Laryngeal Muscle Activity during Vocal Pitch and Intensity Changes*

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Laryngeal control mechanism of vocal pitch and intensity has been studied electromyographically by several authors, among them, Faaborg-Andersen in 1965 who reported his work systematically, and the most recent report, of Hirano, Ohala and Vennard in 1969.

These studies, however, have been qualitative analyses of a small number of EMG signals, and a detailed description of the activity of the laryngeal muscles in relation to the fundamental frequency and intensity of voice is still to be examined.

This paper is a report on electromyographic studies on the voice and intensity control mechanism using a computer averaging technique. The technique is as follows:

Raw EMG signals for a number of tokens of the same type of phonation are recorded on a multi-channel tape recorder. Acoustic

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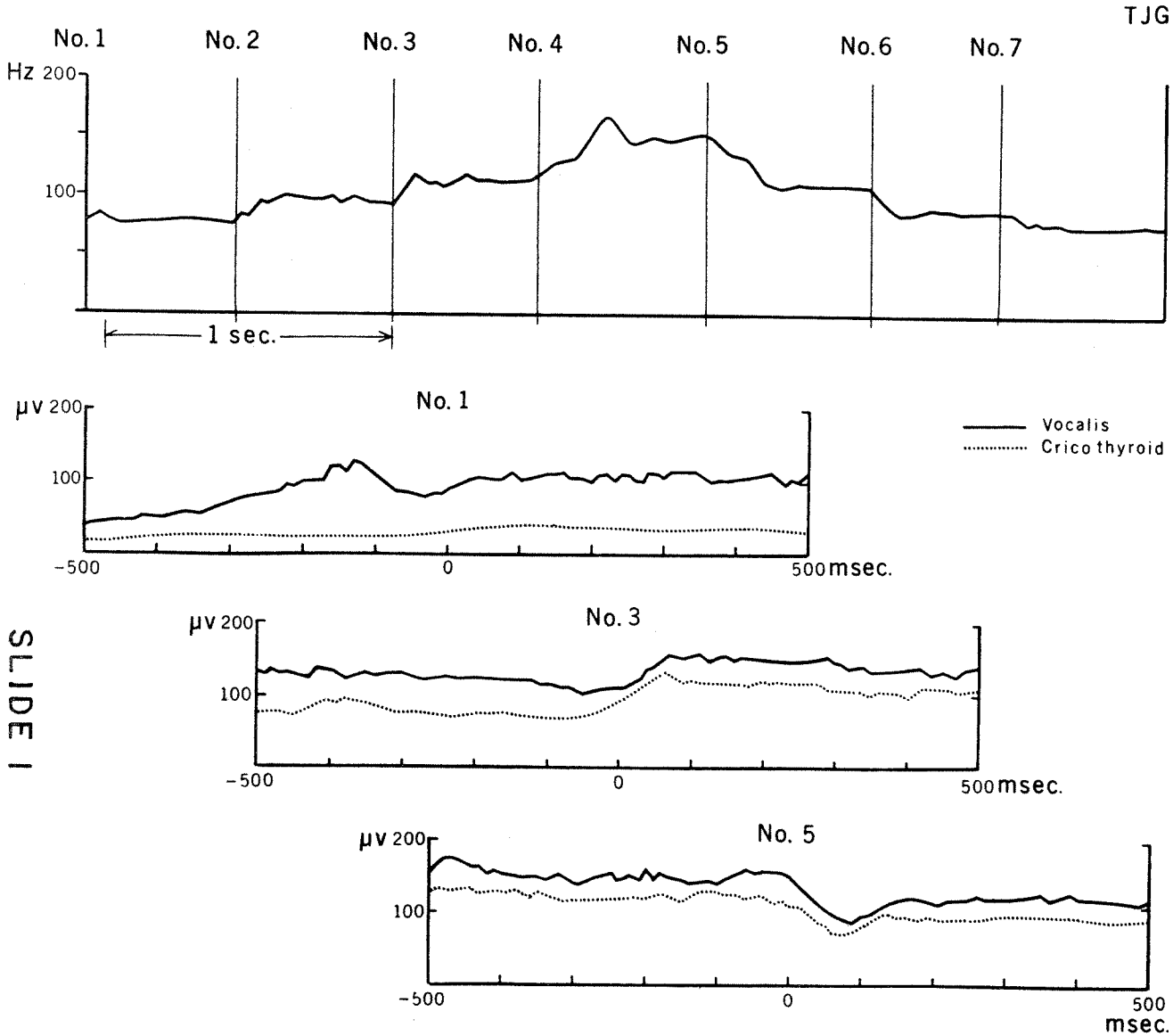

