AN EXPERIMENTAL ANALYSIS OF THE FIVE LEVEL TONES OF THE GAOBA KAM

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ABSTRUCT
The analysis of tonemic systems with five level tones is of great sinificance in the study of tone. Languages with five level tones are rarely found in the world. We have not found any language that has more than five level tones. This is the relection of the physiological adjusting process of the local folds. The on-glides may give the informations for us to distinguish different tones possibly.
This experiment shows the pitch range of tone changes in plysyllabic utterances. The general tendency is towards raising of the five level tones, four tend to rise and only the highest one both rises and falls.

I. INTRODUCTION

Languages with five contrastive level tones are rarely found in the World.
It is generally considered that five level tones are the maximum number that a language can possibly have. For this reason, the " tone letters " created by Y-R Chao have only five pitch levels.[1] In order to distinguish five level tones, S-Y. Wang proposed the feature Mid in the system of distinctive features of tones.[2] Maddison considered the maximum number of five pitch levels as the first of the universal features of tone languages in the world. [3]
The analysis of tonemic systems with five level tones is of great significance in the study of tone. What we frequently encounter in our studies are ones systems of languages or dialects which have one, two or three level tones. There is a considerable physiological and psychological space between neighboring level tones, whose acoustic between neighboring level tones, acoustice behavior displays a considerable degree of freedom.And falling or rising tones are often distinguished from each other only interns of pitch contour without being limited to their pitch levels. Therefore, it will enrich our knowledge of tone to study the articulation of the five level tones in the same system, to observe their acoustic behavior and features of recognation, and to perceive their relationship in monosyllables and their variations occurring in polysyllabic words. This is helpful both theoretically and in practice.

II. THE GAOBA KAM

The sound system of Gaoba kam has only 20 initials and 29 finals, (which the southern dialect of kam has 30 initials and 56 finals and Chinese Putonghua has 21 initials and 35 finals.)

The tone system of Gaoba Kam is comparatively more complicated. It has 9 long tones and 5 short tones. In fact, Gaoba Kam has only 9 distinctive tones in terms of pitch, because pitch values of all the short tones are equal to those of the related long tones. In terms of pitch value, Gaoba Kam has 5 level tones, 3 rising tones, and one falling tone, which can be illustrated as follows:
Tone 1 is a high rising tone,the pitch value being 45;
Tone 1' is a low level tone, the pitch value being 11;
Tone 2 is a low-mid level tone, the pitch value being 22;
Tone 2 is a mid level tone, the pitch value being 33;
Tone 3' is a low-rising tone, the pitch value being 13;
Tone 4 is a low falling tone, the pitch value being 31;
Tone 5 is a high level tone, the pitch value being 55;
Tone 5' is a mid rising tone, the pitch value being 24;
Tone 6 is a high mid level tone, the pitch value being 44;
The five level tones above are thus tone 1' (11), tone 2 (22), tone 3 (33), tone 6 (44) and tone 5 (55).
The present paper presents an elementary analysis of the acousitc representation of level tones in the phonological system on the basis of experimental data.

III. THE EXPERIMENT

The speech sample consisted of the following 3 types of read materials.
(1) Monosyllabic words;
(2) Polysyllabic words;
(3) Sentences;

After a native Gaobanese was recorded in the recording room, the anlysis was made Key 7030` sound spectrograph, which produced narrow band spectrograms and amplitude displays for each signal.
The parameters of each syllable's pitch, length and intensity were thus measured and counted:
(1) Length
Syllabic length; pitch length.
(2) Intensity
The greatest syllabic intensity.
(3) Pitch
Five points are selected on the pitch contour for measurement the pitch length is divided into fur sections. Starting, middle and ending point are marked first, and then two subpoint are also marked respectively between the starting and middle,the middle and ending point. Thus we have five points: a,b,c,d and e, of which a is the starting point, c the middle point, and e the ending point. The frequencies of the five points are measured in Hz.

IV. ANALYSIS

1) Tone in monosyllablès
We have examined the variations of the five level tones in different phonological environments according to their behavior in monosyllables. The results show that all of the five level tones behave quite similarly in terms of pitch. They have the same pitch shapes and very limited dynamic ranges as well.
From the average frequencies of the five points (point a,b,c,d,e) of each tone, the related pitch values in the pitch range can be obtained. The patch tern curve of each tone is made on a modified plane logarithm coordinate. For convenience of comparison between the level tones, we take the same length from each tone for consideration. (See Fig. 1)
The speaker's pitch range is from 120 H2, the lowest limit, to 259 H2, the highest limit.

