



Lecture 2-1: Voice Quality

Overview

1. **Laryngeal Structures.** The important parts of the larynx for voice production include the **thyroid cartilage** which surrounds and supports the **vocal folds** which are two muscular tissues joined at the front and separated at the back by attachment to the **arytenoid cartilages**, see figure 2-1.1. Through muscular control, the arytenoids can be swivelled to draw the vocal folds together across the top of the **trachea**, thereby closing off the air passageway from the lungs. The vocal folds can be changed in length and tension by movements of the arytenoid and thyroid cartilages, and the tension can also be varied by contracting the thyroarytenoid muscles that lay inside the folds. The gap between the vocal folds is called the **glottis**. The **false vocal folds** are fleshy structures above the vocal folds which do not normally take part in phonation.
2. **Laryngographic Analysis.** Because direct observation of vocal fold vibration is difficult and intrusive, we use an electrical means to get information about vocal fold movement. The **Laryngograph** (or Electroglottograph) is an instrument for measuring relative vocal fold contact area through the voicing cycle. Gold-plated guard ring electrodes are placed on either side of the thyroid cartilage, and a small electrical current is passed from one electrode to the other. The guard rings ensure that the current does not simply pass over the surface of the skin. When the vocal folds are closed, the impedance of the neck to the current flow is slightly reduced compared to the situation when the vocal folds are apart. The **Laryngograph Waveform (Lx)** shows how the current flow (contact area) changes with time. From the Lx waveform individual phonation cycles can be seen, and the individual phases of that cycle can be inferred, see figure 2-1.2.
3. **Source-Filter Model.** The larynx excitation signal is a complex periodic signal typically rich in harmonics. This passes through the vocal tract tube and is modified according to the frequency response of the tube to emerge as speech sounds. Note that the tube only changes the amplitudes of the harmonics, so never affects the pitch of the sound. However the excitation spectrum changes with larynx settings, see figure 2-1.3.
4. **Voice Qualities.** In **Modal** or normal voice quality, the vocal folds are approximated so that they completely cover the airway. They are also tensed to some degree which sets a fundamental frequency value toward the centre of the range for the speaker. Air from the lungs forces the folds apart and air flow builds up between them. There are two forces which pull the folds back to their central position: the natural elastic qualities of the folds themselves and the **Bernoulli effect**, which causes a reduction in pressure inside a constricted fluid flow. As these forces pull the folds together, the air flow increases in velocity which increases the reduction in pressure caused by the Bernoulli effect. Eventually the folds 'snap' together, cutting off the flow. This 'snap' causes a sudden reduction in pressure immediately above the folds, and it is this reduction which is the main source of energy for vocal tract excitation. Once closed, the cycle repeats; in modal voice the cycles are regular and the closures are complete. In **Breathy** voice quality, the folds are not fully approximated so that complete closures do not occur. This has a number of consequences: firstly that air flow continues throughout the cycle which can lead to turbulence at the glottis, secondly that the closures are less sharp, and thirdly that the vocal folds remain open for a longer portion of the cycle. In **Creaky** voice quality in contrast, the vocal folds are very tightly approximated and this can lead to cycles which are closed for a longer proportion of the cycle and which are irregular in duration. Creaky

voice is commonly found at the bottom of a speaker's pitch range when the folds are slack. A common form of creaky voice is called **Diplophonia**, where long and short cycles alternate. In **Falsetto** voice quality, the vocal folds are extremely tense and are held in such a way as that only the internal edges of the vocal folds are involved in phonation. This means that the amplitude of phonation is small and of high fundamental frequency. Waveforms, spectrograms and Laryngograph traces of different voice qualities are shown in figure 2-1.4.

