

Precision Stroboscopy, Voice Quality and Electrolaryngography¹

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1. Aim

The aim of this brief overview is to introduce the use of Laryngograph voice measurement equipment and to give some examples of the newer methods of voice quality assessment that these techniques are beginning to make available. Special reference is made to the use of these methods in,

- precision stroboscopy,
- the analysis of connected speech,
- and in regard to their auditory relevance.

2. Background

The term “Electroglottograph” – or EGG for short, has become a generic name for a simple electrical method for the non-invasive examination of vocal fold phonatory vibration. The apposition of two electrodes on the alae of the thyroid cartilage provides a circuit element which can be monitored either in terms of its impedance or in regard to its admittance.

The technique was first applied to voice work by Fabre (1957) and he used a constant current, impedance based, method of observation. He also introduced the term “électroglottographie” considering that the main information derived from the device was in respect of the glottal opening. In fact, however, the main information concerns vocal fold contact, and it was for this reason, early on, that the term “Laryngograph” was used (Lx is used here as an abbreviation for the resulting signal, now derived via a constant voltage, admittance based, method).

The practical importance of vocal fold contact has since been established in several ways. Direct synchronised cinematic/Lx observation of vocal fold movement with different voice qualities (for example: Lecluse (1977); Donovan, Roach and Fourcin (in Fourcin, 1974)), made it feasible reliably to infer the contribution to Lx waveforms made by contact between the opposing faces of the vocal folds. Human experiments in vivo by the interposition of a non-conducting strip within the glottis (Gilbert, Potter & Hoodin (1984)) radically established the overriding importance of contact between the folds to the Lx waveform. (Earlier work, based on electrical admittance measurements, had shown that up to 4.5MHz resistance was potentially the more important electrical contributor to the Lx waveshape than capacitance, Fourcin & Norgate (1965)). Cadaver experiments have confirmed and extended these results. For instance using an excised single canine vocal fold dynamically abutting a conducting viewing plate (Scherer, Druker & Titze, 1988) the correspondence between conductance and contact area was shown. Using excised human cadaver larynges the nature of the contact waveform as a function of some of the physical factors influencing vibration was investigated (Laukkanen, Vilkmán & Laine, 1992).

Initially, essentially only the Lx signal was presented in the form of a waveform going positive (up) for increasing vocal fold contact area (this was also Fabre’s aim, but his

¹ Reprinted from Chapter 13 of ‘Voice Quality Measurement’ (2000) Kent R.D. and Ball M.J. (eds) San Diego: Singular Publishing Group

actual waveforms were positive for increasing glottal opening). As the result of the work described above, and many other contributions, the near universal practice is now to use both EGG as well as Lx information with positive contact polarity.

In normal voice the main acoustic excitation of the vocal tract coincides with vocal fold closure and since this is a salient aspect (see Baken (1985) pp 221-227, for an excellent discussion), the Lx signal is widely relied on to provide larynx frequency information.

Even though the separate contributions of the two vocal folds cannot be established using Lx, the waveshape is also a potentially rich source of voice quality information. In recent years this has led to the combined use of Lx waveform information together with laryngeal stroboscopy. A first step towards routine clinical use was made by Anastaplo and Karnell (1988) so that both synchronisation and waveshape came from an Lx signal source.

A logical extension of this approach is to use a clinical desktop computer to control the stroboscope on the basis of Lx period to period closure information. This gives two advantages. First, the instant of illumination of the vibrating vocal folds can be automatically adjusted so that an exact sequence of stroboscopic light pulses can scan through successive periods, providing precision vocal fold images in the computer memory for immediate subsequent animation/examination. Second, a longstanding objection to stroboscopy itself can be, in some measure, avoided by the use of these precisely defined single light flashes each uniquely linked both to a single image and to a defined point on the reference Lx waveform. Pathological voices are often temporally irregular and this variable periodicity makes it impossible with ordinary stroboscopy both to freeze a picture at one point in the vibration cycle and also adequately to interpret a sequence of images. By associating each single image with its corresponding Lx/EGG waveform these familiar stroboscopic ambiguities are avoidable. This facility has been incorporated in the LxStrobe system.

The first three figures attached have made use of LxStrobe to exemplify some of the special features of Lx/EGG waveforms for three different normal voice qualities: modal, breathy and falsetto.

Figure 1 shows a sequence of eight images uniformly spaced through one vocal fold period during the production of modal voice by a normal speaker. Each of the pictures is linked to the Lx waveform which was responsible for its illumination, and the corresponding trigger instant is shown on that waveform. The images have been automatically acquired to memory in a minimum of phonation time so, for this normal speaker, there is no observable variation in the Lx waveform across the sequence.

In modal voice, the initial closure of the folds, shown by the sharp rise in the Lx waveform, is well defined. This closure is responsible for the initiation of the very marked acoustic response in the Sp (microphone) waveform shown above the lower Lx signal (typically there is a small air path transmission delay of Sp relative to Lx). Closed phase is also well defined and this interval of contact between the vocal folds isolates the supra-glottal resonances from sub-glottal effects. The mucosal wave which is so important to normal voice production is clearly seen in the seventh and eighth strobe flash pictures.

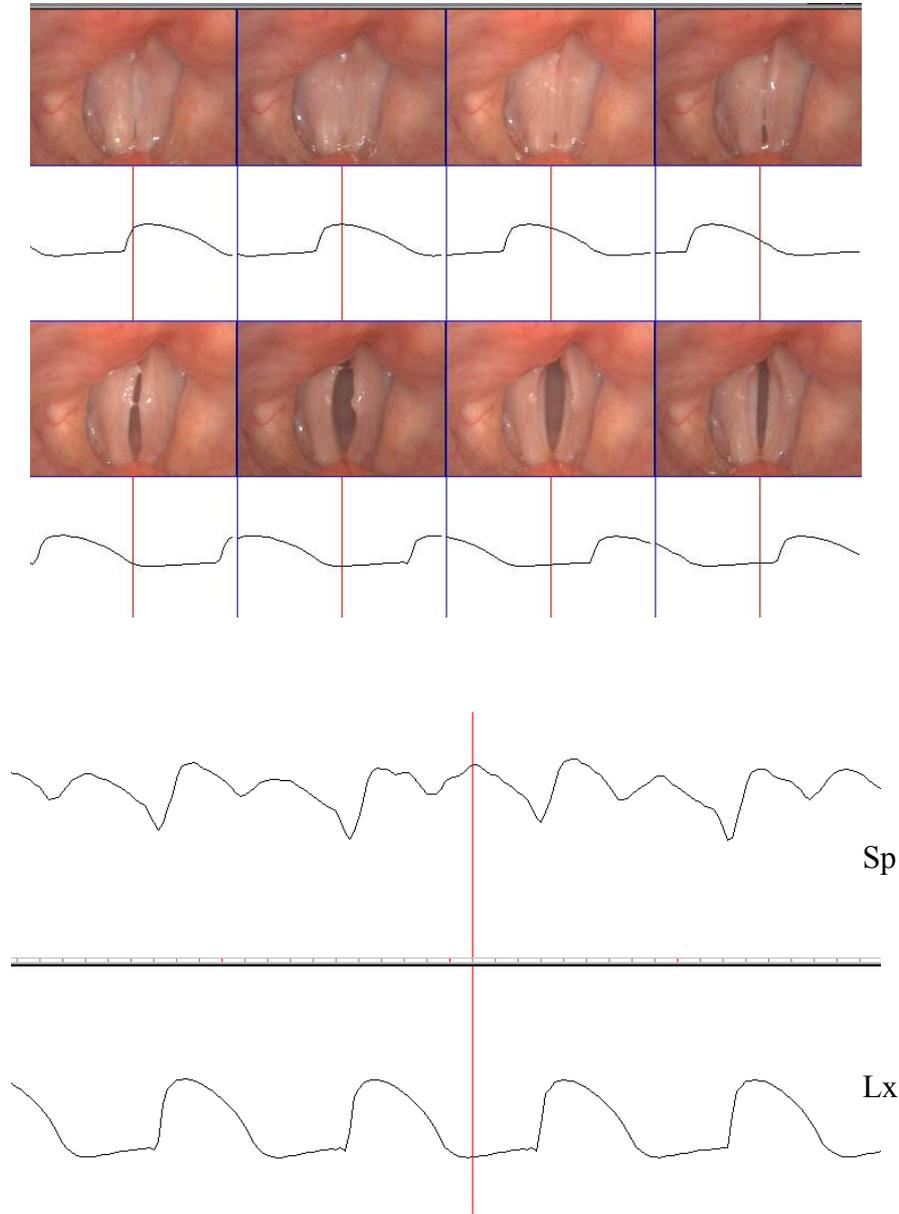


Figure 1 Modal Voice; adult male, 120 Hz

Above, a series of eight stroboscopically derived images of the vocal folds with the corresponding Lx waveform under each image – together with its trigger instant. Below, the Sp and Lx waveforms for the sixth image.

