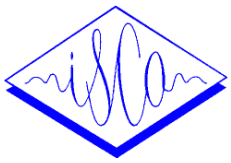


First International Conference on
Spoken Language Processing (ICSLP 90)
Kobe, Japan
November 18-22, 1990

# AN ELECTROMYOGRAPHIC STUDY ON LARYNGEAL ADJUSTMENT FOR PRODUCTION OF THE LIGHT TONE IN MANDARIN CHINESE

Seiji Niimi, Qun Yan, Satoshi Horiguchi* and Hajime Hirose

Research Institute of Logopedics and Phoniatrics,
Faculty of Medicine, The University of Tokyo, Tokyo, Japan
* Department of Neuro-otology, Tokyo Metropolitan Neurological Hospital, Tokyo, Japan

## Abstract

Cricothyroid and sternohyoid muscle activities were examined in a male adult subject of Mandarin Chinese. The main interest of the present study is to know the neural organization for production of light tone. Syllables with light tone and syllables with tone 4 are selected for investigation. Since the latter tone type is falling as well as that of the light tone, the comparative study of the EMG patterns for production of these two tone types should give us some physiological correlates of the light tone production. Suppression of the cricothyroid muscle and activation of the sternohyoid muscle were observed in both tone types. However, the degree of suppression of the cricothyroid activity is less marked in the light tone than in the tone 4. Physiological interpretation is discussed.

## 1.Introduction

It is well known that in disyllabic words in Mandarin Chinese, some syllables can lose their original tones and be pronounced in a neutral tone with a slight declination of pitch. This tonal feature has been described as a light (or neutral) tone. It has been reported that the light tone appears in 4.6% of Mandarin Chinese[1].

There have been several investigations on the light tone mainly from an acoustic point of view[2]. They all agree in terms of the following points

1) The duration of the syllable with the light tone is shorter than that of the ordinary tone syllable.
2) Although the tonal pattern of the light tone depends on that of the previous syllable, the essential tonal pattern of the light tone is falling.
3) The acoustic power in the light tone is weaker than in the traditional four Chinese tones.

The acoustic characteristics mentioned above could be produced by the factor of the subglottic driving force which decreases near the end of the phrase, so that it should not be necessary to control the larynx actively. In other words, the light tone could be produced without any active neural control for the larynx, but by the contribution of the decreasing subglottic pressure in an uttered phrase. On the other hand, in order to realize the pitch pattern of the light tone, it is possible to assume that there should be active or unique neural commands for its production. These arguments turn on the question of whether there is particular neural command for production of the light tone.

In order to answer this question, the present electromyographic study was conducted.

## 2.Method

Two native speakers of Mandarin Chinese served as the subjects. Test words were bisyllable meaningful words whose first syllable was either tone 1,2,3 or 4 and where the second syllable was either the light tone or tone 4 (List 1). For the convenience of processing, all test words began with a voiceless stop consonant /p/. These test words were embedded in the carrier sentence

这是ＯＯ的意思。[tsəsl ˙˙tə i sl]

which means that "this word means .....".

These test sentences were uttered by the subjects 14 times as naturally as possible.

Electromyographic signals were recorded from the cricothyroid muscle (CT) and the sternohyoid muscle (SH) by using hooked wire electrodes with acoustic signals. The CT muscle is known as a pitch raiser, and the SH is supposed to be one of the contributing muscles for pitch lowering[3,4,5,6,7,8,9]. The EMG signals were rectified and integrated for a certain period of time (5 msec). These pre-processed signals were digitized with 12-bit accuracy and fed into a personal computer. The acoustic signals were also recorded on a DAT recorder for fur-

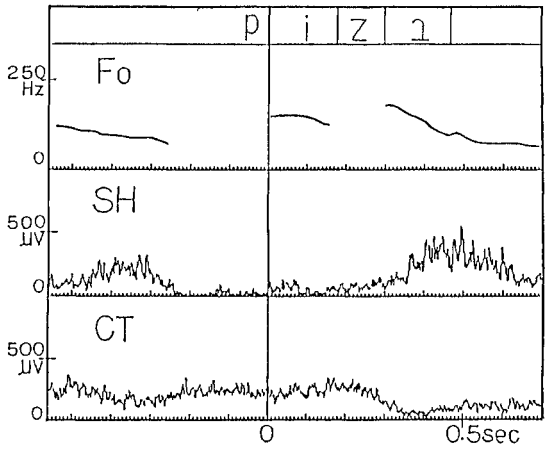
List 1

| | | |
|---|---|---|
| 1+4 | 批字 | [p'i z1] |
| 1+light tone | 坯子 | [p'i z1] |
| 2+4 | 癖字 | [p'i z1] |
| 2+light tone | 庇子 | [p'i z1] |
| 3+4 | 笔字 | [pi z1] |
| 3+light tone | 鼻子 | [pi z1] |
| 4+4 | 碧字 | [pi z1] |
| 4+light tone | 鼻子 | [pi z1] |
| 4+null | 壁 | [pi ] |

