PHYSIOLOGICAL PROPERTIES OF "BREATHY" PHONATION IN A CHINESE DIALECT
—A FIBEROPTIC AND ELECTROMYOGRAPHIC STUDY ON SUZHOU DIALECT—

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ABSTRACT

Physiological features of the difference in phonation types were investigated on Suzhou Chinese by use of fiberoptic endoscopy and electromyography. The findings suggest that "normal" vs. "breathy" opposition in phonation type in Suzhou should be brought about by antagonistic setting in the larynx.

1. INTRODUCTION

It is known that there is an interesting interaction between initial consonants, vowels and tones in Wu dialects in China. Recent phonologists often mention the term "phonation type" in treating this phenomenon, but the physiological reality of it is still unclear. In Wu dialects, a breathy (or murmured) syllable is initiated by so called "muddy" initial (usually indicated by a phonetic letter [ɦ], like in [pɦ], [tɦ], [kɦ], [sɦ] and [ɦ]), followed by a breathy vowel with low pitch initiation; whereas a normal (or clear) syllable is initiated by a "clear" initial (i.e. voiceless inaspirates and aspirates), followed by clear vowel with high pitch initiation.

Experiments were conducted on Suzhou dialect, one of the main dialects in Wu area, to reveal the physiological aspects of the difference between "breathy" and "normal" phonation. Seven lexical tones are discriminated in Suzhou as described below by tone letters. Among seven tones Tones IVa and IVb, are characterized by shorter duration in their syllables than in other syllables as indicated by one numeral(5) or two numerals with an underline(23)[1].

Yin Tones		Yang Tones	
Ia	55	Ib	24
IIa	52		
IIIa	412	IIIb	231
IVa	5	IVb	23

The normal phonation and clear initials are associated with Yin tones (indicated by "a"), and the breathy phonation and muddy initials with Yang tones("b").

2. PROCEDURE

Laryngeal views were observed by a flexible fiberscope and were recorded on VTR at a rate of 30 frames (60 fields) per second. The intraoral pressure (Po) was simultaneously measured by introducing a miniature pressure transducer through the nostril to the mesopharnx. Electromyographic(EMG) recording was made on the same day but separately from the fiberoptic experiment. The electrodes were inserted into the cricothyroid (CT), thyroarytenoid (Vocalis, VOC) and sternohyoid (SH). The EMG signals were rectified and integrated over a period of 5 ms. and sampled at a rate of 1 kHz.

In the experiments syllables with zero initials and dental stops, [i]/[ɦi], [ti]/[tɦi], were uttered, first in isolation and second in the carrier sentences:
A: [i155 kø41____kɦə21 kə25 zɿ31]
"He looks at this character____"
B: [kɦə 21 kə25 zɿ 31 in55 ta25 ____iI 25 iã412] "This character, its pronunciation is the same as ____"

3. Results

3-1 Acoustic evidence

Spectrographic observations show that the breathy phonation is characterized in vowels by frication components at the higher frequency range with the damping of the upper formants. Closure duration and VOT for [t]/[tɦ] were measured and the results of the measurements are shown below. VOT is identified here as the interval from the release point to the onset of the periodical vocal wave since it was often the case

NORMAL [ti55] BREATHY [tɦi124]

(A) (B) (A) (B)

Fig.1 Selected frames of the laryngeal views for Suzhou [ti55](normal) and [tɦi24](breathy) uttered in isolation. In both syllables laryngeal views are selected from beginning part of the vowels; (A) approximately corresponds to the point of oral release, and (B) to 40-70 ms. after release.

with the muddy stops that the exact value of VOT was hard to detect by oscillographic and spectrographic inspection.

Closure Duration(ms.)

	Avg.	Min-Max.	Std.	No.
[t]	165.8	131.0-225.2	20.9	30
[tɦ]	128.2	99.9-171.9	23.3	21

t-test: $p<1\%$

VOT(ms.)

	Tone I, II, III			Tone IV		
	Avg.	Std.	No.	Avg.	Std.	No.
[t]	12.2	2.4	22	8.5	1.3	7
[tɦ]	20.6	3.9	14	10.8	0.6	6

t-test: $p<1\%$

Closure duration is significantly longer in unaspirated stops than in muddy stops. VOT in the muddy stop ([tɦ]) is invariably positive. It was reported that there was no significant difference in VOT between muddy stops and voiceless unaspirated stop[2]. But the present analysis has revealed that the difference is statistically significant if the VOT is defined as above.

3-2 Intraoral air pressure(Po)

Maximum Po in initial stops is lower in [tɦ] than in [t]. The difference is significant at the level $p<5\%$ in carrier sentence A; $p<2\%$ in carrier sentence B; and totally $p<1\%$.