TJG
No. 1
No. 2
No. 3
No. 4
No. 5
No. 6
No. 7
Hz 200
100
1 sec.
No. 1
μv 200
100
-500
0
500 msec.
Vocalis
Crico thyroid
No. 3
μv 200
100
-500
0
500 msec.
No. 5
μv 200
100
-500
0
500
msec.
SLIDE 1

data along with calibration and code pulse signals are also recorded simultaneously with EMG onto other channels of the tape recorder. The raw EMG signals are then rectified, smoothed and averaged on a digital computer. The final print-out shows an averaged amplitude of EMG in microvolts at five millisecond sampling points along the time course of the phonation.

Two muscles were studied, namely, the cricothyroid and the vocalis muscle. Electrodes were DISA concentric needle electrodes with a diameter of .45 mm. The electrodes were inserted transcutaneously, that is, through the skin of the neck, into the muscles.

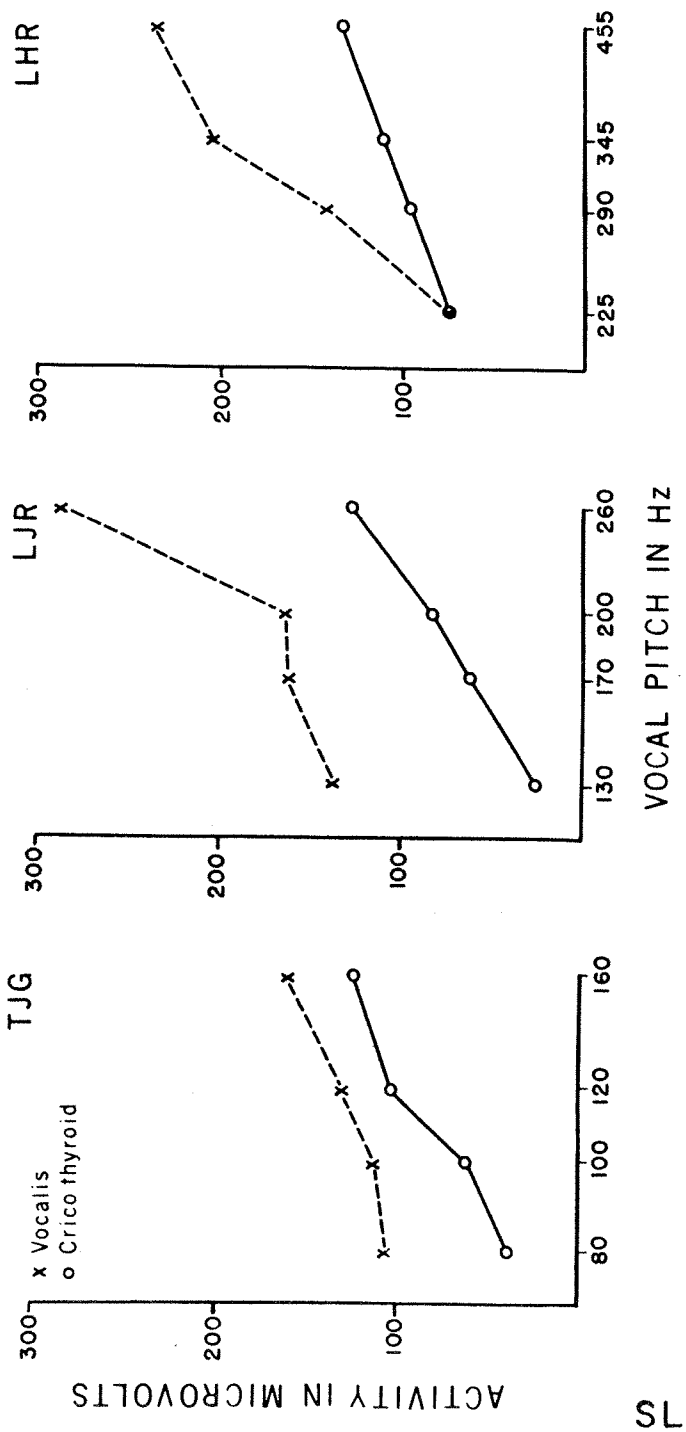
Three young adult subjects, two males and one female, were used for the pitch experiment, and two subjects, one male and one female, for the intensity experiment. All subjects were non-singers. The subjects phonated the sustained vowel /a/ from ten to twenty times in succession for each of several different conditions of pitch and intensity.