5. **Variety and Pathologies.** Larynx sizes vary considerably from child to adult, with smaller vocal folds giving rise to higher fundamental frequencies. In addition the larynges of men undergo an increase in size at puberty causing an increase in the length and mass of the folds which causes a reduction in fundamental frequency. The Fx range used for normal speech is roughly 100-200Hz for an adult man, 150-300Hz for an adult woman, and 200-400Hz for a child. The larynx can also move up and down, shortening and lengthening the pharyngeal cavity. This can affect certain vowel qualities. Different individuals choose different standard settings for voice quality, for example a preference for a more breathy or a more creaky phonation style. The most common **pathologies** are **inflammation** of the folds (laryngitis) in which the swelling and mucus can prevent phonation; **nodules** and **polyps** which grow on the folds themselves and can interfere with phonation; **neuromuscular control** failure which can lead to an inability to maintain long periods of phonation; and other forms of **organic damage** to the folds or the larynx structures (e.g. cancer)

Readings

At least one from:

- Hewlett & Beck, An introduction to the science of phonetics, Chapter 18: Phonation, pp256-284. *Comprehensive description of phonation.*
- Baken, Clinical Measurement of Speech and Voice (1st edition), Chapter 6: Laryngeal function. *Covers other measurement techniques.*
- Abberton & Fourcin (1997) Electrolaryngography. In Ball & Code, Instrumental Clinical Phonetics. *Describes use of laryngograph.*

Learning Activities

You can help yourself understand and remember this week's teaching by doing the following activities before next week:

1. Write a description in your own words of the cycle of events in the larynx during phonation. Be sure to name all the structures involved and explain the role of the Bernoulli effect in shaping the pattern of vibration.
2. Research the development of the Laryngograph (otherwise called the Electro-Glottograph: EGG) and write an explanation for how it is able to monitor changes in vocal fold contact.
3. Sketch diagrams that relate a single period of a typical Laryngograph waveform to the position of the vocal folds at different points in the phonation cycle.
4. Write an impressionistic description of the sound of different voice qualities and try to relate that description to your knowledge of the way in which sound is generated in the larynx.

If you are unsure about any of these, make sure you ask questions in the lab or in tutorial.

Reflections

You can improve your learning by reflecting on your understanding. Here are some suggestions for questions related to this week's teaching.

1. What anatomical structures are involved in changing the pitch of your voice?
2. What is the Bernoulli effect? Why is it important in voice?
3. How do you change the loudness of your voice?
4. How would you describe the voice quality characteristics of "hoarseness"?
5. What is meant by "losing one's voice"?
6. What is a "frog in the throat"?
7. Why do boys' voices "break"?
8. How is singing different from talking?

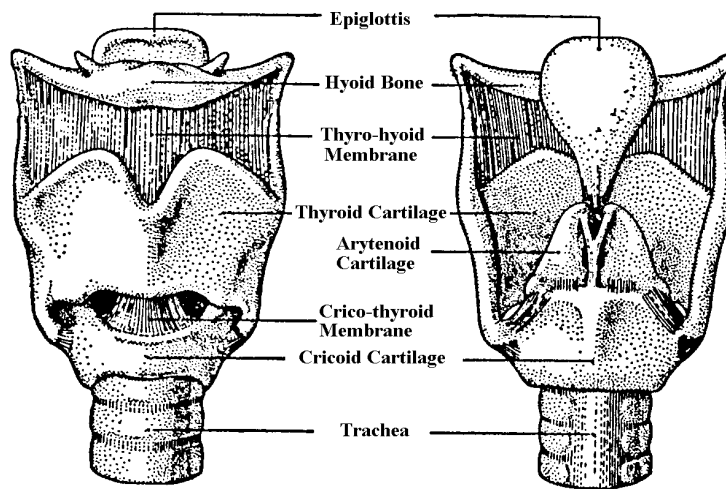
Laryngographic Analysis Problems

These are questions from past exam papers. You may like to practise writing outline answers or to discuss them in tutorial.