The breathy voice phonation quality shown in Figure 2 is characterised primarily by its longer open phase. This is especially easy to see both in the Lx waveforms for each of the strobe shots and in the Sp and Lx waveforms at the foot of the figure. During the open phase the supra-glottal vocal tract is coupled to the sub-glottis and, as a consequence, its resonances are more damped than for modal voice. Vocal tract resonances are also less well defined in amplitude because this voice quality is associated with a less rapid closing phase. An additional aspect of breathy voice, as its name implies, is that it is associated with a frictional quality coming from glottal turbulent air flow excitation. Although Lx is periodic this gives an auditorily perceptible component of irregularity to the Sp waveform from period to period which can just be seen in the Sp open phase intervals of the waveform figure.

The falsetto voice quality images and the speech and Lx waveforms displayed in Figure 3 show the main features of this phonation type by the length, and extension, of the vibrating vocal folds, the lack of mucosal waves on their surfaces and the somewhat sinusoidal Lx waveshape. This phonation type is also characterised by near sinusoidal simplicity of vocal fold motion. The consequently less rapid vocal fold closures give a relative lack of higher spectral components in the vocal tract excitation, and this is reflected in a correspondingly simple Sp waveform.

3. Subjective Assessment and Objective Evaluation

In many cases the original impetus to seeking a clinical check on voice function comes from the auditory observation that there is a deficiency in voice quality – made by a teacher, family, friends or in the workplace or by the speaker himself. Normality is partly subjective, it can be culturally determined (eg Moore, 1971), phonetically defined as a function of the language environment (eg Maddieson, 1984), or simply exist in the ear of the particular listener (eg Aronson, 1985). Kent (1996) regards the clinician as the final arbiter and in modern society this must be largely the case, at least administratively, since final outcome measures depend on demonstrable results which can only come from appropriate clinical investigation.

Auditory assessment is intrinsically difficult to administer in standard, repeatable fashion and a number of clinical multi-dimensional scaling approaches have been evolved to objectivise auditory subjective methods. Well known examples are: the GRBAS scale from Japan (Hirano, 1981) and its extended form recently developed and applied in Europe (Dejonckere, Remacle, Fresnel-Elbaz et al); in Sweden, Hammarberg & Gauffin (SVEC, 1995) have worked on another comprehensive set of clinically relevant voice descriptors with special reference to perception. Laver (1991) has introduced a phonetically motivated set of dimensions, which, however, add further to this real dilemma by confounding voice, in the sense of vocal tract excitation, with attributes of the vocal tract setting. All these approaches suffer from the unresolved problem of providing links between the levels of auditory description used and the levels of objective analysis and measurement which it is convenient and possible to apply clinically.

The auditorily based methods of voice quality assessment aim to give a basis for quantification and they have the great advantage that they are applicable to connected speech. The main techniques of objective evaluation, however, tend to be directed towards the use of sustained sounds as the foundation for their measurements. Prominent examples are the CSL system (Kay Elemetrics, Computer Speech

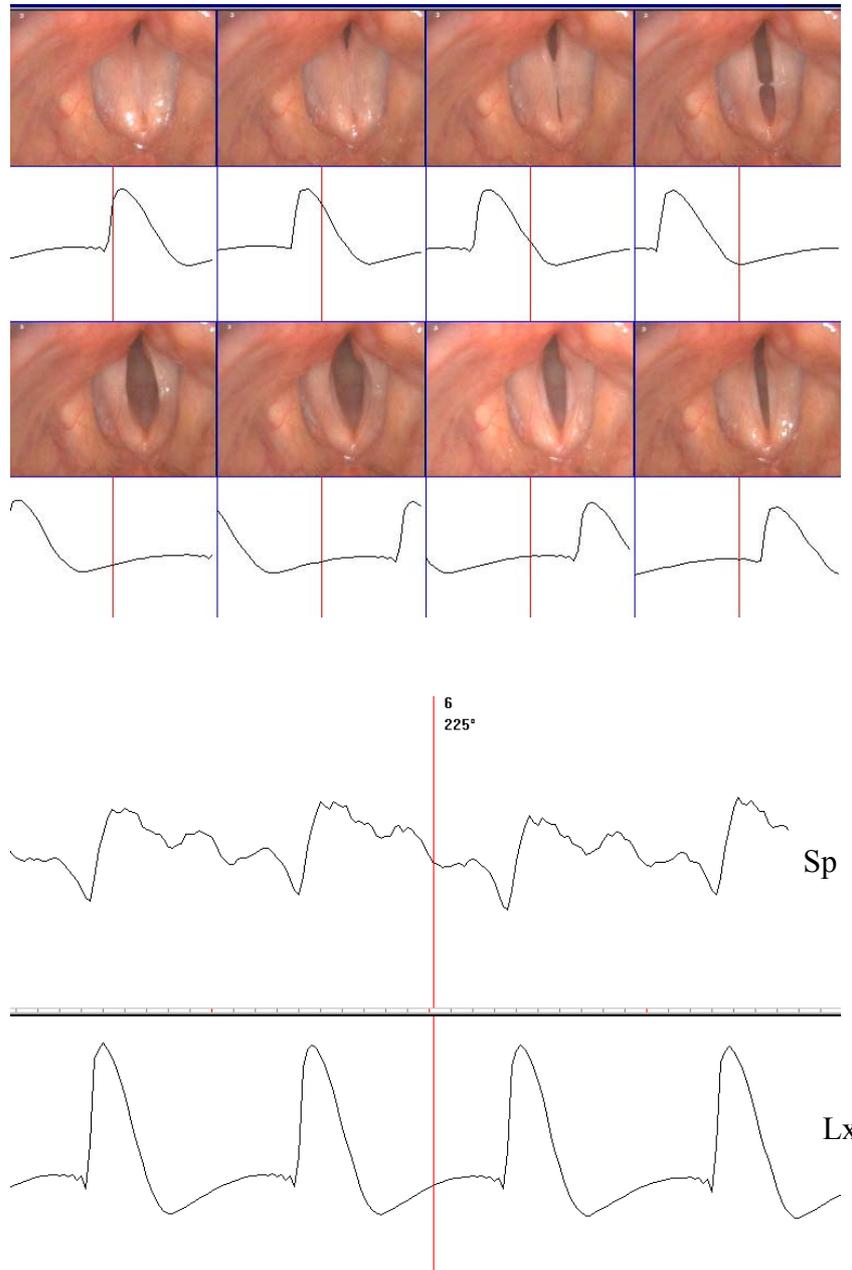


Figure 2 **Breathy Voice; adult male, 105 Hz**
 Eight stroboscopic images above, each with its triggering instant superimposed on the corresponding Lx waveform. Sp & Lx waveforms below for image 6.

