LARYNX CLOSED QUOTIENT MEASURES FOR THE FEMALE SINGING VOICE

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ABSTRACT

Electrolaryngographic techniques previously used to quantify larynx closed quotient (CQ) change with singing training/experience for adult males are further applied to a group of 21 adult female singers. This data suggests that there is a change in the *patterning* of CQ variation with fundamental frequency which correlates with the number of years singing training/experience.

1. INTRODUCTION

Professional singers often report that when their voices are working well less voice productive effort is required. Acoustic explanations have been offered for this effect, particularly the presence of the *singers' formant* (e.g. [7] and [8]). Electrolaryngographic larynx measures suggest ([4], [5]) that for adult male singers there is a statistically significant positive correlation between the number of years singing training/experience and larynx closed quotient (CQ) -- the percentage of each vocal fold cycle for which the folds remain in contact. This is acoustically plausible since high CQ values mean reduced loss of energy to the sub-glottal cavities. This paper presents CQ data for adult female singers, and discusses it in terms of its variation with singing training/experience. Possible applications of this work include the development of new visual displays for use in research and training of both the singing and speaking voice.

2. SUBJECTS AND DATA

Twenty-one adult female singers (F1 - F21) took part in the experiment. Each subject completed a questionnaire relating to her singing training/ experience and other musical skills, as well as environmental, dietary and general health factors which she felt could affect her voice. In this paper, the subjects have been ordered by the number of years singing training/experience, which is summarised as follows:

F1-F5 at least 5 years formal training, extensive choral and solo experience;
F6-F8 less than 5 years formal training, some choral experience
F9-F10 minimal formal training, some choral experience;
F11-F15 no formal training, some choral experience;
F16-F21 no formal training, no choral experience.

Stereo digital audio tape (DAT) recordings were made in a sound-isolated room at University College London. The speech pressure waveform from an electret microphone was recorded on one channel and the output from the electrolaryngograph (Lx) on the other [1]. The recorded data consisted of:

1) a read prose passage lasting approximately two minutes, and
2) a two octave sung major scale, ascending and descending from G (196 Hz) on the vowel of *palm* with each note lasting approximately a third of a second. (Some of the less experienced singers were unable to sing a two octave G major scale accurately and they were encouraged to produce notes across as wide a range as possible.)

3. DATA ANALYSIS

The Lx was analysed on a MASSCOMP 5600 computer system, using the *Speech Filing System* [6], to give a scattergram for each subject's sung scale. This scattergram, referred to as Qx [1], shows the distribution of CQ values against the logarithm of fundamental frequency (F0).

The technique of cycle-by-cycle CQ measurement is described in [3]. Lx (polarised to ensure increased inter-electrode current flow is represented as a vertical deflection) is time-differentiated and the positive peaks are used to mark the start of the closed phase. The closed phase ends when the negative-going Lx waveform crosses a fixed ratio (7:3) of the current cycle's amplitude. The time between the start of the closed phase in one cycle and the next gives the fundamental period for that cycle. CQ is thus given by: ((closed phase) / (fundamental period) * 100) %.

Figure 1 shows Qx plots for the scales sung by all subjects (F1-F20), ordered by the number of years' singing training/experience.

4. DISCUSSION AND CONCLUSIONS

The Qx plots for the sung scales by our adult female subjects (see figure 1) tend to have CQ values which are confined within a narrow range for a given sung note, but vary as the pitch is altered. The Qx data for our 18 male subjects on the other hand [5], also based on a sung two octave ascending and descending G major scale, tended to exhibit comparatively constant CQ values with fundamental frequency, with a statistically significant correlation between their mean CQ value and the number of years' training/experience.

A survey of the data presented in the figure reveals some patterning in the variation of CQ with F0. Subjects with more training/experience tend to exhibit an upward change in CQ with rising F0 (e.g. F1, F2, F5) whilst those with minimal or no formal training exhibit a downward trend in CQ with rising F0 (e.g. F10-F17 and F18-F21). Amongst these data are subjects who exhibit a mixture of rising and falling CQ with F0, some in a 'V' shape (e.g. F9, F16, F17), some with an inverted 'V' (e.g. F3, F4) and some with more than one change in CQ trend with F0 (e.g. F19). Subjects F11 and F13 have a general downward trend in CQ with rising F0, but they both show some much higher CQ values in their upper F0 range. This suggests a change from a downward CQ trend with rising F0 towards a 'V' shape.

Singing ability can be developed with singing training and to a lesser extent with singing experience, but the number of years' singing training/experience cannot *in itself* be used to quantify a singer's ability, excluding as it does considerations such as those of natural talent. It does, however, provide a useful indicator. Singing ability can be viewed as position along a developmental continuum (c.f. [9] for children's singing), from those with an inability to 'sing a note in tune' at one end, to those acknowledged as having mastered the art of singing. Singing training and singing experience are just two aspects of singing development which encourage and enable movement along the continuum.

When our adult female Qx data is considered in terms of this continuum, the following trend in the Qx patterning can be observed. Singers towards the 'untrained' end of the continuum exhibit a definite falling of CQ values as F0 increases, while those towards the other end have rising CQ values as F0 increases. Thus the *tilt* of CQ values with respect to F0 appears to give some measure of position along the developmental continuum for our adult female singers. Qx scattergrams for singers with limited training/experience are indicative of a development from a downward tilt towards an upward tilt. Thus there appear 'V' and inverted 'V' shaped scattergrams as CQ in only certain parts of their vocal range is being increased at that time; these may relate to register breakpoints. (Sundberg [8] discusses 'chest', 'middle' and 'head' registers for the female voice.)