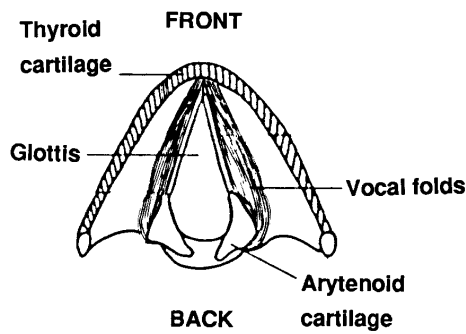
1. Describe the articulatory and aerodynamic processes in the phonation of an isolated vowel sound starting and ending with fully abducted vocal folds. What differences would you observe for a breathy-voiced phonation, and how might this difference be measured instrumentally? [2006/7]
2. Describe what changes occur in larynx settings between modal, breathy and creaky voice. Explain how these changes would likely affect measurements of closed-quotient, jitter, shimmer and harmonic-to-noise ratio. [2007/8]
3. Voice quality can be quantified using acoustical and Laryngographic means. Describe two measures of voice *regularity* and two measures of voice *breathiness*. Be sure to discuss the strengths and weaknesses of the different measures. [2009/10]

Figure 2-1.1 Anatomy

Front/Back Views of Larynx



Superior View



Vertical section and air-flow schematic

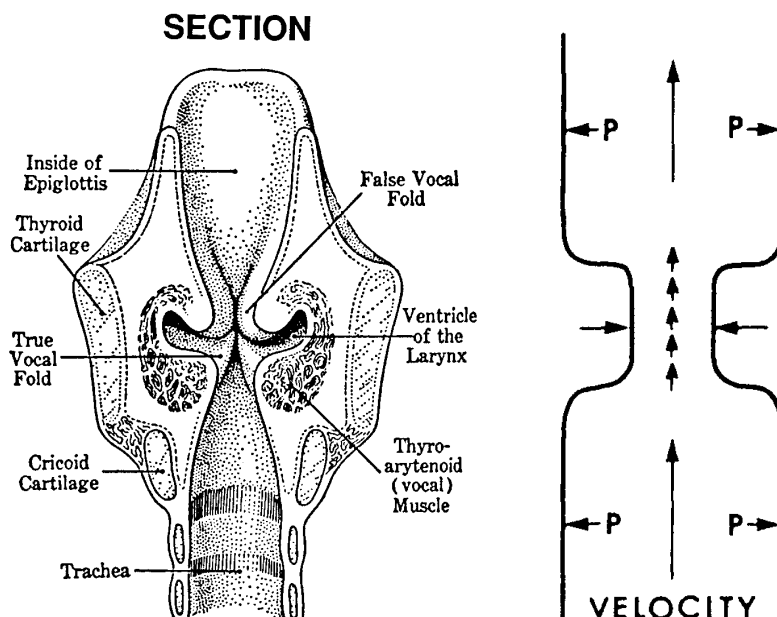
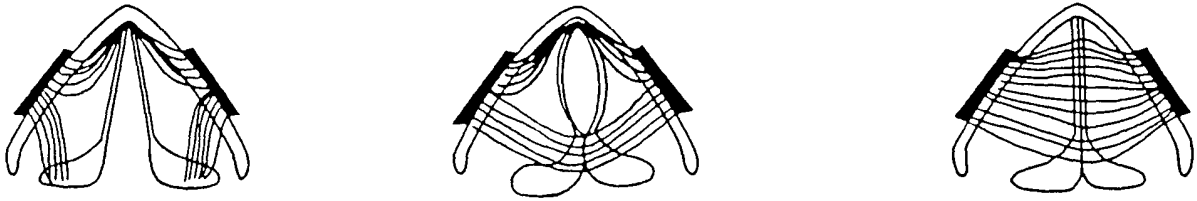
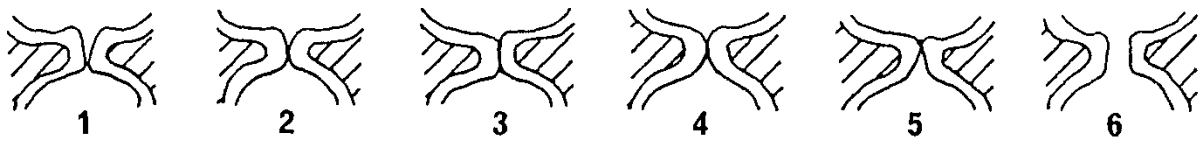