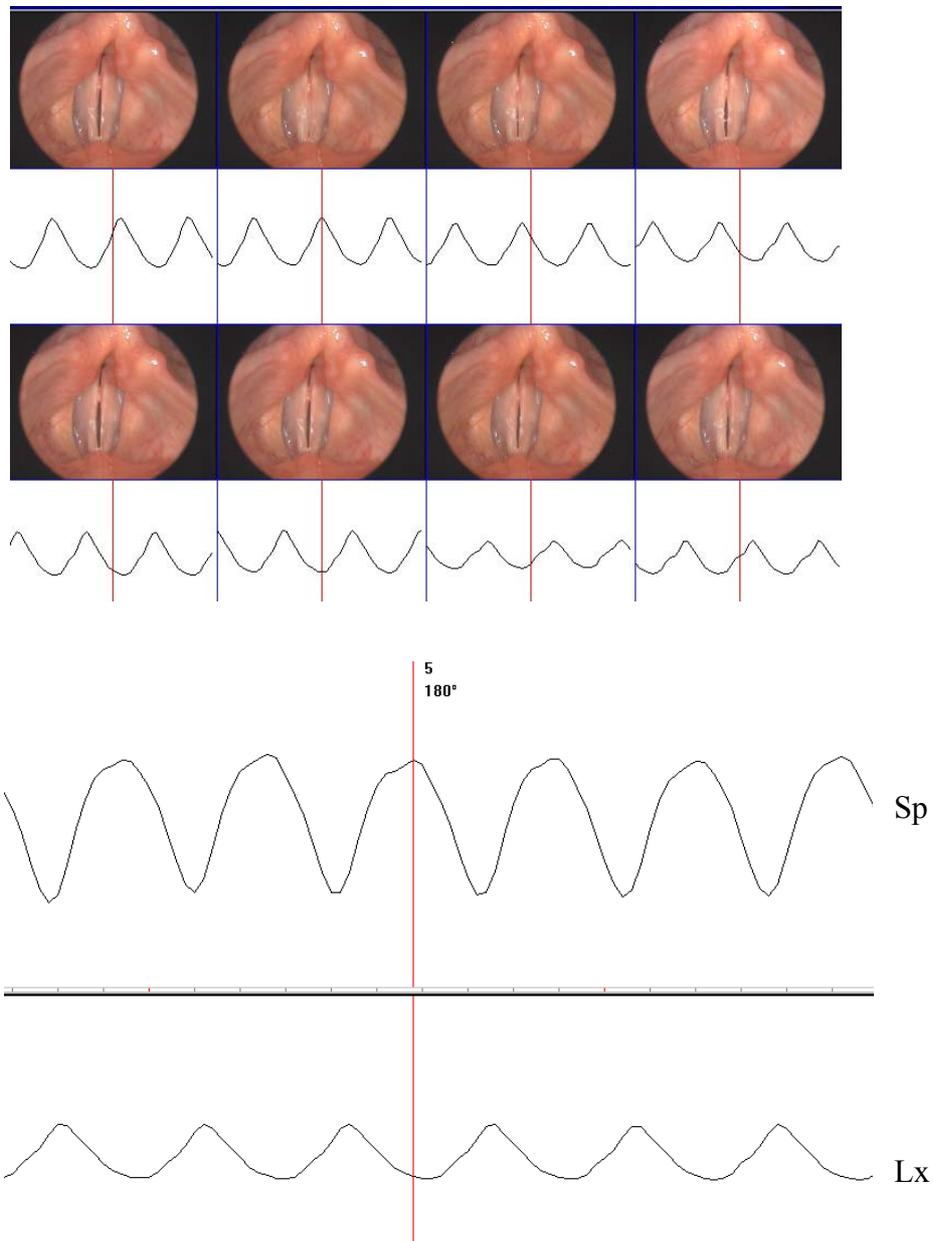


Figure 3 Falsetto Voice; adult male, 323 Hz
 Eight stroboscopic images above, each with its triggering instant superimposed on the corresponding Lx waveform. Sp & Lx waveforms below for image 5.

Laboratory) and the “Dr Speech” system (Tiger Electronics) worked on by Huang and Minifie. A possible reason for this difference may arise from the obvious need to assess connected “real-life” speech, which motivates subjective work, and the real difficulties which arise in applying rigorous signal analytic techniques to real-life clinical material (mobile telephone networks cannot even cope with some “normal” phonation).

The following examples of Lx based processing of clinically derived pathological material are intended as a contribution towards the future solution of some of the problems associated with the development of auditorily significant, rigorous methods of objective speech, and voice quality, analysis.

4. Laryngograph data and the objective analysis of connected pathological speech

[The following four sets of data were derived from Mr Julian McGlashan’s Voice Clinic at QMC Nottingham. The LxStrobe observations were in each case routinely preceded by a speech and laryngograph recording session organised by Ms Beverly Towle. In each case the connected speech sample had a duration of about 2 minutes.]

Figure 4(a) gives an open phase view taken from a sequence of eight images uniformly spaced so as to cover, within a sustained utterance, one vocal fold period, as for figures 1, 2 & 3.

The speaker is a woman of 35 years who had previously had a left vocal fold cyst removed. Subsequent to this visual inspection it was found that her left vocal fold epithelium was very adherent to the underlying ligament. Her preferred “comfortable” frequency of sustained phonation was around 300Hz, a quite abnormally high value. The use of the laryngograph (Lx) recording makes it possible to make two more complete quantitative checks. The simple larynx frequency distribution of Figure 4(b), [called Dfx1] shows that this very high pitch has been chosen because it is at the dominant mode. Although the overall shape of the distribution is grossly abnormal, the sub-mode at 160Hz is appropriately placed and shaped. It is interesting to note that in the region of 300Hz the ratio of vocal fold contact duration to period (Qx) in fig 4(c), often an indication of good voice quality, is abnormally large. In auditory terms, the two quantitative distributions are related to the subjective impression of a very hoarse, irregular voice [from Dfx1], with an unnaturally dominant high pitched component, [from both Dfx1 and Qx].

These examples of Lx based processing could not be obtained either as easily or as reliably from the acoustic signal (Sp) alone. The “instantaneous” frequency, Fx, which is measured on a period by period basis from Lx, is especially suitable for the analysis of most pathological voices. And the contact phase ratio within a single period, Qx, can be at least usefully estimated again from the Lx/EGG signal (the values used here are taken from period by period ratio estimates of Lx closure width, 70% down from each positive peak, to the instantaneous period Tx).

Figure 5(a) is from another stroboscopic larynx period related sequence, here for a man of 57 years with a voice use problem. Neither this image nor the waveforms indicate any special source of difficulty. Figure 5(b), however, taken with the folds retracted, shows a granuloma. The distribution of figure 5(c), with its marked step down above 100Hz, also shows an abnormal condition. By using the temporal accuracy of the Lx

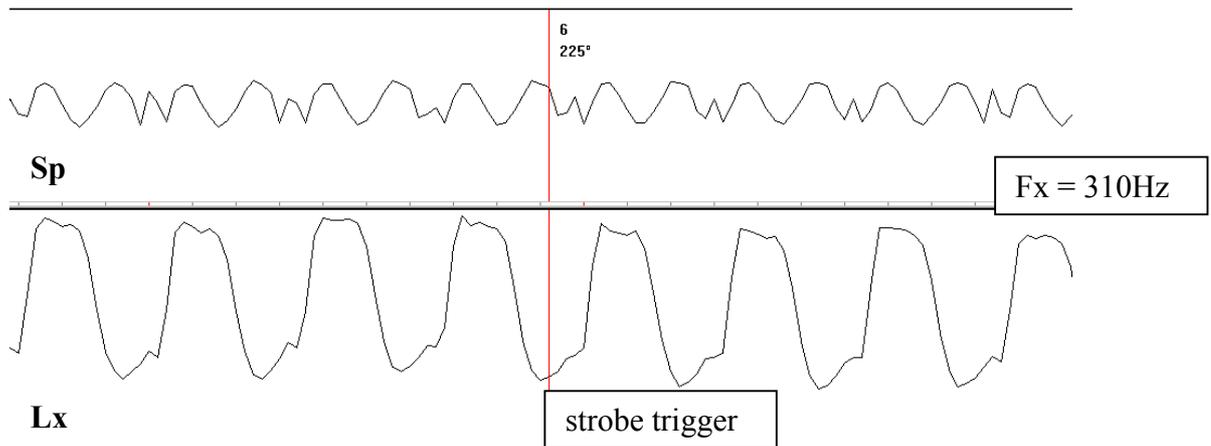
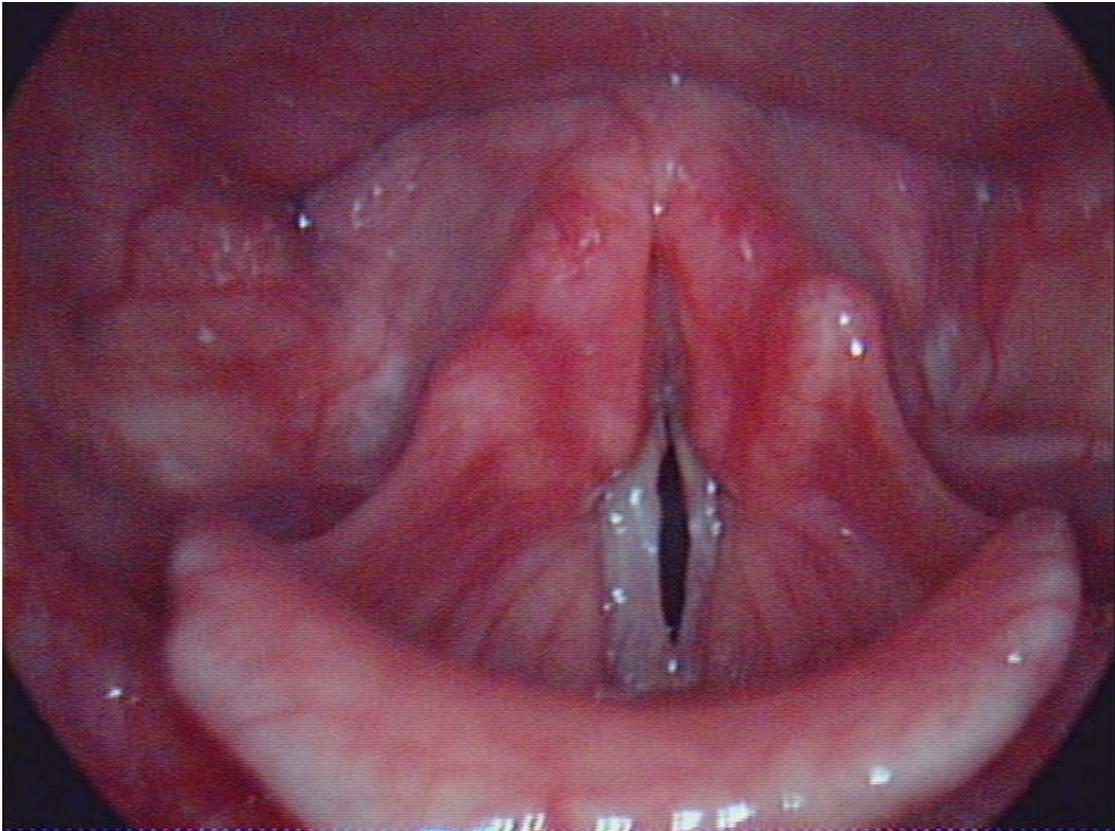


