REGULATION OF INTENSITY AND PITCH IN CHEST VOICE

Helmér Strik and Louis Booves

Institute of phonetics, Nijmegen University,
P.O. Box 9103, NL-6500 HD Nijmegen
The Netherlands

ABSTRACT

The simultaneous control of fundamental frequency and intensity of phonation was investigated. Simultaneous measures were obtained of laryngeal muscles and the respiratory system. An inverse relation between intensity and activity of vocalis and cricthyroid was found at high pitch chest voice.

INTRODUCTION

Studies of the simultaneous control of fundamental frequency (F0) and intensity of phonation have dealt with either the intrinsic laryngeal muscles [1,2,3,4] or with the respiratory system [5,6]. In one study [7] subglottal pressure (Ps) was measured simultaneously with electromyographic (EMG) activity of intrinsic and extrinsic laryngeal muscles for singing. The purpose of the present study is to reexamine the simultaneous control of F0 and intensity in speech. To that end Ps, lung volume, and EMG activity of cricothyroid (CT), vocalis (VOC) and sternohyoid (SH) were obtained while the signals were chosen because they are believed to be instrumental in control of both intensity and pitch. No open vowels were used because jaw opening may influence the activity of the radiated sound and the EMG-activity of certain laryngeal muscles.

METHOD

Speech Material

The subject was a male native speaker of Dutch. He was possible to keep constant F0. This task was repeated five times for each of twelve different conditions: 2 vowels (i/ and u/), 3 intensities (soft, normal, and loud) and 2 frequencies (low and high), making a total of 36 phonations. The intensity levels (IL) normal IL, and the IL of the loud utterances was approximately 7 dB above the normal IL. The audio signal was led to a pitch-extractor, and the subject Fo, v, a low pitch level of 3 Hz, and a high pitch level of 160 Hz, were indicated on the oscilloscope screen. In this way the subject could control his Fo.

RESULTS AND DISCUSSION

The duration of the sustained vowels varied between 10 and 20 seconds. While phonating the EMG-activity of VOC and CT, the Ps, IL, and F0 were approximately constant. The EMG-activity of SH had a peak value immediately before the onset of phonation. Collier [12] and Hirose and Sawin [13] also observed SH activity just before voice onset and assumed that the SH helps in preparing the larynx for the "speech mode." The peak value of SH activity depended on the frequency and intensity of the vowel that had to be produced. The largest peak values were recorded in the low frequency - high intensity condition, while the peak was almost absent in the high frequency - low intensity condition. In all utterances the EMG-activity of the SH had levelled off to a more or less constant value 2 seconds after voice onset. Therefore for each measured physiological quantity the mean value was calculated from 2 to 10 seconds after voice onset, as mentioned above.

The mean values of the average signals are shown in the Figures 1 to 4. For each repetition the mean value between 2 and 10 seconds after voice onset is also given. The results are analyzed by making three different comparisons for the relevant physiological quantities.

1. 1e vs. u/

A comparison is made between the data of the vowels i/ and u/. Both are closed vowels and therefore the jaw opening was roughly the same. The major distinction between the two vowels is a difference in their formants, caused by a different vocal tract shape. This did not result in big dissimilarities between the recorded signals, but some differences did occur. Ps, at equal intensity levels the Ps was always slightly higher when the vowel i/ was produced.

CT. For the low Fo condition the activity of the CT was about the same for both vowels, but for high Fo the activity of the CT was less for the vowel i/. This can be a compensation to keep Fo constant, because an increased Ps could lead to an increased F0.

VOC and SH. These two muscles showed more activity for the vowel i/ when phonating at low Fo, and approximately the same activity when phonating at high Fo.

2. For Fo regulation

With the aim to control intensity, the signals recorded at low and high pitch voice are compared. VOC and CT. From the Figures 1 to 4 it can be seen that the activity of VOC and CT was substantially higher at a high-pitch chest voice than in low-pitch chest voice. This confirms previous findings that the VOC and the CT are the prime muscles in regulating Fo, especially in chest voice [3,4].

SH. The activity of the SH decreased with increasing frequency, a result also found by Ohata [14] and Collier [12]. The Figures 1 to 4 show that the decrease of SH activity was more obvious at the high IL.

EL. Across different fundamental frequencies Ps was always the same. This is contradictory to the general belief that Fo and Ps are positively related [12,15]. In this case the Fo is not raised by increasing Ps, but probably by an appropriate adjustment of the activity of CT, VOC and SH.

3. Intensity regulation

Since the vocal intensity is also a function of the acoustic impedance of the vocal tract, comparison of intensity is only done between two states in which the shape of the vocal tract is approximately the same, i.e. when the subject produced the same vowel.

Ps. Intensity was always positively related to Ps. This is consistent with the results obtained by Iwahashi [5] and Baer [7].

EL. The glottal flow was more or less constant for different intensities. The EGG recordings revealed that the QG decreased with increasing intensity. Therefore, although Ps increased with increasing intensity, Ig could remain fairly constant [5].

In the chest register glottal flow is not dominant in controlling intensity; apparently, the form and spectral content of the flow signals are more important.

SH. A positive relation between intensity and the EMG activity of the SH was found.

VOC and CT. At low chest voice no significant change in the EMG-activity of the VOC and CT as a function of intensity were found. Gay et al. [4] also found that muscle activity, of all five intrinsic laryngeal muscles, remained relatively steady across changes in vocal intensity.

At high pitch chest voice a negative relation between intensity and the EMG activity of VOC and CT was found. The compensatory mechanism is necessary to keep Fo constant, because some of the factors that increase intensity also increase Fo.

CONCLUSIONS

First of all, it appears to be possible to maintain a constant subglottal pressure during a prolonged utterance, regardless of the decreasing volume of the lungs. Also Fo and IL can be kept constant without the need of apparent actions of CT, VOC or SH. Thus there seems to be no reason to assume that the often observed deciliation in speech is an involuntary effect of the decreasing lung supply.

The findings of this study are in agreement with those of previous studies: VOC and CT are the primary muscles in regulating Fo, IL is positively related to Ps, and Ig is more or less constant for different intensities in the chest register. Miller found that an increase in vocal intensity without an associated rise in Fo had to be accompanied by a decrease in CT activity [16]. Rubin also speculated on a decrease in intensity of contraction of the CT with increasing loudness, if Fo is to remain constant [17]. Hisano actually measured that CT activity changes often varied inversely with the vocal intensity [1,2]. In the present study it was found that the increase in subglottal pressure was compensated, not only by a decrease in CT activity, but also by a decrease of VOC activity. Further studies need to be conducted to explain why this compensation mechanism only occurred at high pitch voice.
Figures 1, 2, 3 and 4. In these figures the Ps (cm H2O) and the EMG activity (μV) of SH (●), CT (○) and VOC (△) are plotted as a function of IL (dB). The open symbols represent the mean values of the tokens, and the closed symbols represent the mean values of the averaged signals (for further explanation see text).

REFERENCES