ther acoustic analysis. The EMG data were aligned with a line-up point and were ensemble-averaged. For the present study, the moment of the release of /p/ in the test words was selected as the line-up and was defined by an inspection of the acoustic wave form. A sound spectrograph was used to extract the fundamental frequency (F0) of the speech sample. The averaged EMG and F0 patterns were aligned on the same time scale.

### 3.Results

Results are shown in figures 1 from 7. In each figure, the top panel indicates the fundamental frequency, middle one is averaged EMG from the SH and the bottom one is that of the CT.
The vertical line of each panel indicates the moment of /p/ release in the first syllable of the test word which served as the line-up point for the averaging.
Figure 1
F0 contour and EMG patterns for Tone 1 + tone 4.F0 coutour, EMG pattern of SH and CT are shown at top and bottom respectively. A vertical line indicates the line-up point for the averaging (the moment of the release of /p/ in the test sentence).The test sentence is
/ zhe$^{4}$ shi$^{4}$ pi$^{1}$ zi$^{4}$ de$^{0}$ yi$^{4}$ si$^{1}$ /.
这 是 批 字 的 意 思。




As noted before, the duration of the light tone syllable is shorter than that of the ordinary tone syllable. For example the ratio of the tone 4 to the light tone was approximately between 0.5 and 0.7 in this speaker.

As for the EMG, CT showed higher activity for the higher F0 in general. On the contrary, SH was activated for production of the lower F0. In other words, at least for F0 control, these two muscles behaves antagonistically.

In order to clarify the physiological characteristics of laryngeal controls for the light tone production, differences of the EMG pattern between the tone 4 and the light tone were investigated. Since both tones are falling tone, the expected EMG pattern are supression of the CT and activation of the SH during the second (target) syllable. For the beginning of the second syllable, the EMG of the CT incicates supressed activity and the SH becomes active for the pitch declination during the end of the second syllable. This activity patterns are seen for the all utterance types. However, interestingly, the degree of the supression of the CT for the tone 4 and the light tone is different. Supression is more evident for the tone 4 than the light tone. As for the SH activity, the onset of the activation is earlier for the light tone than the tone 4.

### 4.Discussion

Although the physiological mechanism of pitch lowering is still under discussion, there are two major factors contributing to lower the pitch. One is the subglottic driving force and the other is the laryngeal adjustment. Assuming that the laryngeal adjustment is stable during phonation, the declination of the fundamental frequency can be seen and is caused
Figure 2
Tone 1 + light tone Test sentence is
/ zhe$^{4}$ shi$^{4}$ pi$^{1}$ zi$^{0}$ de$^{0}$ yi$^{4}$ si$^{1}$ /.
这 是 坯 子 的 意 思。

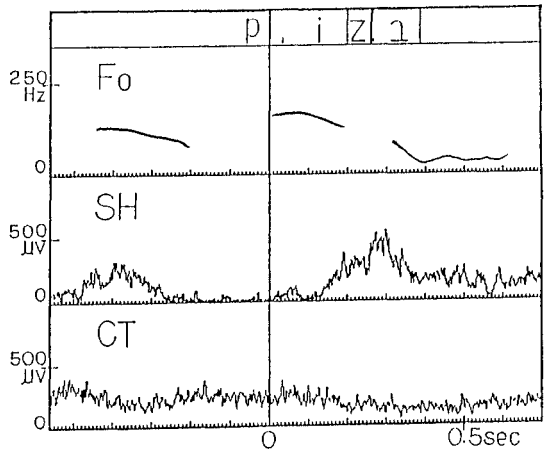


Figure 3
Tone 2 + tone 4 Test sentence is
/ zhe$^{4}$ shi$^{4}$ bi$^{2}$ zi$^{4}$ de$^{0}$ yi$^{4}$ si$^{1}$ /.
这 是 荸 字 的 意 思。

