phonetically. Tone 24 either displays a level plateau through approximately the first half of the vowel followed by a rise in frequency or it falls for the first third of its duration, flattens out for the second third of its duration, and goes back up for the last third of its duration.

2.1. Methodology

The analysis is based on recordings consisting of words produced in citation form by six native speakers of Hainan Cham (three female subjects (F1, F2, F3)) and three male subjects (M1, M2, M3)). The data was recorded on a laptop computer using SoundEdit software and a head mounted Telex H-831 mic. The analyses were performed using Macquarer software. The recordings were digitized at a sampling rate of 11,025 Hz.

For each level tone, there were 5 words with /i/ and 5 words with /a/ (except for vowel /i/ in tone 11, for which there were 3 words); for each word the first two repetitions were measured. All together 336 tokens were measured for level tones. As there was no significant difference between high front and high back vowels, for the rising 24 tone, IF0 values for /i/ and /a/ were combined, and, for the falling 43 tone, IF0 values for /a/ were used. For each contour tone, there were 4 words with the high vowels and 4 words with the low vowel. As with the level tones, the first two repetitions of each token were measured. All together 192 tokens were measured for the two contour tones.

Except for the rising 24 tone, measurements were made at two points, one near the beginning of the vowel and the other near the end of the vowel. For tone 24, measurements were made at three points: at the beginning, in the middle, and at the end.

2.2. Level tones

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2.2.1. Tone 55

Of the six Cham subjects, the oldest (M3) speaker’s pitch height correlates most robustly with vowel height. In tokens with the high vowel /i/, the highest mean value of F0 is ca. 328 Hz; in tokens with the low vowel /a/, the highest mean value of F0 never rises about 216 Hz (Figure 1). For this speaker, the difference between the peak value of /i/ and the peak value of /a/ is ca. 112 Hz. In a parallel way, with the high vowel /i/, the lowest mean of F0 is ca. 222 Hz; with the low vowel /a/, it is only as high as 166 Hz. The difference between F0 with /i/ and F0 with /a/ at the onset of tone 55 is 56 Hz. Even though smaller than the difference in IF0 at the offset by 56 Hz, it is still a robust difference in IF0 at the onset.

Figure 1: Interaction of vowel height with F0 (M3).

For two other Cham speakers, speakers F2 and M2, the difference in IF0 at the high tone offset is 23 and 18 Hz, respectively. For the remaining three speakers, speakers F1, M1, F3, the difference in IF0 is present, but small, only between 3 and 6 Hz.

At the onset of tone 55, where the fundamental frequency is smaller than for the offset, speaker M3 has the most robust difference (56 Hz), while for the remaining speakers, the difference in IF0 is either absent (speakers F2 and F3) or very small, from 2 to 7 Hz (speakers F1, M1, M2).

2.2.2. Tone 33

Subject M3, who robustly distinguishes the pitch height of tone 55 with the high vowel /i/ from the pitch height of tone 55 with the low vowel /a/, does the same with tone 33. The measurements are plotted in Figure 2. For comparison, the mean F0 values for his 55 tones are also given. The solid line represents the tokens with /i/; the dotted line represents the tokens with /a/.

Figure 2: Interaction of vowel height with F0.

Figure 2 shows that there is an interaction between the vowel height and the fundamental frequency not only for the high 55 tone but also for the mid 33 tone. Even though the F0 difference between the high and low vowels is bigger for tone 55 than tone 33, there is clearly a difference in the intrinsic F0 for the mid 33 tone: The F0 is about 30 Hz higher with /i/ than with /a/. Figure 4 also shows that the tonal contrast is not at risk: tone 55 is clearly separated from tone 33.

For the remaining five speakers, the difference in IF0 is either much smaller than for speaker M3 or it is absent. A small difference in IF0 (from between 5 to 1 Hz) is shown by three speakers (M1, F2, and F1). A neutralized IF0 is shown by two speakers (F3 and M2).

2.2.3. Tone 11

Speaker M3 has tone 11 onset higher by ca. 35 Hz for the high vowel than for the low vowel (Figure 3). In his speech, the 11 tone is a falling tone with /i/ and a level tone with /a/.

Figure 3: Mean F0 of tone 11 for high and low vowels.

For tone 11, speakers M3 and F2 show the biggest difference of F0 between the high and low vowels; for the former it is ca. 35 Hz and for the latter it is 14 Hz. The difference in F0 is non-trivial, but less robust than the difference with tone 55 for the same two speakers (112 Hz for speaker M3 and 35 Hz for speaker F2). For the remaining three speakers (F1, M2, M1) the difference of F0 between the high and low vowels is also smaller for tone 11 than for tone 55. The effects of vowel height on fundamental frequency is
smaller for the low 11 tone than for the high 55 tone for all but one speaker (speaker F3).