Figure 4(a) Left vocal fold scarring – speaker CW

The image shows a single shot, in the middle of the open phase, from a stroboscopic sequence using LxStrobe to cover the interval of one period. The acoustic, laryngograph, and strobe trigger (centre) signals are below.

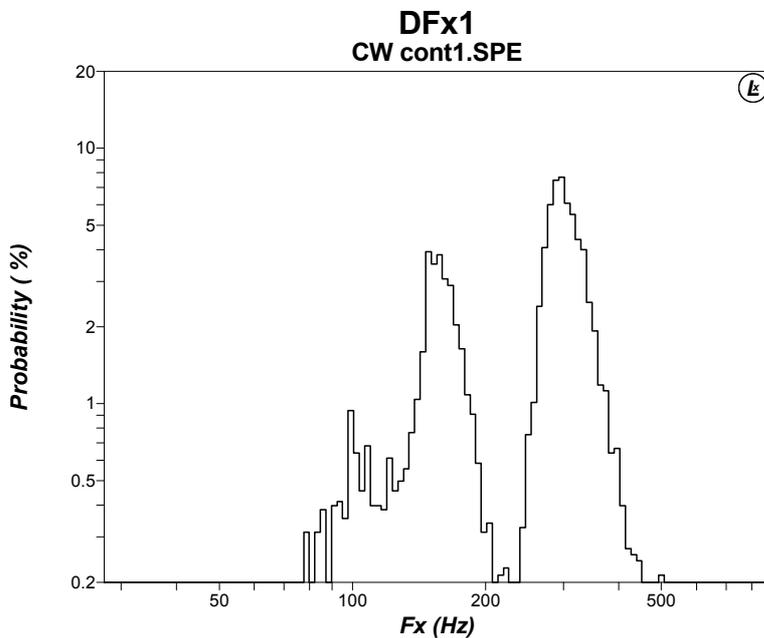


Figure 4(b) DFX1 Larynx frequency distribution
 Since the laryngograph signal makes it easy to detect each vocal fold closure on a period by period basis, even very irregular phonatory activity can be measured. The simple larynx period distribution shown here for speaker CW, has three modal peaks. Only the central mode is appropriate, the others arise from the pathology – but it is the highest which is typically chosen at “comfortable pitch”, as in the stroboscopic image.

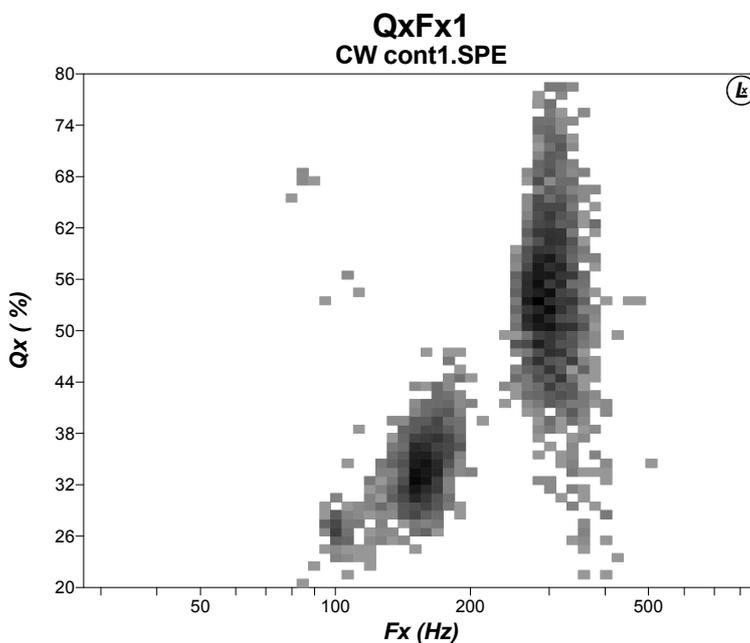


Figure 4(c) QxFx Quality Index Distribution
 Contact phase ratio is one of the indices of good quality voice production and the Lx signal can be used to give a useful indication of this parameter, Qx. The distribution on the left shows Qx plotted against Fx. The main concentration of high closed phase ratio voicing is at the abnormal mode, in the vicinity of 300Hz.

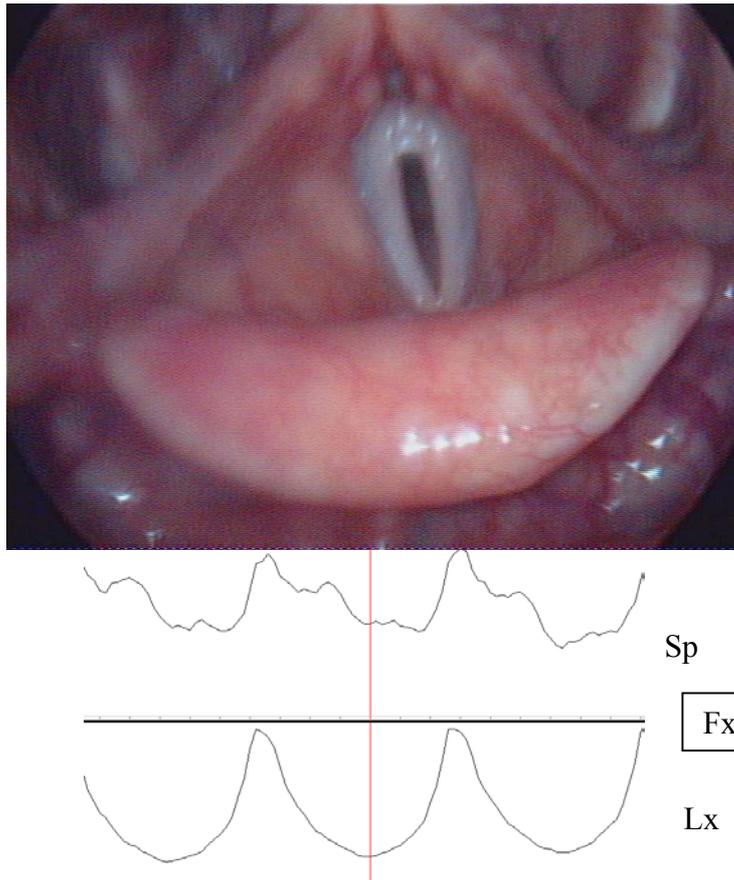


Figure 5a Speaker DC
Open phase view above; Sp & Lx waveforms and trigger for this view

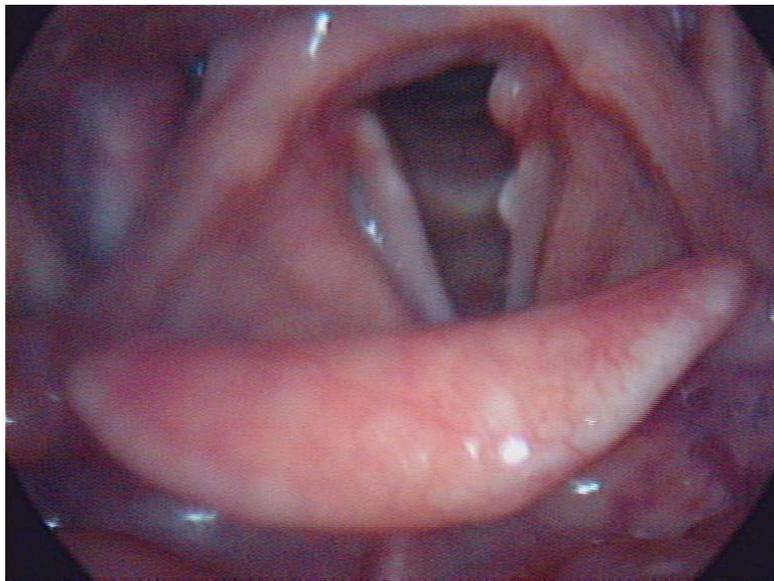


Figure 5b Speaker DC1
Granuloma of the left vocal fold process – visible during abduction
(mucus anterior to the granuloma)

