CONSONANTS AND VOWELS INFLUENCE ON PHONATION TYPES IN ISOLATED WORDS IN STANDARD CHINESE

A. Belotel-Grenié, M. Grenié
Université de Nice-Sophia Antipolis,URA CNRS 1235, Langues, Langage & Cognition
1361 Route des lucioles, F-06560 Valbonne-Sophia Antipolis France
e-mail : belotel@tana. unice. fr

ABSTRACT

The aim of this paper is to study the effects of consonants and vowels on phonation types in Standard Chinese. Tone 3 and tone 4 are often associated with the production of creaky voice. Our results show significant differencies in the type of vowel involved in the production of creaky voice. Creaky voice is observed not only for low vowels but also for high vowels. In term of initial consonants mode of articulation, significant effects have been found in term of duration of vowels produced with creaky voice.

INTRODUCTION

Standard Chinese has four tones, and each syllable has one of these specified lexically. According to the F0 contour on the vowel, the four tones are : high level (tone 1, hereafter T1), rising (tone 2, T2), low falling (tone 3, T3) and falling (tone 4, T4) tones. Generally the phonetic realisation of tones are described in term of F0 contour, amplitude and duration [5]. However, despite extensive litterature on Chinese tones, little data have been published on the effect of tones on segmental realisations. In several Chinese dialects changes in phonation types are involved in production of tones [2, 3, 9]. Although changes in phonation types are not phonologically distinctive in Standard Chinese, we have shown in previous study [1] that vowel /a/ at tone 3 and 4 is often produced with creaky voice. Significant differencies have been found between tones in the measure of relative energy of the fundamental and the largest harmonic in the first formant (F1-H1) at the beginning, the middle and the end of the vowel. The main purpose of the present study is to examine the role of initial consonant and subsequent vowel in production of creaky voice for isolated monosyllabic words. Our study addresses the following questions : Do all kind of vowels affected by creaky voice ? What is the effect of initial consonant on vowel phonation ? The following section presents the speech materials, the next section shows the distribution of vowels produced with creaky voice according to tones. We will then discuss the effect of vowels on creaky voice. Finally, we will describe the effect of initial consonants on phonation types.

SPEECH MATERIALS

The speech materials used in this study was collected in a sound proof chamber by researchers of the Chinese Academy of Social Sciences. Nine Beijing native speakers (seven males and two females) speaking Standard Chinese as their primary language, recorded all the Chinese monosyllables (1279 monosyllables including zero-initial syllables) in isolation using a DAT. They were students of Beijing University. All recorded speech samples were digitized with a Digidisign™ audio card on Macintosh™ with 16 bits quantization using a 10 kHz sampling rate. The tokens were analyzed, segmented and hand-labelled using Signalyze™. In this paper we present preliminary results for only one male speaker who uttered 634 isolated words. Duration and fundamental frequency maximum and minimum were measured for vowels.

CREAKY VOICE DISTRIBUTION

Each utterance was listened and have been visually inspected from a CRT display that simultaneously presented waveform, F0, amplitude, zero crossing and spectrogram. It seems that the speaker produces different phonation types (modal voice and creaky voice). Our analyses of his creaky voice replicate the findings published in [6, 7]. Figure 3 shows the oscillogram, the fundamental frequency curve, the amplitude curve, the zero crossing curve and the spectrogram of the syllable "xiao" produced at tone 3 with creaky voice. Creaky voice is characterised on oscillograms by irregularly spaced pulses, on spectrograms by eneven vibrations of vocal cords and by the presence of energy in the higher frequencies, on amplitude curves by a decrease of the amplitude and a greater shimmer. Table 1 presents the number of words produced with creaky voice with regard to the total number of words for each tone. It confirms our previous results [1] : creaky voice is never produced for tone 1. It also shows that creaky voice primarily affects tone 3 (45.8%) and secondly tone 4 (10.5%). The fact that none creaky voice was observed for tone 2 is not surprising because we have shown in [1] that changes in phonation seems to be a gradual speaker dependent phenomenon.

Table 1 : Number of words produced with creaky voice for each tone for one speaker with regard to the total number of words uttered by this speaker.