Pitch
Tone 1': the tonal contour lies at the bottom of the pitch range. It begins at a rather high position and then falls slightly, appearing to be a low level tone. This is quite consistent with the behavior of the low level tone of the Chinese Tianjin dialect.[4] It seems that, if a level tone is at the bottom of the pitch range, there must be a falling transition in the initial portion, which is the acoustic representation of the physiological process of the larynx from natural phonation to the stable low pitch.

Tone 2: the contour is at the bottom of the speaker's frequency range, about a " half-step " higher than that of tone 1'. The starting point is close to tone 1'. The initial portion does not fall so low as tone 1'.

Tone 3: this contour lies in the lower middle part of the frequency range, about two " half-steps " higher than that of tone 2. Both the inital and terminal portions are close to level.
Tone 6: this coutour is in the higher middle part of the frequency range, about 4 " half-steps " higher than that of tone 3. Both the initial and terminal portions are close to level. This tone is similar to 1st tone of mandarin in tonal coutour.
Tone 5: the coutour is in the upper part of the range. The starting point is a bit lower. The initial portion has a rising transition, the portion after the middle point becomes stable and the terminal portions is close to level. The pattern is that of a convex tone. The last half of the contour is about five " half-steps " higher than tone 6. It has a contour similar to the high rising tone of Tianjin dialect, i.e. they are both in the upper part of the pitch range, both are convex tones, and both have rising transition [5]. This reflects the process of speech organs from natual phonation to the stable high frequenly.
The contours of the five level tones in Fig. 1 appear to be an interesting radiant symmetry. Tone 3 and 6 are in the middle part the frequency and the initial portions of their contours are close to level. Tones 1' and 2 have a falling transition, while tone 5 has a rising transition. Their initial portions are all toward the middle of the pitch range. This is very helpful for us to understand the appearance of the orglide of the tone.
In connection with the appearance of the onglide, Maddison proposed one of his universals of tone: " phonetically Central tones unmarked, Extreme tones are highly marked." [6]
We have also found that, though the five level tones are distinctive auditorily and basically " equidistant " from each other, the "equidistance" is hard to describe with some objective criterion.
The supposed equidistance does not show up when either on the mel scale or the Herz scale, neither linearly, nor logarithmically

The frequency value from 129 Hz of tone 1' to 259 Hz of tone 5 happens to be that of the musical octave from C2 to C3. For the convenience of explanation, we take the musical pitch as our criterion. There are 8 scales including 12 half-steps from C2 to C3. If we mark five levels "equidistantly ", the distance between each level should be 3 half-steps. But the actual situation turns out contradictory to that assumption. In fact, tone 2 is one "half-step from tone 1', tone 3 is two "half-steps" from tone 2, tone 6 is four "half-steps" from tone 3,and tone 5 is five : half-steps' from tone 6. In terms of musical interval, the frequency between high pitches is larger than that between low pitches, i.e. the frequency of each scale is twice that of the correspond-

ing scale in the next octave. But the five level tones are not "equidistant" even in terms of musical interval. This shows that the human ear's recognition of speech sounds differs from that of musical sounds 1' is upward 11 Hz, which is equal to one " half-step ", but it already enters the limits of its neighbor, tone 2. The frequency span of tone 5 is downward 44 Hz, which is equal to three "half-steps", but it still has two " half-steps " to go to reach the limits of tone 6.
In this study, we have found a way in which the relationship between the five level tones can be approximately explained limit of the pitch range from each level tone respectively, we get 9 Hz of tone 1', 18 Hz of tone 2, 37 Hz of tone 3, 77 Hz of tone 6, and 139 Hz of tone 5. In this case , the frequency difference of each tone is twice that of its lower neighbor. This is a special equal proportional relatonship. Its significance is uncertain until more experimental data are collected.
We can see that the frequency values of the three middle points b, c and d of each level tone are relatively stable and have rather small dynamic ranges, representing the stable values of the tones. For example, the frquency variations of tones 1', 2, 3 and 6 are all within 10 Hz. Since we often can not determine the shape of a tone contour because of the lack of an objective criterion, this method can be taken as a useful reference.

2) Tone in polysyllables
The behavior of the five level tones in polysyllables as well as in sentences is illustrated in Fig 2. As compared with their behavior in monsyllables, the difference is early seen and the variations can thus be understood.

Duration
The average syllabic length and pitch length both show the same feature, i.e. it is longer in monosyllables than in polysyllables, and it is the shortest in sentences. Another feature is that the length varies with the position of the syllable. The syllable of the same tone is short at the beginning or in the middle of polysyllabic utteranes, but is longer at the end. All the five level tones behave in this way.

Intersity
In general, the upper limit of the dynamic range of every tone's intensity does not little in polyllables or in sentences, but the lower limit falls. This reflects the fact that speech sounds in polysyllables and sentences show clear cadence, which enhances the difference between strong syllables and weak ones.