During the experimental run, fundamental frequency and intensity of voice were monitored by a pitch meter and a sound level meter. Fundamental frequency contours were later made by a narrow band trace of a sound spectrograph. Intensity levels were also rechecked later on the VU meter of a tape recorder.

For the first series of the pitch experiment, EMG data were obtained for the phonation of a sustained /a/ with stepwise change in vocal pitch as an arpeggio, "do mi sol do sol mi do" in chest register. The intensity level was kept as constant as possible.

Slide 1

In the upper part of this slide, a fundamental frequency contour of a single phonation by a male subject is shown. During the phonation, the subject changed his fundamental frequency from 80 Hz along ascending steps to 100, 120 and 160 Hz, and then along descending steps to 120, 100 and 80 Hz.


TJG
LJR
LHR
x Vocalis
o Cricothyroid
300
200
100
80
100
120
160
130
170
200
260
225
290
345
455
ACTIVITY IN MICROVOLTS
VOCAL PITCH IN Hz

SLIDE 2

It should be noted that, in spite of the subjects intention to change pitch very rapidly and distinctly and keep the steady pitch for each step, the trace of the fundamental frequency contour shows a slurred pitch change with some overshoot from one step to the other. This contour varied for each phonation. After the transition period, the pitch contour reaches a steady state for each step. The fundamental frequency of the steady state showed a good agreement for repeated phonations. Fundamental frequencies mentioned in this report are those of steady state.

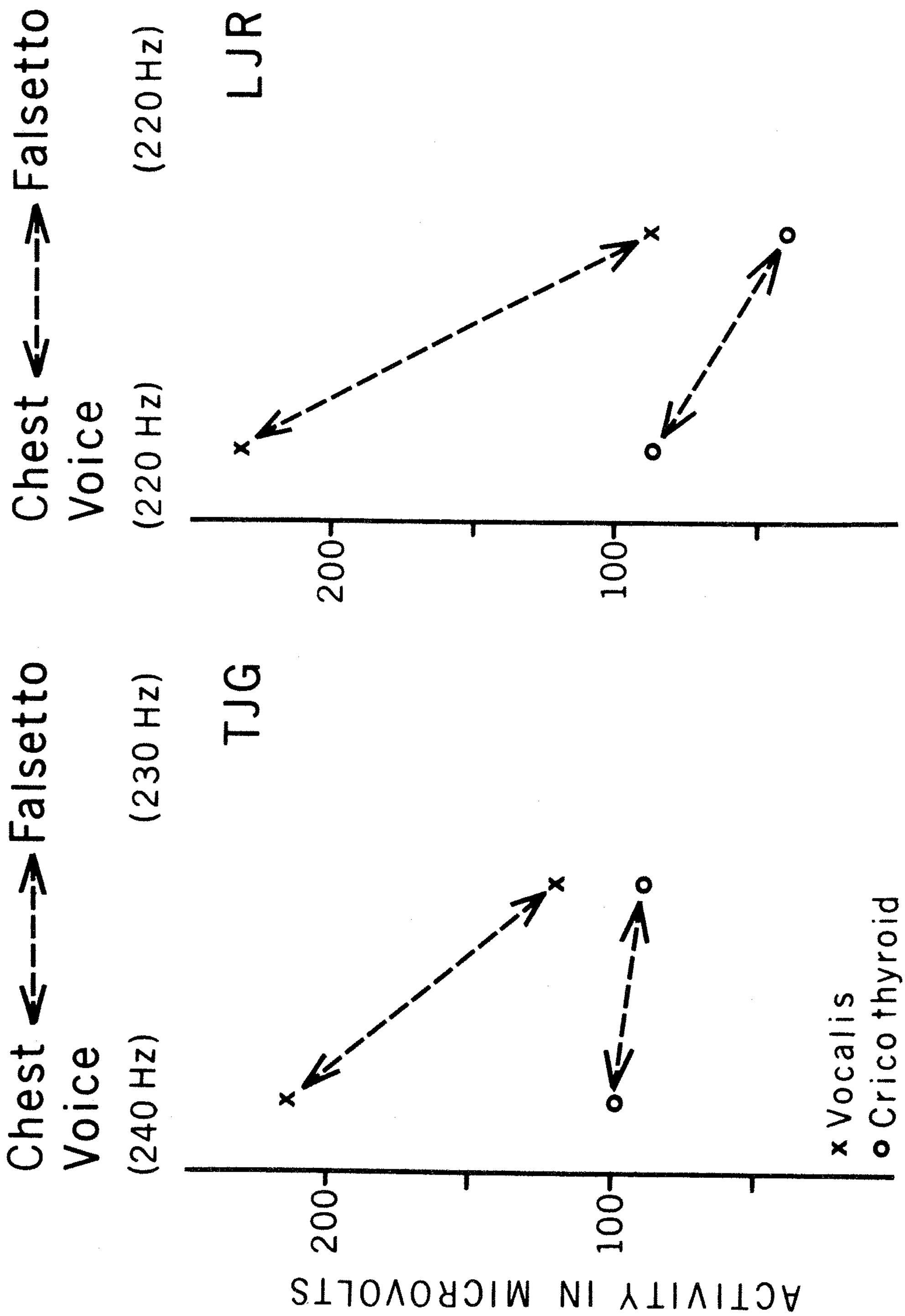
The vertical lines numbered from one to seven on the pitch contour indicate at which points the samples are lined-up for averaging. These points are at the beginning of each pitch change.