One goal of singing training is to 'cover' the register breakpoints to make them imperceptible. It is suggested ([8] and [2]) that more experienced singers keep the larynx in a lowered position to cover the tone around the breakpoints. Untrained singers tend to raise the larynx in order to attain higher pitches, in many cases producing a 'strained' sound. The smoothly rising Qx patterns exhibited by our most trained singers could be the result of keeping the larynx lowered and the pharynx open to help cover the breakpoints. The Qx patterns exhibited by our least trained singers could result from inappropriate larynx/pharynx usage, the 'V' and inverted 'V' shapes being considered as intermediate snapshots along the developmental continuum. For these singers the voice is beginning to work efficiently (rising CQ with F0) over some of the F0 range and elsewhere it is not (falling CQ with F0). The turning points in the Qx pattern thus represent voice register breakpoints. Clearly a true longitudinal study of these effects is a desirable next step in this research.

5. ACKNOWLEDGEMENTS

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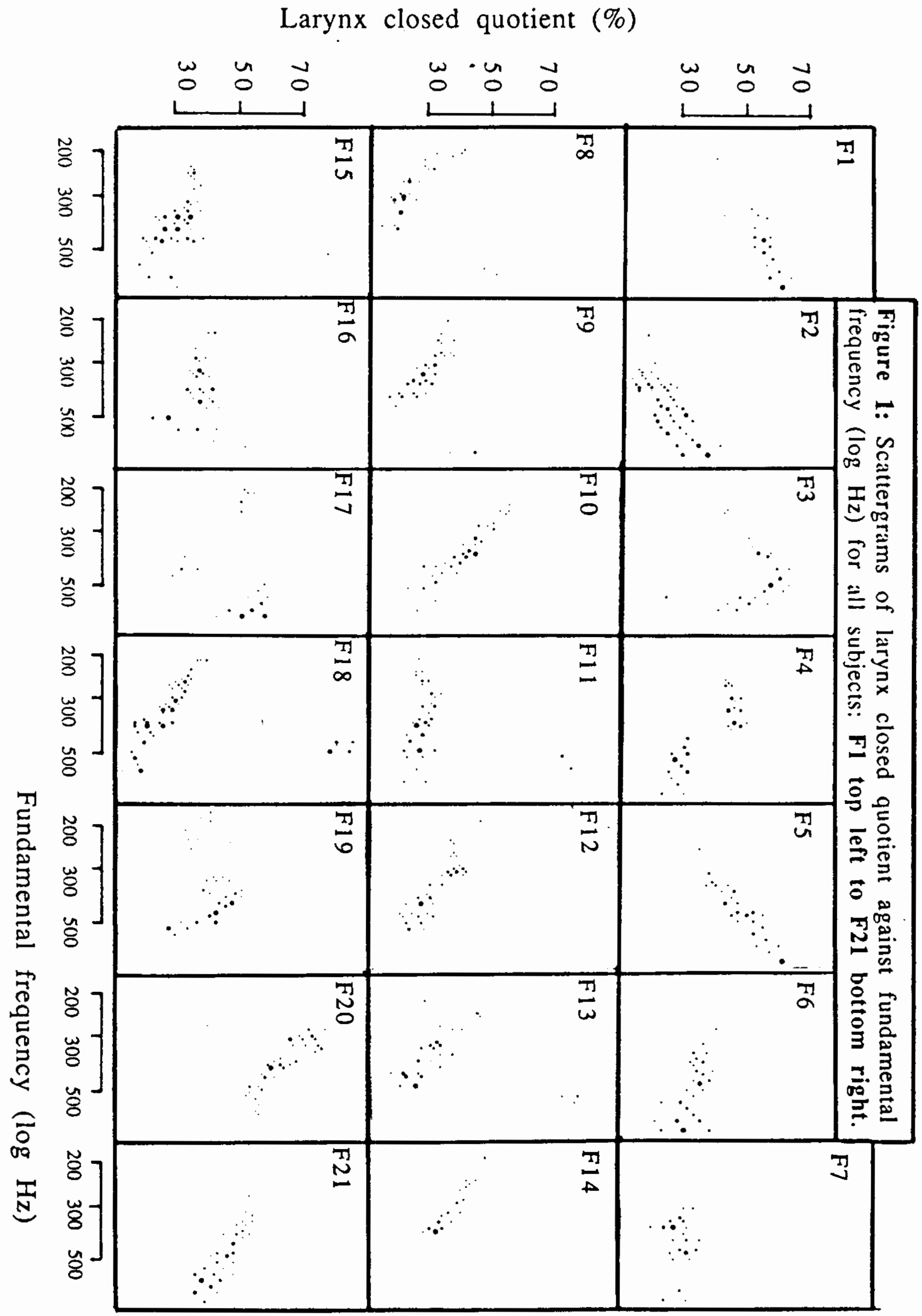

Figure 1: Scattergrams of larynx closed quotient against fundamental frequency (log Hz) for all subjects: **F1 top left to F21 bottom right.**