Pitch
The most striking feature in terms of pitch is that the pitch range of every tone is obviously expanded. The pitch range of a level tone combined with a contour tone is larger than that of the pitch range of a level tone in sentences is larger than that in polysyllables. Therefore, the highest From the figures, we see that, in polysyllabic utterances, every tone stubbornly keeps and manifests its own characterestics in order to maintain contrast with the other tones. Therefore, although the starting and end points rise and fall a grent deal and the whole pitch contour also rises and falls in the pitch range, the basic tonal pattern does not change, and neither does the relative position of each tone's variations with-tone sandhi operates in Gaoba Kam only at the phonetic level . Tones do not change tonmic class under the influence of contiguous tones.

V. CONCLUSION AND DISCUSSION

The five level tones of Gaoba Kam attest the existence of five distinctive tone levels. But the distances between the neighboring levels are not equal either in terms of pitch frequency, or musical interval. This observation may be significant in the study of the recognition of tone.
This experiment demonstrates the pitch range of tone changes in polysyllabic utterances. The general tendency is towards raising. Of the five level tones, four tend to rise and only the highest one either rises or falls.
In the present study five points were selected to measure and analyze the pitch contours of tone. We have found that there is a big frequency difference between the starting and end points of the variations of same tone. This because of the occurence of the transitions of both on-glides and off-glides. But the frequency difference between the other three points in the contral region of the variations of the smae tone is small This plays an important role in the stable behavior of level tone. The middle point particularly plays a decisive role. One analyst has described the appointed tone level" . In this case, we may çonsider that this tone level should be defined by the middle point of the pitch contur. The frequencies the three middle points are almost identical and the related stable section occupies more half of the whole pitch contour. It may be considered to be the typical informaton-carrying section of the tone pattern.
Finally the five level tones as pronounced in monosyllables are separated from each other in the frequency range with few overlaps. On the other hand, the overlaps occure quite often in polysyllabice utterance, of which the Tone 1', and 2, and 3, Tone 6 and 5, (or even Tone 1 and 3,and Tone 3 and 5 in a few cases) overlap some portion of frequency range. The influence of this phenomenon is a considerable problem to the recognition of tone and to study within the boundary theory of speech sound.

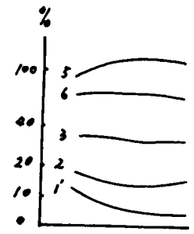

Fig.1a Pattern curves of Five Level Tones in Monosyllables

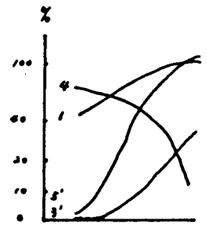

Fig.1b Pattern curves of Four Contour Tones in Monosyllables

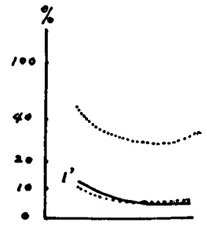

Fig.2a Tone 1' in Polysyllables

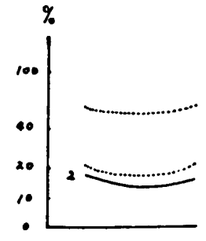

Fig.2b Tone 2 in polysyllables

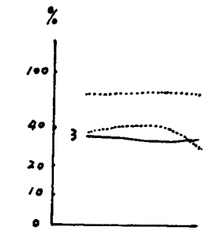

Fig.2c Tone 3 in Polysyllables

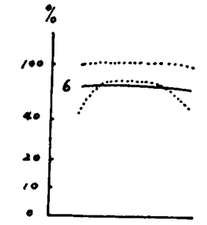

Fig.2d Tone 6 in Polysyllables

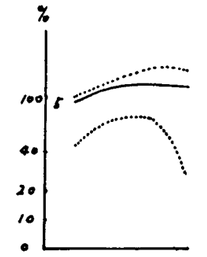

Fig.2e Tone 5 in Polysyllables

Notes:
[1] Yuen-ren chao, a system of tone letters, Le Maitre Phonetique. 45. 24-47 (1930)
[2] William S-Y. Wang, Phonological Features of Tone, International Journal of American Linguistics, Vol. 32, No.2, 93-105 (1967)
[3] I. Maddison, Universals of tone, from Universals of Human language, Vol.2,Stanford Univ. Press, 1978.
[4] Shi Feng, an experimental analysis of the monosyllabic tones in Tianjin dialect. Yu Yan Yan Jiu Lun Cong, Vol. 4 (in print) An experimental analysis of the bisyllabic tones in Tianjin dialect. Yu Ya Yan Jiu vol 10, 1986.
[5] See [4]
[6] See [3]