The lower half of the slide shows the averaged EMG for line-up points No. 1, No. 3 and No. 5 respectively. Ordinates of the graphs indicate the levels of the averaged EMG in microvolts and the abscissae indicate the time course in milliseconds. Zero in the time course indicates the line-up point.

In these graphs, we see the pattern of the averaged EMG from 500 milliseconds before, to 500 milliseconds after the line-up points. The levels of the averaged EMG, for both the cricothyroid and the vocalis muscle, show stepwise increases and decreases along with ascending and descending steps in vocal pitch. Each step has some unstable period for transition from one step to the other, after which it shows a steady state. We measured the mean level for the period of 300 to 500 milliseconds after each line-up point as an indication of muscle activity to maintain the vocal pitch.

Slide 2

This slide shows the levels of EMG in relation to fundamental frequencies for three subjects. Ordinates indicate level of EMG in microvolts, and abscissae the fundamental frequencies


Chest Voice (240 Hz)
Falsetto (230 Hz)
TJG
Chest Voice (220 Hz)
Falsetto (220 Hz)
LJR
200
100
x Vocalis
o Crico thyroid
ACTIVITY IN MICROVOLTS

SLIDE 3

in logarithmic scale. In the slide we see clearly that the muscle activity, both cricothyroid and vocalis, increases along with the increase in the fundamental frequency of voice in chest register. It seems that the activity of the cricothyroid muscle shows a more linear relationship to the fundamental frequency than the vocalis muscle, although the vocalis muscle has more prominent increase in its activity for pitch rise in some cases.

The next step of our pitch experiment is to compare the muscle activity for chest voice with that of falsetto.

Slide 3

The results obtained from two male subjects are shown in the slide. Compare the levels of averaged EMG for sustained phonations in chest and falsetto registers in almost the same condition of pitch and intensity.