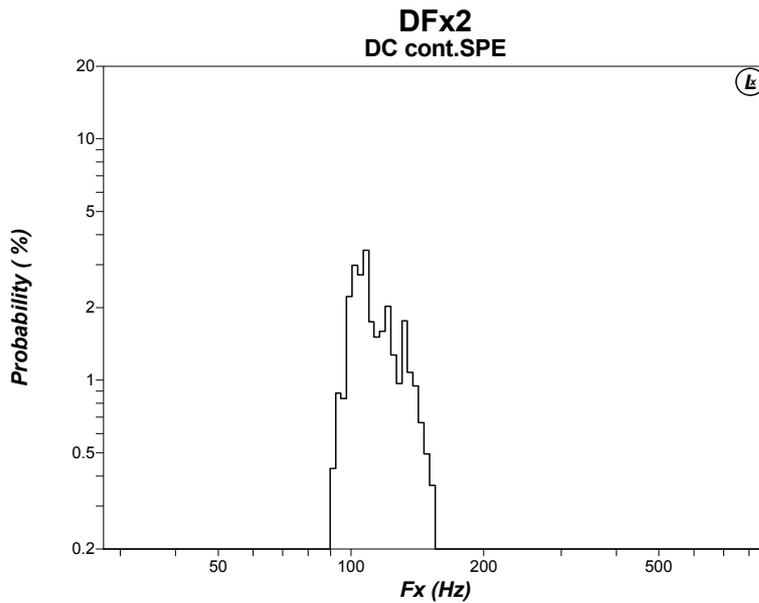


Figure 5(c) DFX2

The second order larynx frequency distribution on the left is produced by only counting the occasions when two successive vocal fold periods fall into the same Fx frequency bin. This picks up regularity in the speech sample – there is a break around 120 Hz

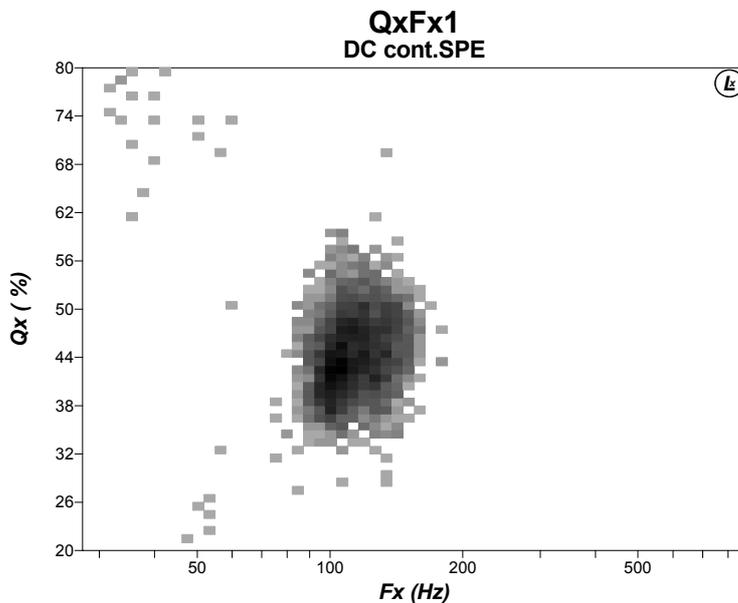


Figure 5(d) QxQx

Qx, the distribution of contact phase ratios is shown here as in figure 4(c). The speaker has an evident reduction in closed phase ratio for the upper part of his register, and this change in Qx corresponds exactly with the break in the larynx frequency distribution.

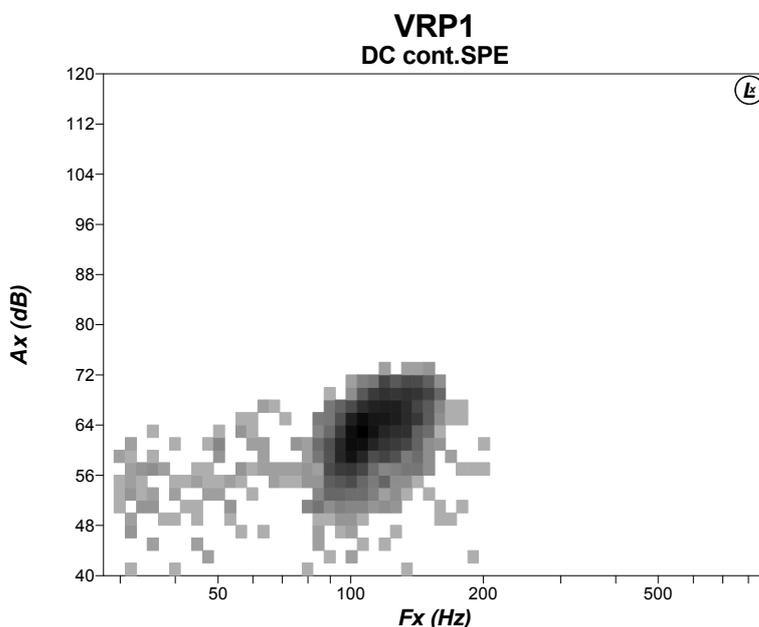


Figure 5(e) VRP1

This distribution is the familiar phonetogram but applied to connected speech rather than sustained sounds; intensity is plotted against larynx frequency, Fx. There is, however, no smoothing and the same sample of connected speech is used. This plot shows how the intensity is also reduced for the upper part of the register.

signal it is possible to produce larynx frequency distributions which seek out vocal fold vibrational regularity – here by only plotting those occasions when two successive periods have essentially the same value (DFx2). A marked reduction in regular vibration is evident from about 120Hz. Above this vocal fold frequency, the Qx distribution, Figure 5(d), is also rather broken, indicating poor closure duration control in the upper register. The control of loudness is similarly affected above 120Hz as shown by the simple connected speech phonetogram in Figure 5(e) (VRP1, in which Fx is, as above, the instantaneous frequency per period and the intensity is derived from the Lx gated acoustic peak in each Sp period). The three plots relate respectively to important subjective aspects of pitch, projection and loudness.

The single image shown in Figure 6(a) is taken from a lady of nearly 80 years with previous mild candidiasis. Her sustained voice is of good quality. Her speaking voice is, however, mildly irregular and she complains of its being of low pitch. Both DFx1 and the Qx distributions are not pathological (although the influence of age is shown by the rather ragged shape of DFx1). The third distribution, (CFx), in Figure 6(d) gives the clue to the auditory component of her voice complaint.

For normal voice (Fourcin (1979)) plotting the frequencies of successive vocal fold vibrations against each other gives a well defined single diagonal distribution – an indication of regularity of vibration. Different pathologies give different types of deviation from this diagonal. Speaker CW for instance, has a main diagonal which has three distinct parts and two outliers corresponding to the abnormal frequency modes. The present analysis shows a quite distinct type of irregularity in which over a large part of the voice frequency range there are structured departures from regularity coming from a tendency for a low frequency larynx pulse to be followed by a high – and vice versa. This voice quality characteristic, when it occurs through range of larynx frequencies, leads to the presence of three parallel lines in the CFx distribution. In the low pitch register of the voice this is often referred to as creaky voice (an irregular paired alternance of well and poorly defined vocal fold closures) but here it is spread abnormally into the higher frequencies. This effect would give an impression of roughness even at modal pitches and could account for the speaker's own auditory impression of low voice pitch in spite of the presence of a higher than normal range.

Figure 7(a) is for a male speaker of nearly 50 years with workplace induced laryngitis. His Lx waveform is abnormal in regard to its opening/open phase shape and his DFx1 (basic voice frequency distribution in Figure 7(b)) very broad. The second order larynx frequency distribution (DFx2), which picks out regularity in the voice recording, shows a core of well defined voice pitch which is at the heart of his speech. The use of the very simple technique of plotting paired regularities has been applied in Figure 7(c) to the Sp/Lx phonetogram analysis of the two minute connected speech sample in regard to both larynx period and speech intensity (on a larynx synchronous basis). This VRP2 plot shows that his speech has a core of intensity regularity as well as larynx frequency.