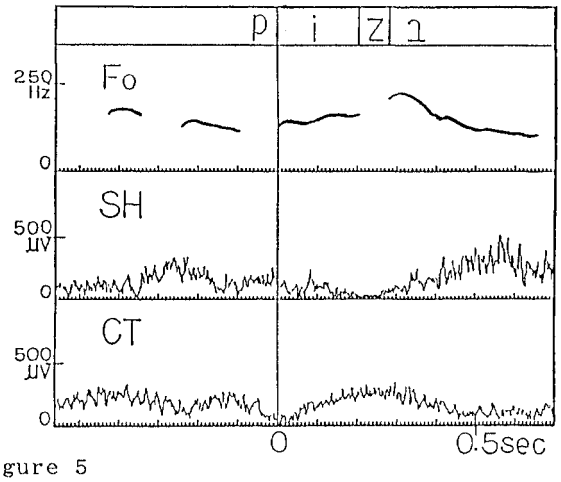



Figure 4
Tone 2 + light tone Test sentence is
/ zhe$^{4}$ shi$^{4}$ bi$^{2}$ zi$^{0}$ de$^{0}$ yi$^{4}$ si$^{1}$ /.
这 是 鼻 子 的 意 思。

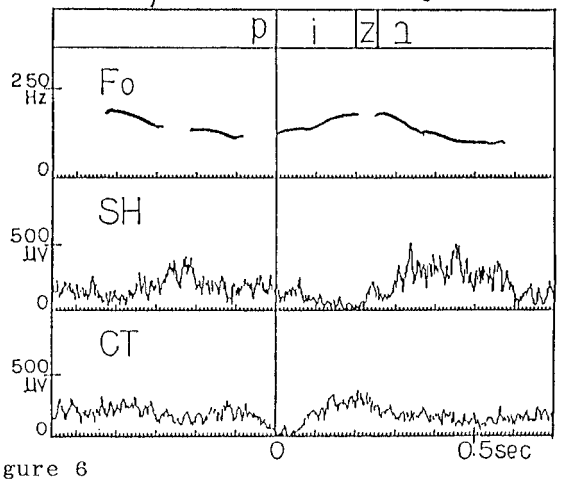



Figure 5
Tone 4 + tone 4 Test sentence is
/ zhe$^{4}$ shi$^{4}$ bi$^{4}$ zi$^{4}$ de$^{0}$ yi$^{4}$ si$^{1}$ /.
这 是 碧 字 的 意 思。

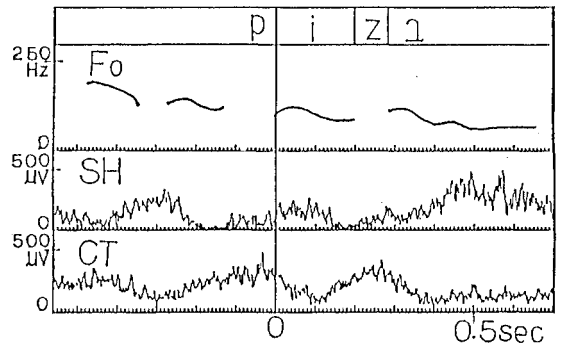



Figure 6
Tone 4 + light tone Test sentence is
/ zhe$^{4}$ shi$^{4}$ bi$^{4}$ zi$^{0}$ de$^{0}$ yi$^{4}$ si$^{1}$ /.
这 是 篦 子 的 意 思。

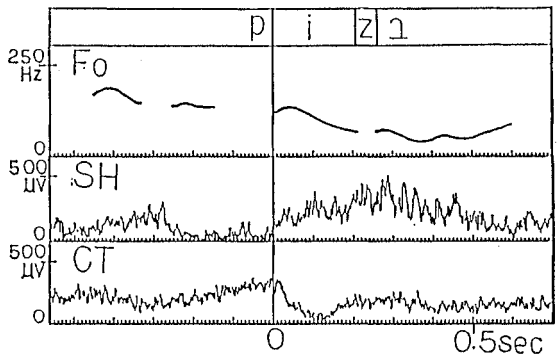
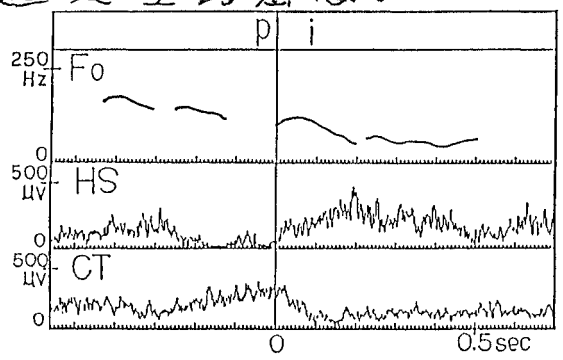



Figure 7
Tone 4 without a following syllable
Test sentence is
/ zhe$^{4}$ shi$^{4}$ bi$^{4}$ de$^{0}$ yi$^{4}$ si$^{1}$ /.
这 是 壁 的 意 思。




by the decreasing subglottic pressure which naturally observed at the end of the phrase.