Figure 2-1.2 Laryngography

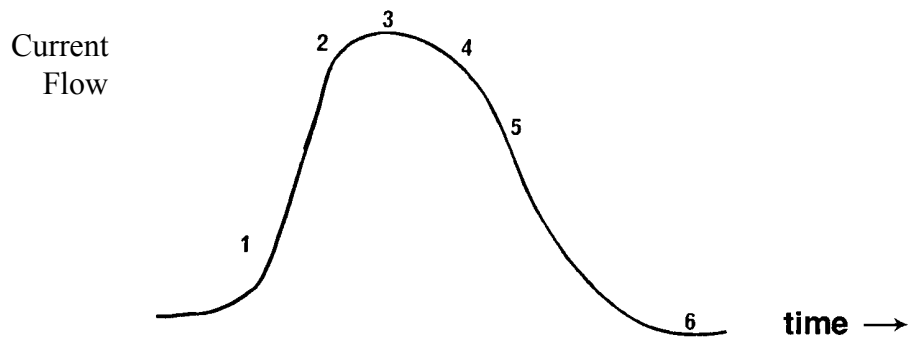
Current Flow between Electrodes



Stages in cycle of Vocal Fold Vibration



The Laryngograph current flow waveform



Speech Pressure, Lx and Flow Waveforms compared

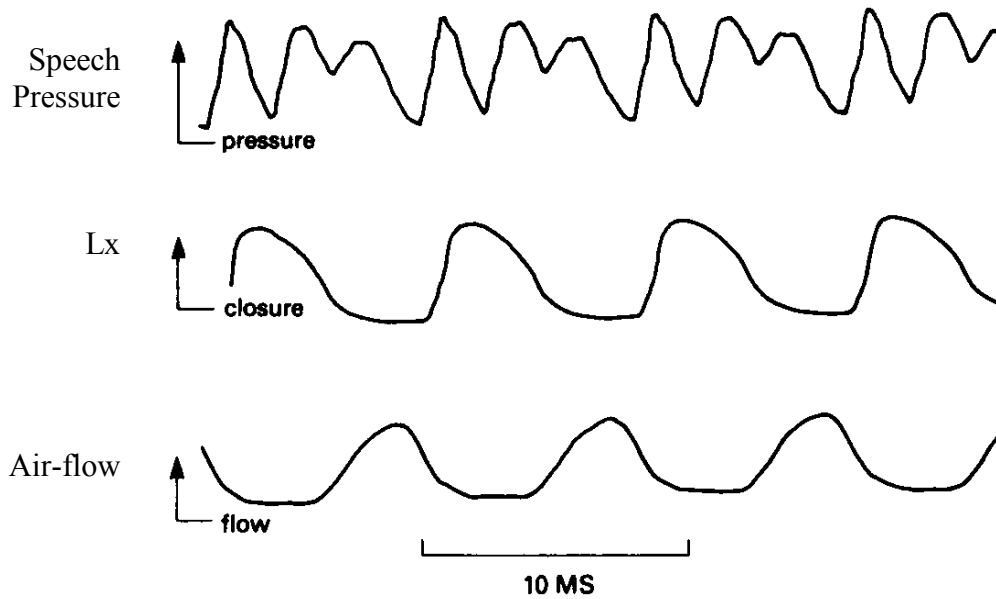
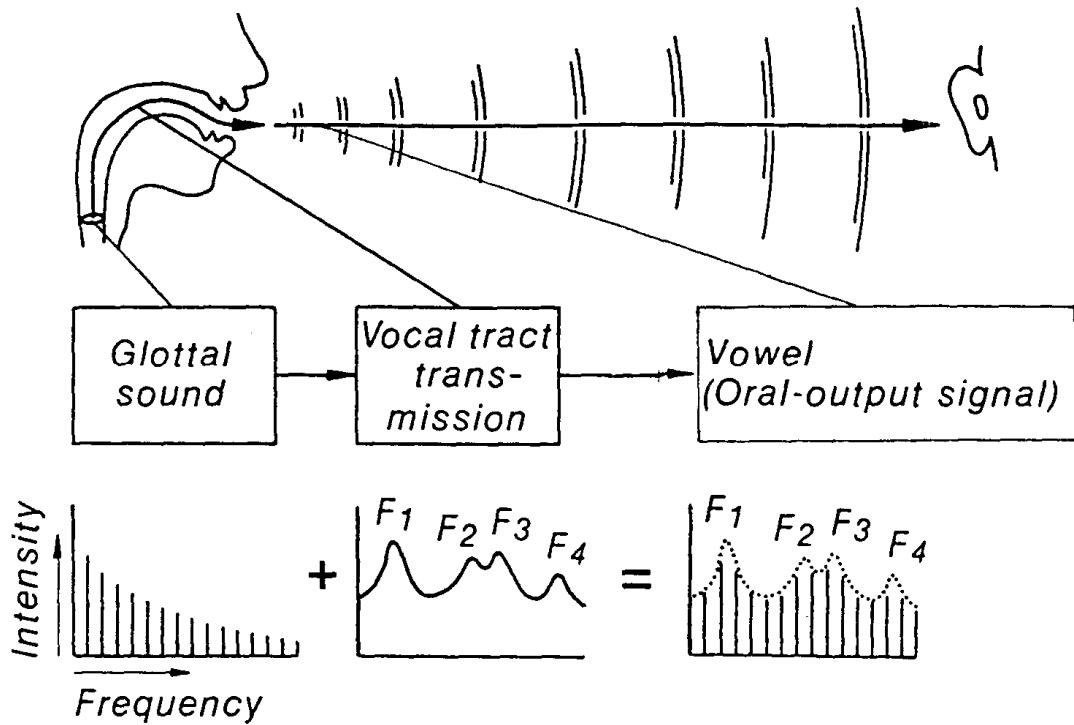
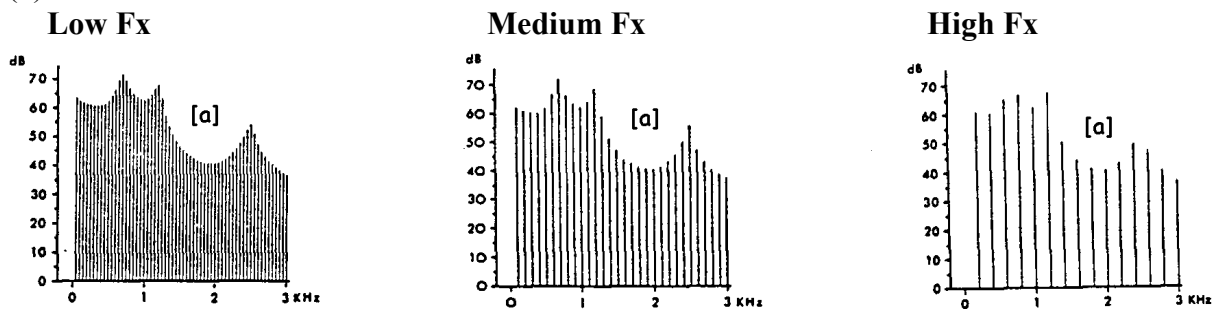