In each one of these four pathological voice samples, derived from connected speech, a different aspect of voice quality has been made viewable by the use of simple Lx based processing. But also in each case there is a quantitative analytic aspect of the work which gives the basis for a rigorous approach to voice quality management that can complement other clinical methods. Speech and laryngograph data files or recordings also provide a basis for comparison over time and contribute to reliable litigation archives.

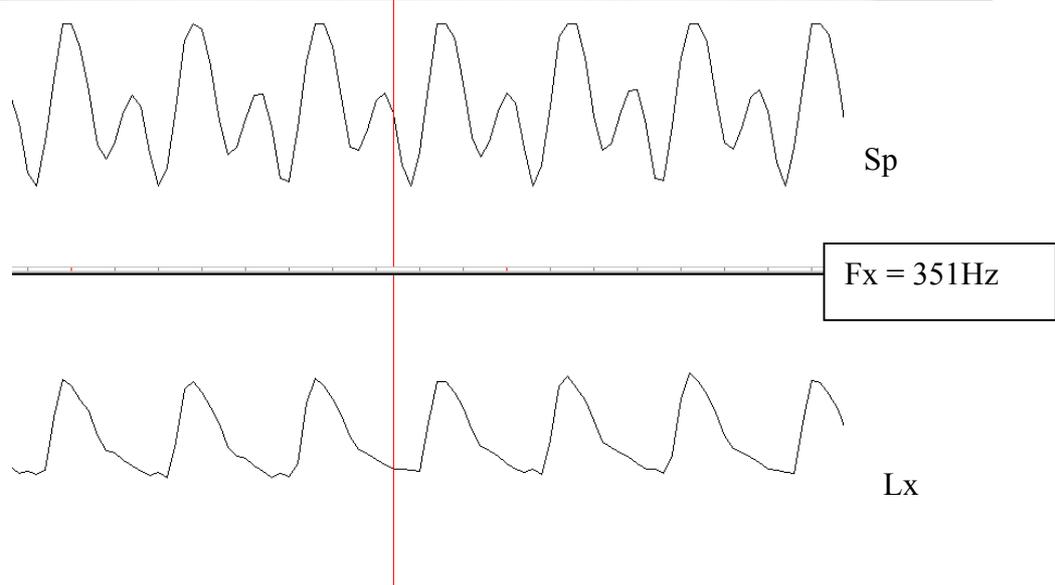
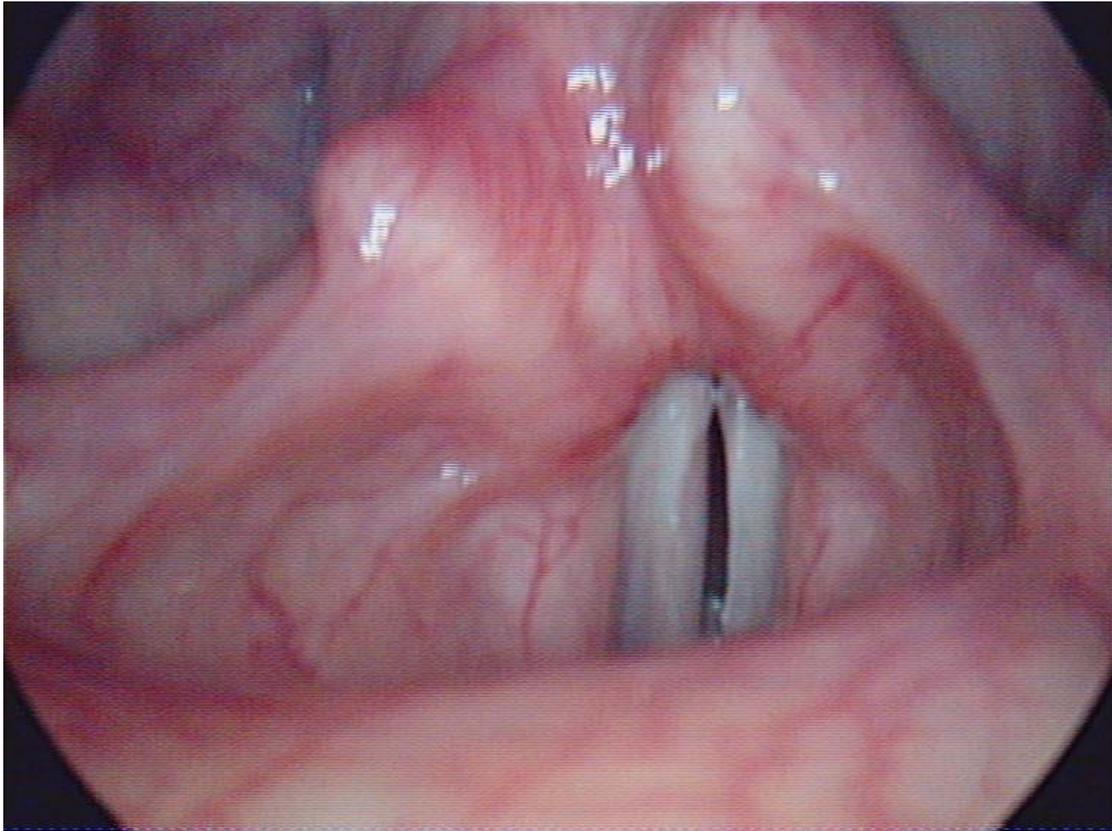


Figure 6(a) Speaker MF

An open phase stroboscopic image is shown above together with the speech and laryngograph waveforms that accompanied it and its trigger instant.

The images and waveforms show no sign of the irregularity found in connected speech

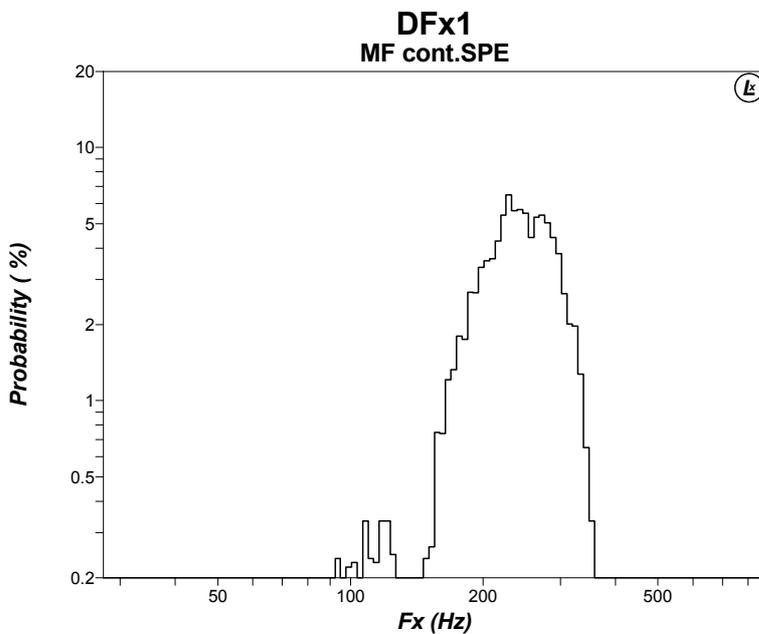


Figure 6(b) DFX1
 The first order Fx distribution is for the female voice of fig 6(a). The slight vocal fold asymmetry seen in the fig 6(a) seems to have given rise to the characteristic broad larynx frequency distribution which is often associated with mild vocal fold vibrational irregularity

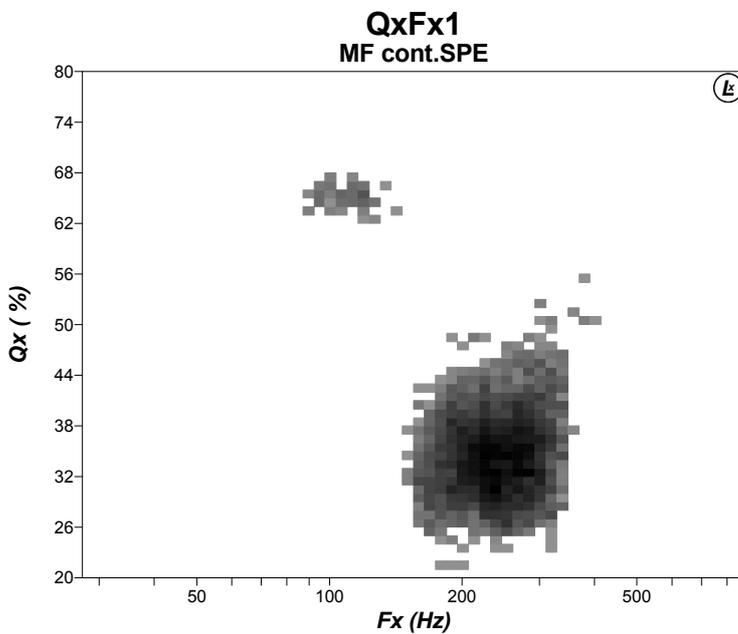


Figure 6(c) QxFx
 The heart of the contact phase ratio distribution, of Qx against Fx, is fairly well formed and shows this aspect of the voice to be under appreciable control in the whole of the centre register, even though there are outlying irregularities.