Tone1 cv/tot	Tone2 cv/tot	Tone3 cv/tot	Tone4 cv/tot	Total cv/tot
0/158	0/120	89/194	17/162	106/634
0%	0%	45.8%	10.5%	16.7%

VOWELS AND CREAKY VOICE

There are about thirty five finals in Standard Chinese. Five of these consist of a single vowel, the remaining thirty finals are combinations of medials, main vowels and endings. That is to say that a final may be composed as many as three elements : a medial that is a short vowel sound or a glide, the main vowel that is the principle carrier of the syllable and the ending that is a short vowel or a nasal consonant.

Presence of creaky voice

Analysis of creaky voice distribution shows that all kinds of vowels could be affected by a change in phonation type. Several occurrences of creaky voice have been found for /i/ utterances. In order to examine the link between phonation types and vowels, vowels were splitted into three classes according to the main part of the compound vowel : low vowels, high front vowels, high back vowels (figures 1 and 2). A Chi-square was computed on these data. For tone 3, highly significant differencies were found among the three classes ($p<0.0001$). The differencies between the three classes are also significant ($p<0.005$) for tone 4. It appears on one hand, that low vowels are more affected by creaky voice than others, and on the other hand, that high front vowels are more associated with creaky voice than high back ones. This pattern was observed for both tone 3 and 4.

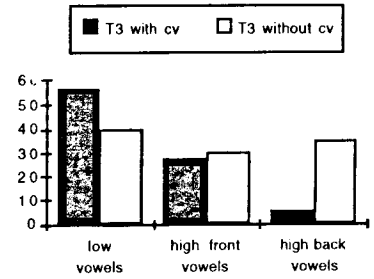

Figure 1 : Occurrences of vowels produced with and without creaky voice phonation at tone 3. The vowels are splitted into three categories (low vowels, high front vowels and high back vowels) according to their main vowel. Differencies between classes are highly significant ($p<0.001$).

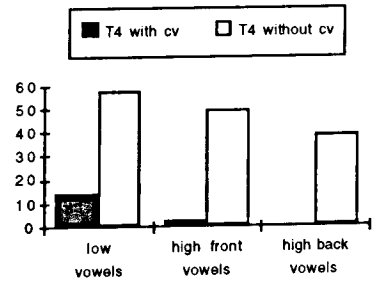

Figure 2 : Occurrences of vowels produced with creaky voice phonation and without creaky voice at tone 4. The vowels are splitted into three categories (low, high front and high back) according to their main vowel. Differencies between classes are significant ($p<0.01$).

Vowel duration and creaky voice

It has been known for many years that vowel duration in Standard Chinese depends on tones [6]. Table 2 presents the vowel mean duration according to tones. Our results are identical to those

observed in [6]. An analysis of variance shows that these variations in duration are highly significant ($p<0.0001$). The longer duration have been found for tone 3 and the shorter one for tone 4 . We observed the hierarchy T3>T2>T1>T4. It is therefore important to evaluate if creaky voice has an effect on vowel duration. An analysis of variance revealed that there is no significant effect of creaky voice on vowel duration.

Table 2 : Vowels mean duration (in ms) according to tones. The differencies are highly significant ($p<0.0001$).

mean	tone 1	tone 2	tone 3	tone 4
duration (in ms)	235.4	281.2	342.7	193.7

Table 3 : Vowels mean duration (in ms) with and without creaky voice for tone 3 and 4. Differencies are not significant.

	tone 3	tone 4
with cv	339.2	199.8
without cv	345.8	193.0

CONSONANTS EFFECTS ON VOWELS WITH CREAKY VOICE

There are twenty-one initial consonants in Standard Chinese. Unlike most European languages, Standard Chinese has no distinctively voiced consonants. There is a primary distinction between obstruent (stops, affricates and fricatives) which are all voiceless and sonorants (nasals, laterals and semivowels) which are all voiced. Stops and affricates falls into two contrasting series : aspirated one and unaspirated one. Considering the place of articulation there are five labial consonants, three alveolars, three dental sibilants, four retroflexes, three palatals, three velars. To complete analyses of our data, consonants have been splitted into categories according to their mode and place of articulation.