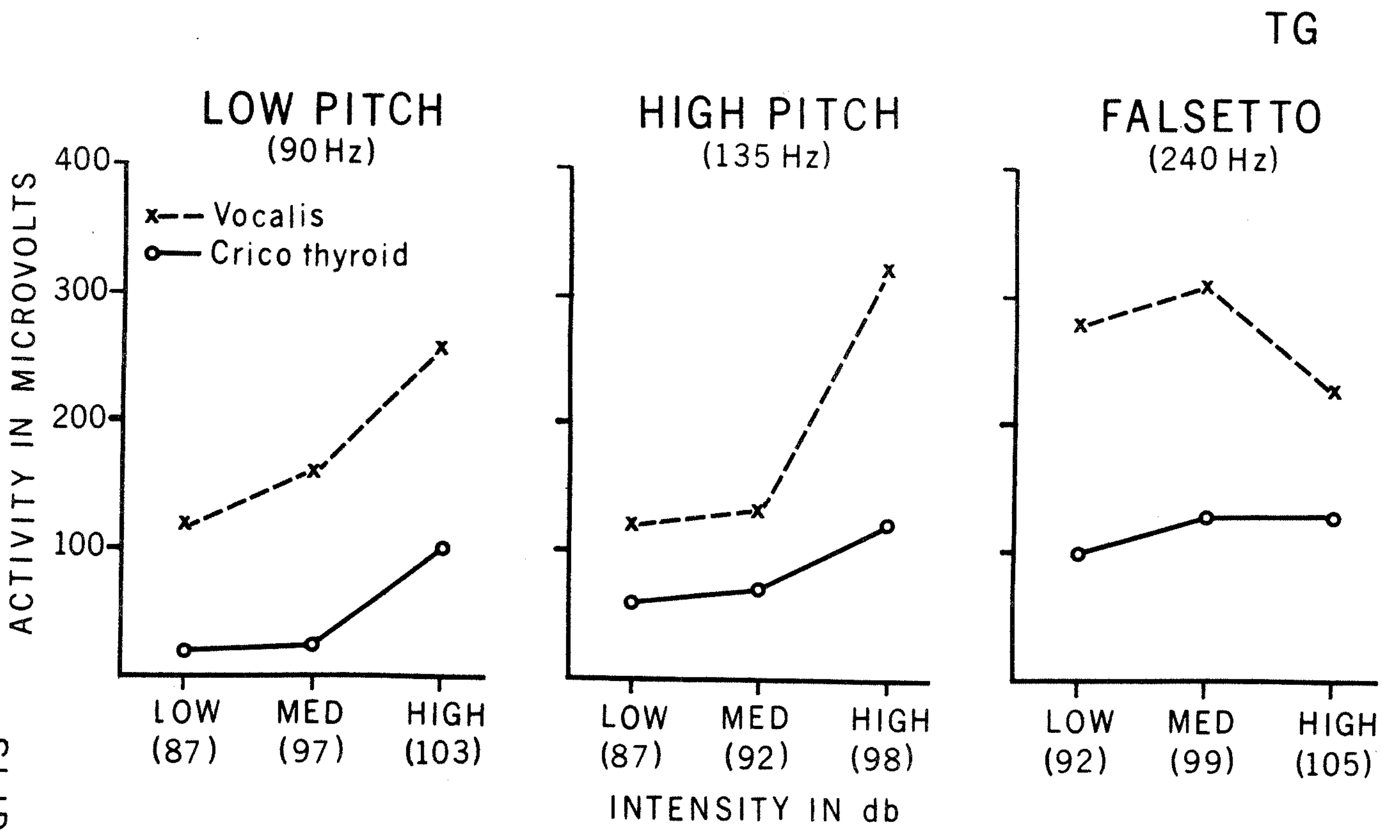
The most interesting finding is that the vocalis muscle for falsetto register shows far less activity than that for chest register. There is also a tendency to decrease the activity of the cricothyroid muscle for falsetto. This result reveals that the difference of chest and falsetto voice is mainly based on the difference in the manner of muscle adjustment of the larynx.

The results obtained in the pitch experiment are generally in good agreement with the previous studies, especially with the latest report by Hirano and others.