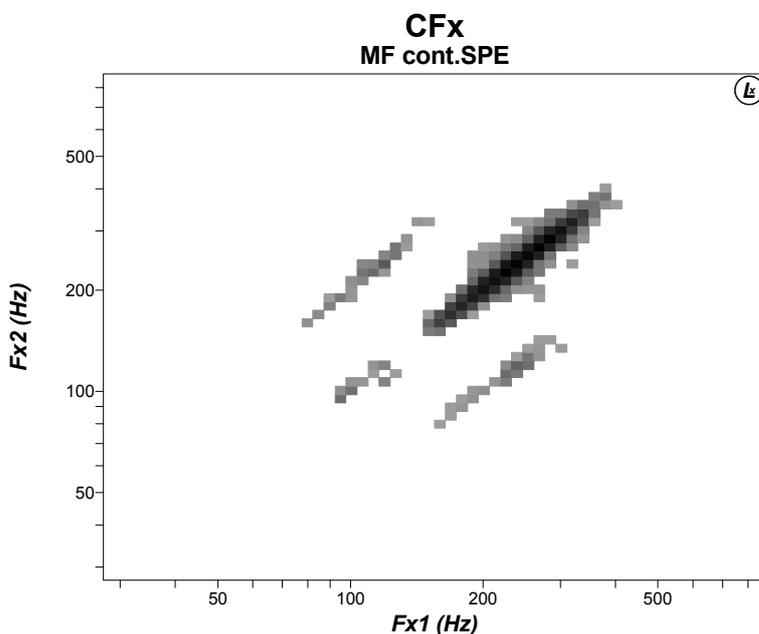


Figure 6(d) CFx
 The larynx frequency cross-plot on the left simply indicates the relation between successive pairs of vocal fold periods each of which has been analysed in the sample of connected speech. Normally only a single slim diagonal is found, but here irregularity gives three lines with a broad centre.

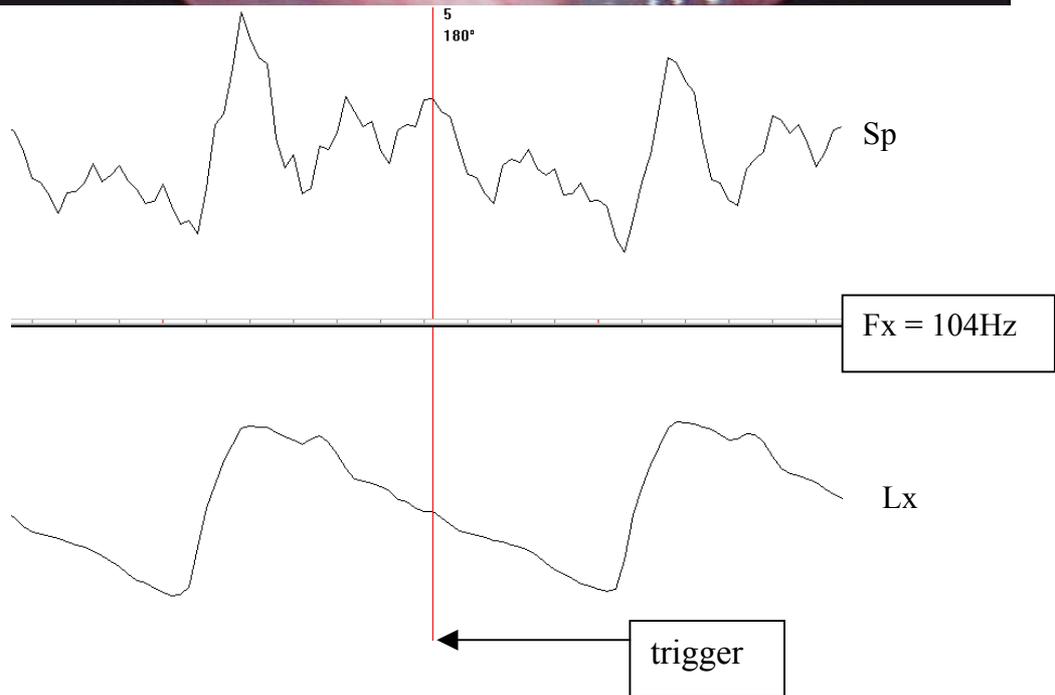
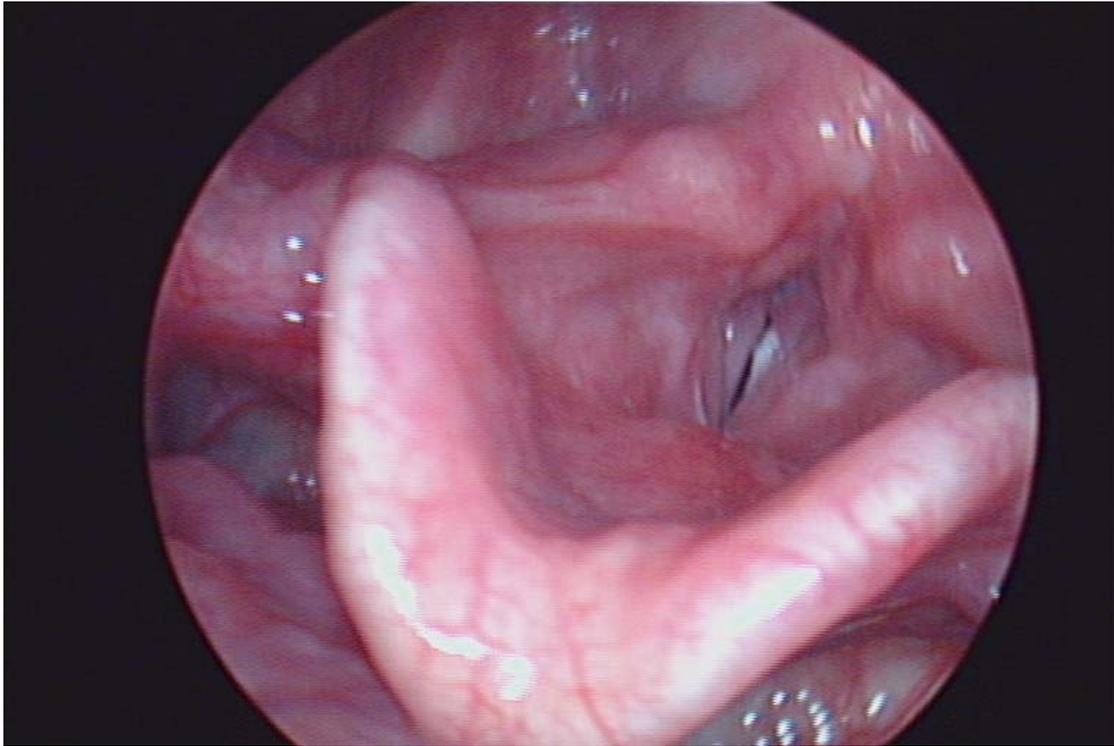


Figure 7(a) Speaker SK Acute Chronic Laryngitis

The view has been taken, as shown by the trigger marker, midway between two closures in what would ordinarily be a well defined open phase. The speech and laryngograph waveforms are at the modal frequency