C.V. distribution and consonant mode and place of articulation

A Chi-square on creaky voice distribution according to mode of articulation does not reveal for tones 3 and 4 any significant effect.

A Chi-square was carried out on the data taking into account the place of articulation. The distribution of vowels with creaky voice and without creaky voice was not significantly different according to their place of articulation.

Effects of consonants articulation on duration of vowels with C. V.

An analysis of variance was run taking into account the mode and the place of articulation of consonants in order to determine whether they have an effect on vowel duration. The results showed a significant effect of the mode ($p<0.001$) on vowels with and without creaky voice. A close examination reveals that these differencies may be mainly due to the effect of aspirated vs unaspirated consonants ($p<0.0001$). After aspirated consonant the vowel is shorter than after unaspirated one. No significant effect of the place of articulation both for tones 3 and 4 have been found.

Effects of consonants articulation on the F0 of vowels with C. V.

Different analyses of variance were carried out to examine whether the articulation of initial consonant have an effect on the F0 values. The results showed that the mode of articulation of initial consonant have no significant effect on the F0 maximum and minimum values, that is to say that mode does not interfere on the F0 of vowels produced with and without creaky voice both for tones 3 and 4. However significant differencies ($p<0.005$) have been found between vowels with creaky voice and without creaky voice in term of F0 maximum. Vowels produced with creaky voice have a F0 maximum value lower than which are not creaky.

CONCLUSION

Changes in phonation types occur in Standard Chinese for all kinds of vowels. Low vowels are more produced with creaky voice than high ones and high front present more occurences of creaky voice than high back ones. Neither mode of articulation nor place of articulation influence phonation changes. Vowel duration shows a significant interaction between phonation type and initial consonant mode of articulation. The analysis of more data (several speakers and temporal measures of pitch) is needed to confirm these preliminary results.

ACKNOWLEDGEMENT

Authors are most grateful to all the members of the Phonetic Laboratory of Beijing Chinese Academy of Social Sciences, in perticular Prof. Lin Maocan, for the use of their speech recordings.

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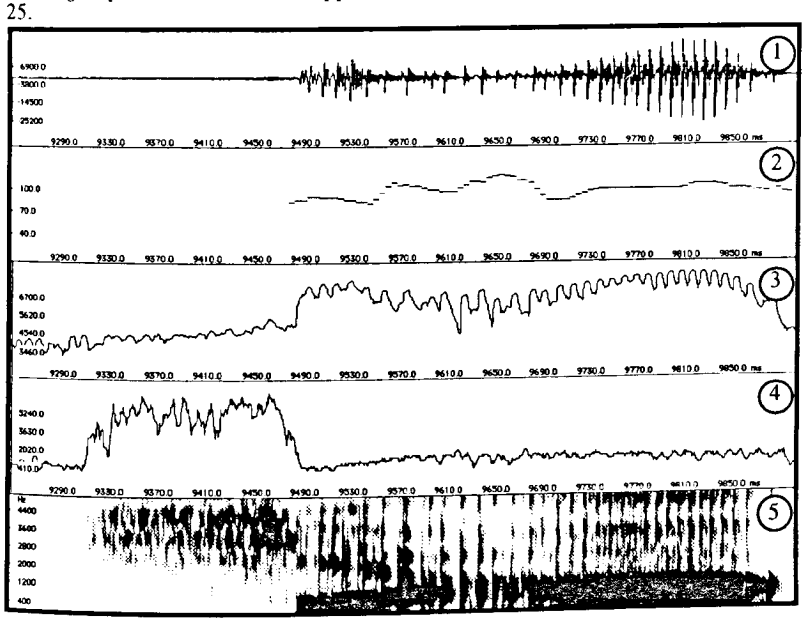

Figure 3 : Acoustic analysis of the syllable "xiao" (in pinyin) /cja^{u}/ produced at tone 3. Oscillogram in (1), fundamental frequency in (2), amplitude curve in (3), zero crossing curve in (4) and large band spectrogram in (5). The presence of creaky voice can be seen at the middle of the word. F0 detection failed to detect the real value of pitch during the production of creaky voice. Amplitude curve shows a greater shimmer during the creaky phase.