Figure 2-1.3 Source Filter Model of Speech Production

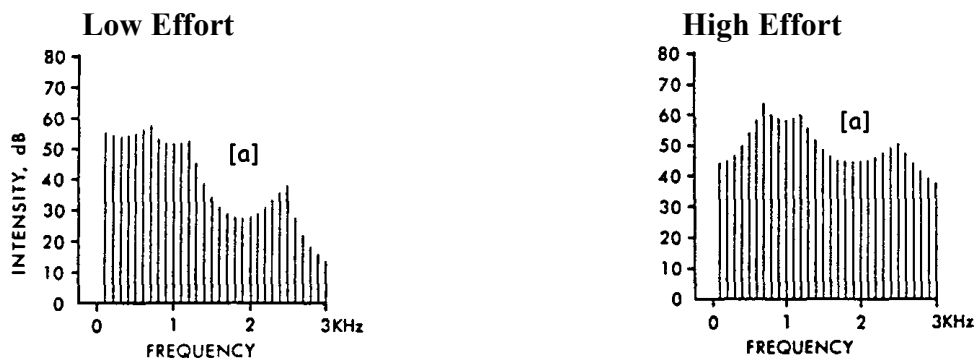
(a)



(b)



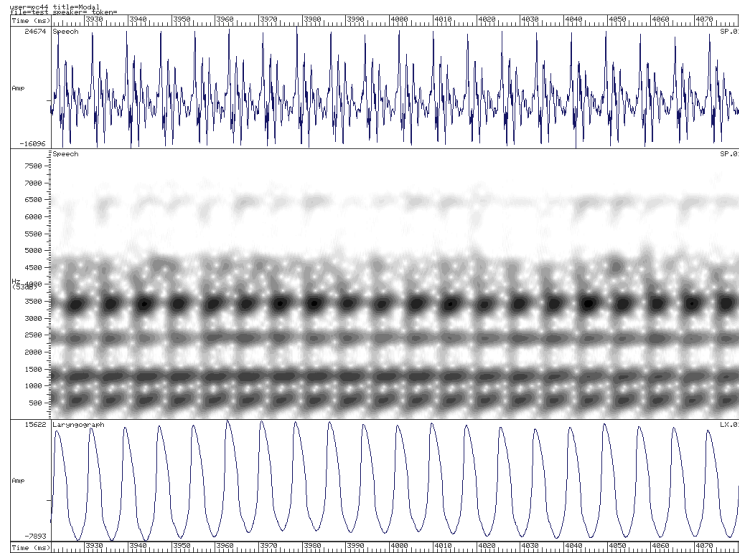
(c)



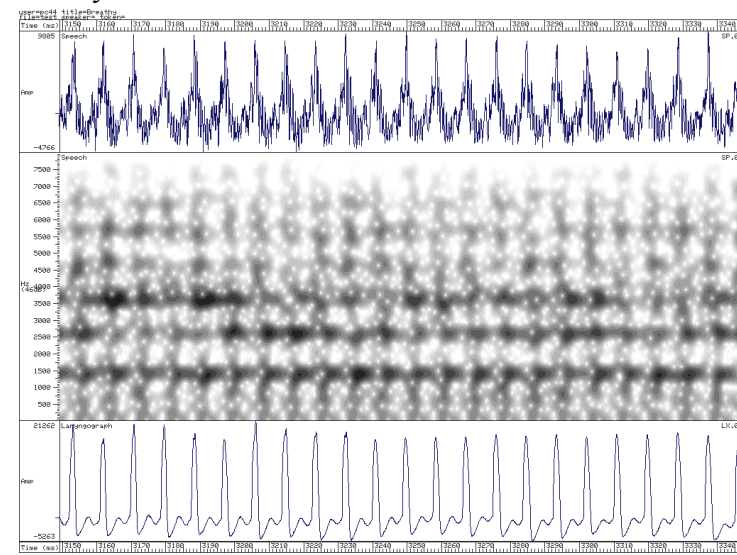
(a) The output spectrum results from the filtering of the excitation spectrum by the vocal tract frequency response. (b) Changes in the fundamental frequency of larynx vibration affects the harmonic spacing but not the location of the formant peaks. (c) Changes in voice quality or effort affects the spectral envelope of the excitation spectrum: in particular, increased effort increases the amplitude of higher frequency components in the spectrum.