$Po(mmH_2O)$

	sentence A			sentence B		
	Avg.	Std.	No.	Avg.	Std.	No.
[t]	106.9	18.3	16	122.9	14.8	8
[tɦ]	91.4	15.4	12	107.6	12.8	6

3-3 Direct observation of the larynx

Fig.1 shows representative frames of the glottal views from the normal([ti55]) and breathy ([tɦi24]) phonation. It can be observed in the figures that the anterior-posterior dimension of the supraglottal structure is remarkably decreased for breathy phonation. The constricted gesture, which can be called "ary-epiglottic constriction"[3], is observed throughout the entire syllable with an increasing degree, but is weakened at the end of the syllable. Note that the adductive movement of the false vocal folds, which is a characteristic feature in the "glottal stop"[1], does not take place in this type of constriction. It appears that the whole larynx moves downward in breathy phonation. The state of the glottis as well as other related features is summarized below.

1) Vocal initiation([i]/[ɦi])

The glottis appears to be closed both in normal and breathy phonation at the initiation of the syllables. In the normal phonation a syllable is often initiated by the glottal stop which is characterized by the adduction of the false vocal folds. In the breathy phonation the glottal stop is definitely absent.

2) Consonantal initiation([ti]:[tɦi])

No remarkable difference is observed in the glottal feature between the two consonant types. There could be four states of the glottis: (1) both cartilaginous and membranous(ligamental) portions of the glottis are open, (2) only cartilaginous portion is open, (3) only membranous portion is open, (4) both of them are closed; and every one of the four states is observed both in [t] and [tɦ], causing no glottal vibration.

3-4 Electromyographic findings

Fig.2 shows the averaged EMG signals for CT, SH and VOC.

VOC: In normal phonation VOC is activated at the vocal initiation, while in breathy phonation it is