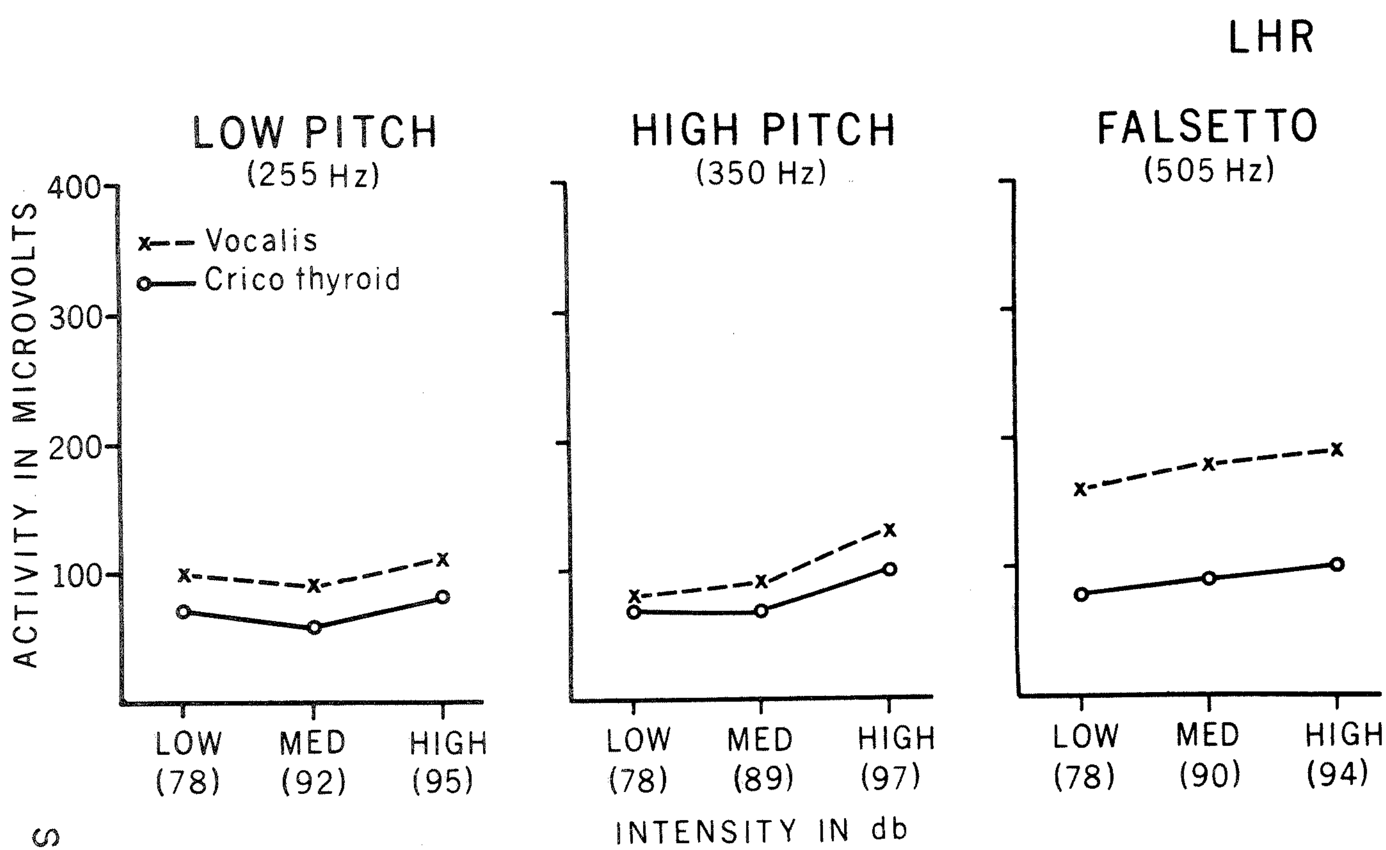
For the intensity experiment, EMG data were obtained for three pitch conditions, low pitch in chest register, high pitch in chest register and falsetto, and three intensity conditions, low, moderate and high intensity. The following slides show mean levels of the muscle activity at steady state of each type of phonation.

Slide 4

The graphs for this subject show a greater activity for both the vocalis and cricothyroid muscles for increases in intensity


TG
LOW PITCH
(90 Hz)
HIGH PITCH
(135 Hz)
FALSETTO
(240 Hz)
x--- Vocalis
o— Crico thyroid
ACTIVITY IN MICROVOLTS
400
300
200
100
LOW
(87)
MED
(97)
HIGH
(103)
LOW
(87)
MED
(92)
HIGH
(98)
LOW
(92)
MED
(99)
HIGH
(105)
INTENSITY IN db

SLIDE 4



LHR
LOW PITCH
(255 Hz)
HIGH PITCH
(350 Hz)
FALSETTO
(505 Hz)
Vocalis
Crico thyroid
ACTIVITY IN MICROVOLTS
400
300
200
100
LOW (78)
MED (92)
HIGH (95)
LOW (78)
MED (89)
HIGH (97)
LOW (78)
MED (90)
HIGH (94)
INTENSITY IN db

SLIDE 5

at low and high pitch in chest register. The increase in activity is more pronounced for the vocalis at especially the highest intensity levels. In falsetto, on the other hand, activity for the cricothyroid remains relatively steady throughout changes in intensity while vocalis activity shows a drop at the highest intensity condition.

It appears then, that this subject uses laryngeal muscle adjustments, probably in combination with subglottal air pressure to control intensity in chest register, while subglottal forces are predominant in falsetto.

Slide 5

This slide shows the same graphs for a female subject. Here, we see that there are small changes in muscle activity accompanying changes in intensity for all three pitch conditions. It seems then that this subject relies more on subglottal forces for intensity control.

These results obtained for the intensity experiment are in general agreement with those of Hirano and others except that we do not find a decreasing amount of cricothyroid activity with increasing intensity.