Figure 2-1.4 Voice Quality Spectrograms

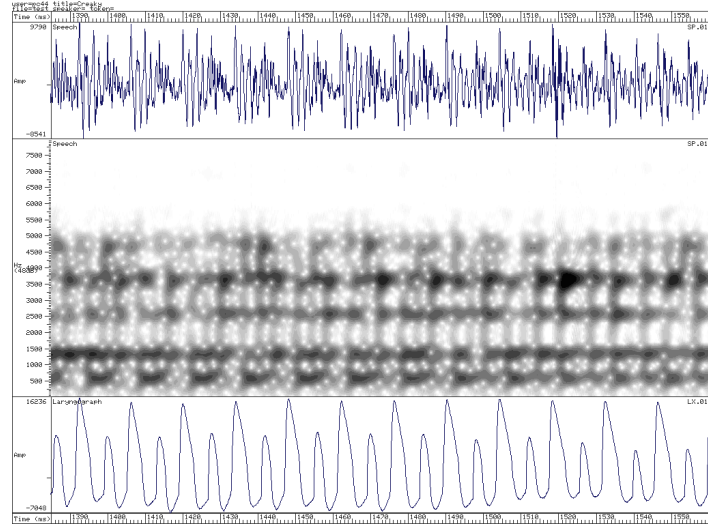
Modal



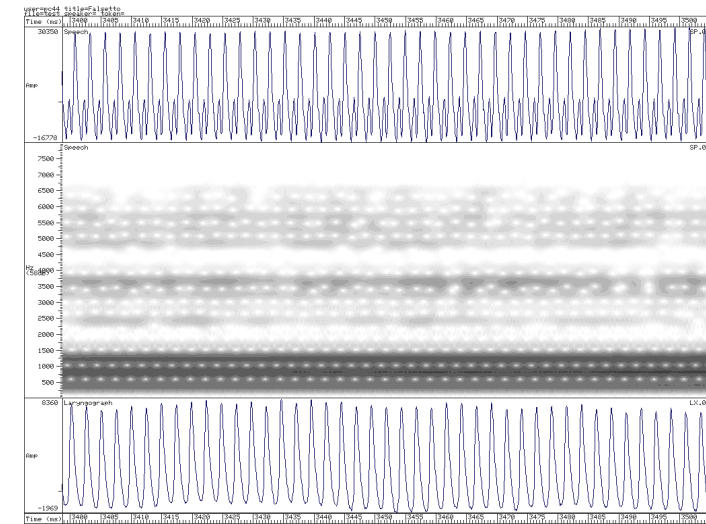
Breathy



Creaky



Falsetto



Lab 2-1: Voice Quality Measurements

Introduction

The Laryngograph provides an electrical means for monitoring vocal fold vibration. The output of the Laryngograph is a measure of vocal fold contact area, and we can study this to gain information about the *fundamental frequency*, the *regularity*, and the *closed quotient* for vocal fold vibration. These parameters are correlated with different voice qualities, with changes in the shape of the speech pressure waveform and with changes in the frequency content of the speech signal.

In this experiment you will use the Laryngograph to look at how vocal fold vibration varies among modal, breathy, creaky and falsetto voice qualities.

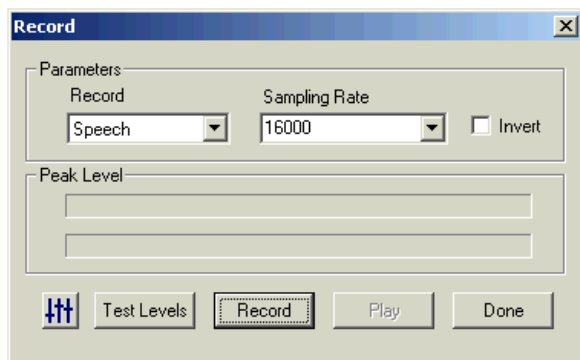
Scientific Objectives

- to determine how different larynx settings give rise to changes in the temporal and spectral properties of the speech signal