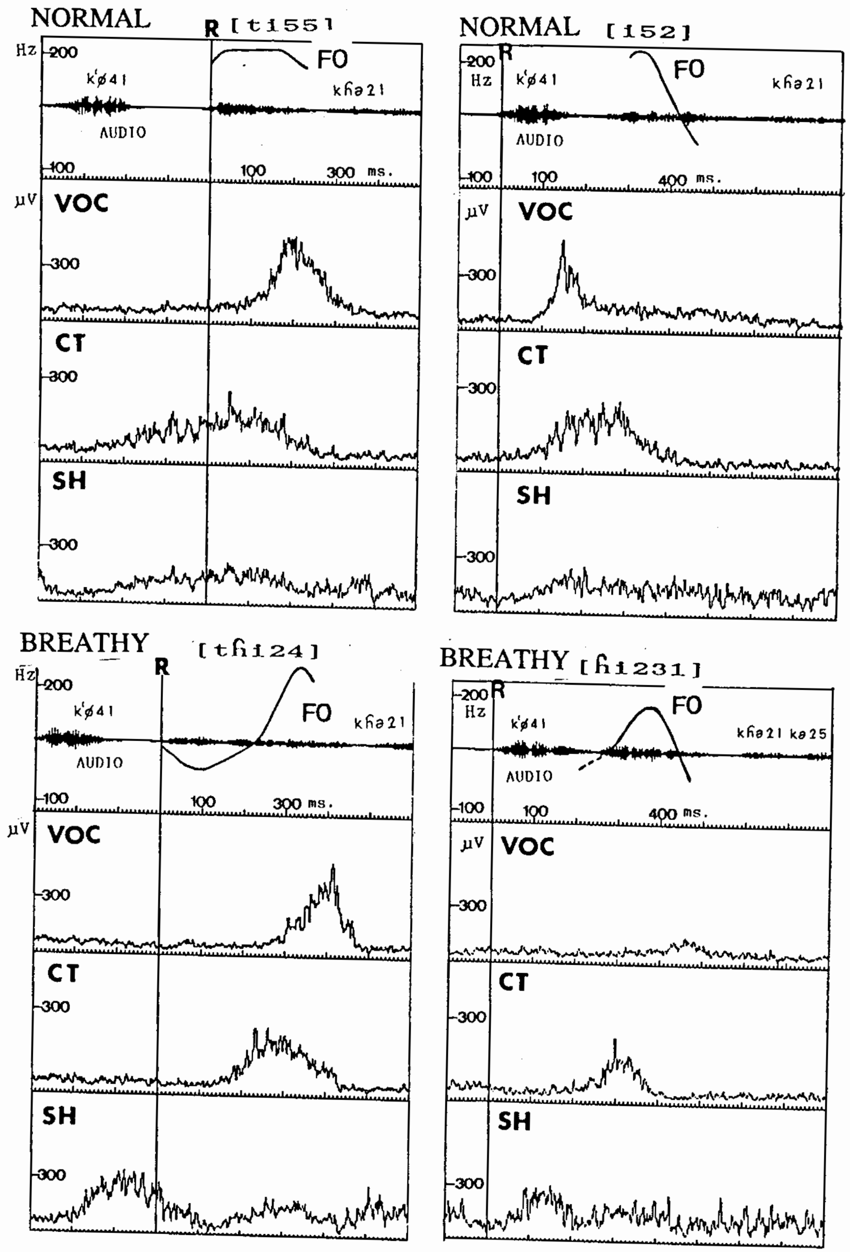

Fig.2 Averaged EMG signals of VOC, CT and SH for "normal" phonation and "breathy" phonation. The vertical line in [ti55] and [tɦi24] indicates the moment of /t/ release ; and in [i52] and [ɦi231], the moment of /k/ release for the syllable preceding the test word. A typical contour of F0 is shown for each test word.

suppressed at the initiation. This evidence is in good conformity with the fiberoptic observation. In the syllables with high or rising F0 contour VOC activity increases at the syllable final portion showing a reciprocal pattern with CT. This is related with the pitch control of the tones as well as the vocal termination of the syllable[1].

SH, CT: The activity of SH and CT is basically antagonistic at the beginning of the syllables: SH is activated for breathy phonation and CT for normal phonation, though SH activity increases to a extent as CT is activated in normal phonation. Both SH and CT show the early initiation in their activities; in the syllables with dental stops, they start their activities at around the closure point or even earlier. In other words, high and low pitch initiations are preceded by early activation of CT and SH.

In pitch rising and falling, however, CT and SH are not antagonistic. CT evidently participates in pitch raising (see EMG for [tɦi24] and [tɦi231]), but SH does not show any marked activity in pitch falling(see EMG for [ti52]).

3-5 Evidence observed in bisyllabic words

The muddy initials have been reported to be realized in fully voiced consonants in connected speech. In the experiment a set of bisyllabic words which have normal or muddy initials in the second syllable were also examined. VOT in muddy stops is in most cases negative and the glottis(both cartilaginous and membranous portions) is closed. The closure duration and peak Po in muddy stops are significantly shorter /lower than in normal stops.

4. Discussion

It is suggested that the difference in phonation types should be produced by the antagonistic setting in the larynx.

The breathy phonation is characterized by "ary-epiglottic constriction", with the downward movement of the larynx. The activity of SH, and presumably other extrinsic muscles as well, undoubtedly contribute to form the constriction and the downward shift of the larynx. These muscles adjust the framework of the larynx as a whole, then externally or vertically effecting the tension of the vocal folds[4][5]. Note that VOC and CT are suppressed at the initiation of the breathy phonation. Conceivably increased activity of the extrinsic muscles would shorten and thicken the folds by exerting the forces externally on them, its adductive tension being decreased[3]. The "breathy" quality of the syllable might be brought about by a "slack" state of the vocal folds, which would provide a favorable condition for low pitch initiation. And this may also be a reason the vocal folds start vibrating in the intervocalic positions.

The normal phonation, on the other hands, is initiated by the increased activity of VOC in the vocal initiation and that of CT in the consonantal initiation, the former of which is often accompanied by the adductive gesture of the false vocal folds. VOC contributes to increase the adductive tension of the vocal folds by supplying the medial compression[6]. CT is primarily a pitch raiser, but note that its activity is initiated quite early. It is assumed that CT also participates in increasing the adductive tension of the folds[6]. Thus a "stiff" state of the vocal folds in normal phonation is unlikely to cause the vibration and would provide a favorable condition for high pitch initiation.

REFERENCES

[1] Iwata,R.,H.Hirose,S.Niimi and S.Horiguchi(1990): "Syllable final "glottal stop" in Chinese dialects", Ann. Bull.RILP,No.24.
[2] Shi,F.(1983):"Acoustic features of muddy initials in Suzhou dialect" (in Chinese) Yuyan Yanjiu, 1983-1.
[3] Lindqvist,J.(1972): "A descriptive model of laryngeal articulation in speech" STR-QPSR,1972,2-3.
[4] Sonninen,A.(1968):"The external frame function in the control of pitch in the human voice" Ann. N. Y. Acad.Sci.,Vol.155.
[5] Ohala,J.(1972): "How is pitch lowered?" JASA,52.
[6] Hirose,H.,T.Gay(1973):"Laryngeal control in vocal attack" Folia phoniat.25.