2.3. Contour tones

2.3.1. Tone 43

The F0 at the onset of tone 43 is higher for the high vowel /u/ than for the low vowel /a/ across all six speakers. For female subjects, the mean F0 is higher by ca. 14 Hz to ca. 26 Hz; for male subjects, it is higher by ca. 20 Hz to ca. 53 Hz. The F0 at the offset of tone 43 is not as uniform as the F0 at the onset. It is higher for /u/ than for /a/ for two subjects (M3 and M1). For these subjects, the averaged offset of /u/ tokens is from ca. 13 Hz to ca. 28 Hz above the averaged offset of /a/ tokens. For three subjects (F1, F3, M2), the offset of tone 43 has not changed. For one subject (speaker F2), the offset is by ca. 17 Hz lower for the high vowel /u/ than for the low vowel /a/. In Figure 4, the measurements are plotted separately for each speaker.

Figure 4: Mean values of F0 for tone 43 in /u/ and /a/.

The graphic illustrating the interaction of vowel quality with fundamental frequency for each speaker is given in Figure 5. Vertical lines represent the averaged difference in F0 between the onset and offset of tone 43; the graph on the left is tone 43 with /u/ and the graph on the right is tone 43 with /a/. For comparison, the horizontal lines give the mean values for the onset of tone 33.

Figure 5: F0 for tones 43 and 33.

Figure 5 shows that with the vowel /u/, tone 43 begins ca. 60 to 33 Hz higher than tone 33; while with the vowel /a/, it begins ca. 38 to 1 Hz higher than tone 33. With the vowel /u/, tone 43 ends ca. 39 to 21 Hz lower than tone 33 for the female speakers, and it ends at about the same level as tone 33 for the male speakers. In other words, for the male speakers tone 43 is phonetically a 43 with the vowel /u/. With the vowel /a/, tone 43 ends at ca. 39 Hz lower than tone 33 for the female speakers and ca. 29 to 3 Hz lower than tone 33 for the male speakers. In other words, with the vowel /a/ tone 43 is phonetically more like a 42 tone.

2.2.2. Tone 24

For the rising 24 tone, vowel height effects on F0 are most noticeable at the offset, at which the difference between the fundamental frequency in high and low vowels can be as large as 58.5 Hz (speaker M3). For the remaining five speakers, the difference is from 17 to 21 Hz for females, and from 10 to 16 Hz for males. The difference between the fundamental frequency in high and low vowels at the onset can be as large as 32 Hz (speaker M3), but for the remaining speakers, it is much smaller (from 6 to 22 Hz for the female speakers and from 6 to 11 Hz for the male speakers). In Figure 6, the measurements are plotted separately for each speaker.

Figure 6: Mean values of F0 for tone 24 in /u/ and /a/.
3. Discussion

Hainan Cham tones have a large IF0 in the higher frequency range, that is, in the high 55 tone, in the onset of the falling 43 tone, and in the offset of the rising 24 tone. Hainan Cham tones show IF0 to be either small or absent in the lower frequency range, that is, in the mid 33 tone, in the low 11 tone, in the onset of tone 24, and in the offset of the falling 42 tone.

Table 1 presents averaged IF0 differences between high and low vowels measured at the highest points. It shows that it is not possible to establish a correlation across the three level tones, such that tone 55 would show the highest effect of IF0, tone 33 the second high, and tone 11 the lowest effect of IF0. Instead, the division seemed to be primarily between tone 55, on the one hand, and tones 33 and 11, on the other. Across all the subjects, the difference in IF0 mean values is consistently higher for the contour tones than for the level tones.

Table 1: Difference in IF0 means for high and low vowels

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Tone 55</th>
<th>Tone 43</th>
<th>Tone 24</th>
<th>Tone 33</th>
<th>Tone 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>M3</td>
<td>112</td>
<td>52.9</td>
<td>42.3</td>
<td>30.9</td>
<td>34.8</td>
</tr>
<tr>
<td>M2</td>
<td>18</td>
<td>30.2</td>
<td>9.9</td>
<td>-3.6</td>
<td>0.3</td>
</tr>
<tr>
<td>M1</td>
<td>5</td>
<td>20.1</td>
<td>5.4</td>
<td>5</td>
<td>-5.8</td>
</tr>
<tr>
<td>F3</td>
<td>3</td>
<td>13.8</td>
<td>17.7</td>
<td>-3</td>
<td>5.2</td>
</tr>
<tr>
<td>F2</td>
<td>23</td>
<td>25.1</td>
<td>38.1</td>
<td>2</td>
<td>14.1</td>
</tr>
<tr>
<td>F1</td>
<td>6</td>
<td>25.7</td>
<td>21.4</td>
<td>0.8</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

Even though the six subjects have shown a range of variability, the measured IF0 clustered five of them together separating one from the group. It appears that speaker M3 intentionally enhances F0 for high vowels for every tone, level or contour, producing an especially exaggerated IF0 effect. It seems, then, that in his speech IF0 is deliberately produced, while in the speech of the other speakers it is a simple consequence of vowel articulation. This deliberate production would make it possible for IF0 to become more than simply a mechanical enhancement, but it does not put the tonal contrast at risk.

4. Conclusions

In this study, the correlations between IF0 and tones were analyzed. While for five speakers it is possible to suggest that this correlation is "an automatic consequence of anatomical coupling between the tongue and the larynx via the hyoid bone" [3, p.126], the production of one subject clearly points to a non-mechanical auditory enhancement. The enhancement is based on controlling F0 and, as a result, "reducing the F1-F0 difference for high vowels and increasing it for low vowels" [3, p.126].

5. References