However, in normal speech, it is well known that the fundamental frequency is controlled not only by the subglottic pressure but also by the laryngeal contribution. There have been many investigations concerning the laryngeal pitch control mechanism during speech or singing. These works agree that the cricothyroid muscle is the primary contributor to the F0 rise and on the other hand, the strap muscles contribute to pitch lowering or at least that the strap muscles become active during low pitch phonation. Since the present study did not aim to clarify the pitch lowering mechanism, but to determine whether there is any particular neural command to the larynx for the production of the Chinese light tone , we chose the EMG activities from the cricothyroid muscle and the sternohyoid muscle as an indication of the neural command for the larynx to control F0.

Some previous studies on Chinese tones have reported that the acoustic characteristics of the light tone are (1) a declination in the pitch; (2) a short

duration of the syllable; and (3) small acoustic power. These acoustic properties could be realized either by the natural decrease in the subglottic pressure or by the active control of the larynx. In this experiment, the test words were selected to compare tone 4 with the light tone, because both of these show a declination of F0. Our assumption was that if there is any laryngeal contribution for the light tone, there should be unique EMG patterns for the production of the light tone.

In all of the EMG patterns examined in this experiment, SH became active and CT was suppressed during the low F0 period. However, the timing of activation of the SH and suppression of the CT was different for different combinations of tone type. Since the duration of the light tone is shorter than tone 4, the perturbations in these activities started earlier in the light tone than in tone 4. In all cases, the starting levels of the F0 declination for the light tone was lower than for tone 4. This acoustic evidence is reflected in the higher activity level of the SH.

Another interesting physiological evidence is that the CT does not show the complete supression for the light tone. Although we cannot fully interpret this physiological evidence, we can speculate that the observed CT activity for the light tone is contributing to slow down the declination of the pitch so that the fundamental frequency would not to be too low at the end of the utterance.

These obaserved facts may indicate that there are some participation of the larynx for the production of the light tone.

Comparing the case of tone 4 + light tone (Figure 6) and the case of tone 4 without a following syllable (Figure 7), the F0 patterns are similar to each other, except for the longer duration in the former case. It seems that this elongation of the utterance is caused by the addition of a syllable with the light tone to the latter case. However, the amplitude of the SH activity is greater for the light tone case along with the elongation of active period. This observed alternation of the EMG of the SH also suggests that the production of the light tone requires some neural commands.

## 5.Conclusion

From the present EMG experiment, it was suggested that the larynx adjusts actively for the production of the light tone. Since the present study does not contain any data on aerodynamic parameters, we can only conclude that at least the larynx contributes to the production of the light tone. Further aerodynamic study is recommended.


## Acknowledgement

This work was supported in part by a Grant-in-Aid for Scientific Research (No.01440071) from the Japanese Ministry of Education, Science and Culture.


## References


[1]Wu, Z.J. & M.S. Lin: An Outline of Experimental Phonetics(in Chinese).Higher Education Press. 230-239,1989

[2]Li, W.M.: A Discussion of Light Tone & Stress in Standard Chinese(in Chinese). Zhongguo Yuwen, No.1, 35-40,1981

[3]R.Collier,"Physiological correlates of intonation patterns,"J.Acoust.Soc.Am., 58,249-255, 1975

[4]J.E.Atkinson,"Correlation analysis of the physiological factors controlling fundamental voice frequency,"J. Acoust. Soc. Am. 63, 211-222, 1979

[5]D.Erickson, M.Liberman, and S.Niimi,"The geniohyoid and the role of the strap muscles. Haskins Labs. SR-49, 103-110, 1977

[6]K.Faaborg-Anderson and A.Sonninen, "Function of the extrinsic laryngeal muscles at different pitches," Acta Otolaryngol. 51, 89-93, 1960

[7]H.Kunitake, "Function of the extrinsic laryngeal muscles - An electromyographic study (in Japanese). Jpn. J. Otolaryngol. 74, 1156-1201, 1971

[8]J.Ohala and H.Hirose,"The function of the sternohyoid muscle in speech. Ann. Bull. RILP, No.4, 41-44, 1970

[9]Z.Simada and H.Hirose,"The function of the laryngeal muscles in respect to the word accent distinction," Ann.Bull.RILP, No.4, 27-40, 1970

[10]Wang, William S-Y.,& Li, K-P.:Tone 3 in Pekinses.Journal of Speech and Hearing Research,10,629-636,1967