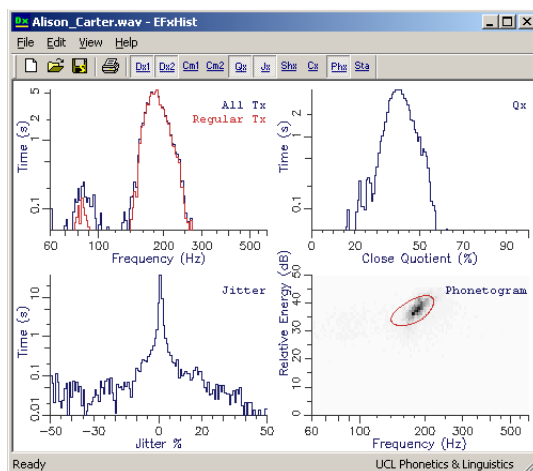
Learning Objectives

- to gain experience of one method used to assess and monitor voice (the Laryngograph).
- to understand how features of different voice qualities may be quantified
- to practise producing different voice qualities

Apparatus



SFSWin



EfxHist

The Lab PCs will be set up to acquire both a speech and a laryngograph signal using the SFS software (<http://www.phon.ucl.ac.uk/resource/sfs/>). The procedure is as follows:

1. In SFSWin select the Item | Record option and set the record parameter to 'Speech & Lx' and the sampling rate to 44100Hz. Click on 'Record' to start recording, and 'Stop' to stop. Only record a short section of vowel.
2. Save the file to the directory c:\tmp using your name for the file.
3. Use the EfxHist program to open the file. Choose the "View|Waveforms" option and select about 500ms from the middle of the vowel using the cursors. Then choose the "View|Analyses" option. On the "Analysis" menu, choose only: Qx Histogram, Jitter Histogram, Shimmer Histogram, HNR Histogram, Statistics Table.

Voice Parameters

Fundamental Frequency	Vocal fold vibration repetition frequency
Closed Quotient	% of time vocal folds are closed in each cycle
Jitter	% change in cycle duration between cycles
Shimmer	% change in speech amplitude between cycles
HNR (Harmonic-to-noise ratio)	Ratio of size of periodic component to size of aperiodic component in speech signal

Method

Analyse your own productions of the four voice qualities on an /a:/ vowel: (a) modal, (b) creaky, (c) breathy voice, and (c) falsetto. Record your results in a table with these headings:

Voice Type	Fundamental Frequency (Hz)	Closed Quotient (%)	Jitter (%)	Shimmer (%)	HNR (dB)

Enter your results in the class table.

Print out one good example of the speech and Lx waveforms corresponding to each voice quality. Ensure that you zoom in to about 50ms of the signal first to get a clear picture.

Observations

1. Look at the printout for modal voice. Identify the points of larynx closure and points of larynx opening on your waveforms. At what point in the larynx cycle does the main excitation of the vocal tract take place?
2. From the class results, what are typical values of the voice parameters for *modal* voice? Explain these in terms of what you know about the production of modal voice quality.
3. From the class results, what are typical values of the voice parameters for *breathy* voice? Explain these in terms of what you know about the production of breathy voice quality.
4. From the class results, what are typical values of the voice parameters for *creaky* voice? Explain these in terms of what you know about the production of creaky voice quality.
5. From the class results, what are typical values of the voice parameters for *falsetto* voice? Explain these in terms of what you know about the production of falsetto voice quality.
6. A recording of a pathological speaker has been stored on the computer in the file POLYPS; display this file, listen to the recording and look at the speech and Lx waveforms and the spectrogram. How would you describe the voice quality? Look at the jitter, shimmer and CQ statistics for individual vowels and discuss what you find.

Concluding Remarks

1. What effect do you think laryngitis would have on vocal fold vibration?
2. What speech problems would someone with no larynx have?
3. What alternatives are there to the Laryngograph for monitoring and assessing vocal fold vibration?