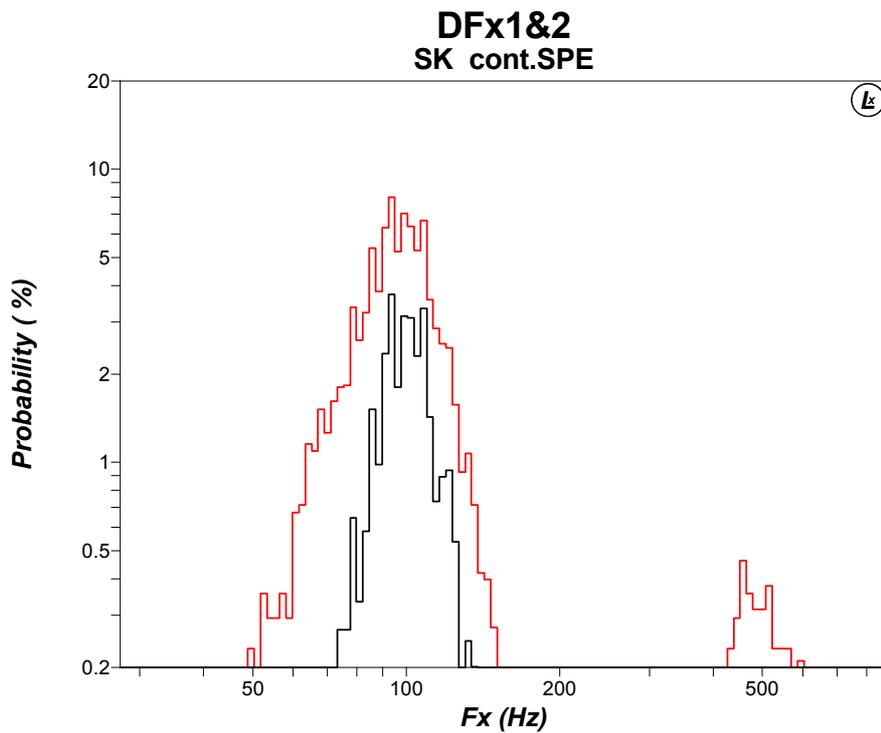


Figure 7(b)
DFx1,2
The basic larynx frequency distribution, DFx1 (red), based on a 2 minute sample of connected speech, is wide and ill-formed. The second order distribution, DFx2, using the same recording, shows by its height and shape that there is a core of well-structured voice of potentially good quality.

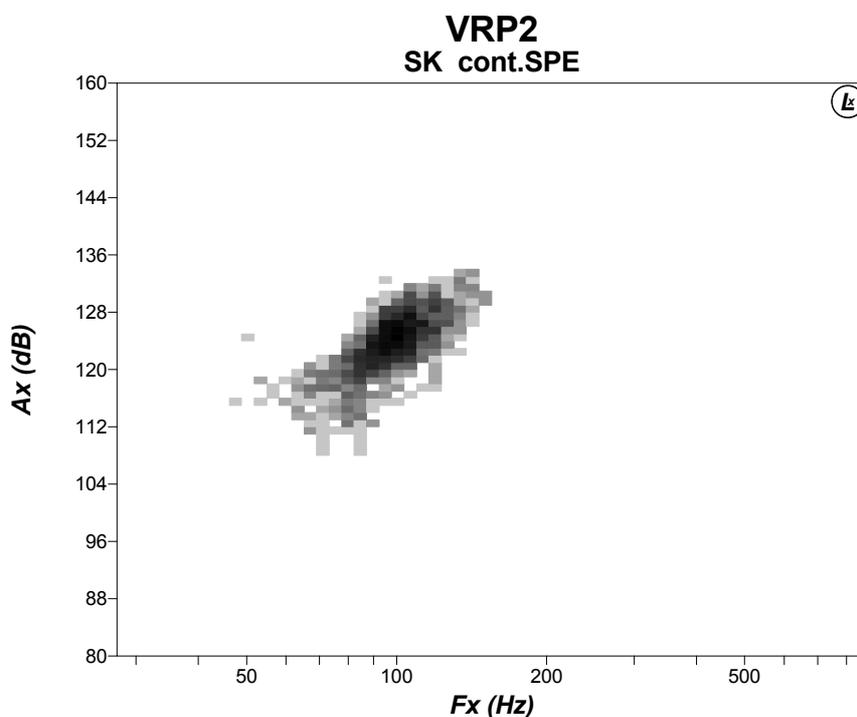


Figure 7(c) VRP2
The standard first order connected speech phonetogram for this speaker is very dispersed in both frequency and intensity. This second order phonetogram, however, which only shows those pairs of periods falling in the same Ax/Fx bin, indicates the existence of a core of voice regularity now in intensity as well as larynx frequency.

5. Laryngograph data and voice quality in the speech of the deaf

In a companion chapter, E Abberton gives an overview of work concerning the “Voice Quality of Deaf Speakers”. Her discussion covers a very wide range of important features and gives instances of the application of EGG/Lx type approaches not only in respect of analysis but also in regard to assessment, training and the design of special speech pattern element hearing aids. The quantitative methods discussed here for speech pathology are also, as she has mentioned, applicable to the analysis of the speech of the deaf. Even though the typical deaf speaker has no laryngeal pathology, the lack of appropriate auditory feedback control can give rise to abnormal voice and Lx information can be of basic assistance in its measurement, understanding and improvement via interactive training.

Abberton refers to the work of Cowie, R., Douglas-Cowie, E. and Rahilly, J. (1988) who report on work in regard to “timing, intensity range, pitch height and change, and frication”; and also to Jones, C. (1967) who uses the descriptors “tense, flat, breathy, harsh, throaty, monotone, lack of rhythm, poor carrying power”.

Lx factors can be of very great help in the investigation of many of these factors and in the following very brief discussion, the voices of two speakers are examined by applying methods which follow naturally once the Lx information is available. Both speakers are ten year old boys. **A** is normally hearing, **B** is congenitally profoundly deaf but has been educated in an intensively oral environment. Figure 8 shows particular examples of the voices of these two boys taken from recordings of their connected speech: (a) is for **A** and (b) is for the congenitally deaf boy **B** (it is important to note that **A** has read a standard text whilst **B**, who has poor reading ability has described a familiar set of pictures). In each plot the lower trace is of Fx, the period by period fundamental frequency modulated in width by the amplitude of the acoustic signal, and the upper part of each plot is the wide band spectrum of their fricatives (both voiced and unvoiced).

It is not possible to generalise on the basis of such a meagre amount of data but the figures do give a striking indication of what really does happen when, as will be seen below, much longer samples are analysed. **A** has well defined intervals of frication and good control of Fx range and voicing durations. By comparison, **B** has a tendency to produce very brief intervals of both frication and voicing.

Figure 9 shows the results of analyses of intervals of frication in long samples of connected speech for the two boys (>3minutes, two channel Sp & Lx). The striking differences between the plots of Figure 8 are now verified and it is evident that the hearing boy has frication segments which do tend to be of greater duration. Cowie et al’s reference to timing and frication effects and Jones’ comment on lack of rhythm are relevant here. In Figure 10 a similar comparison is possible between the distributions of voicing intervals in the same samples of connected speech. Once more there is a quite striking dissimilarity. **A** has much longer voicing durations than **B** and this is a quantitative reflection of many of the auditory descriptors given for voicing onset and intonation control in the speech of the deaf. In the two cases in fact the Fx ranges are very similar although the patterns of intonation control within the ranges are markedly different.

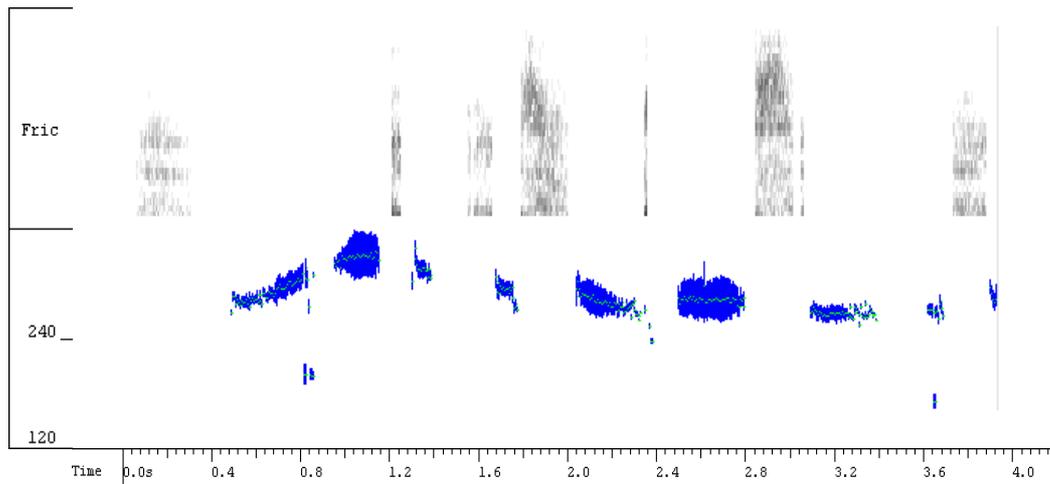


Figure 8(a) Speaker A Normally hearing boy – connected speech

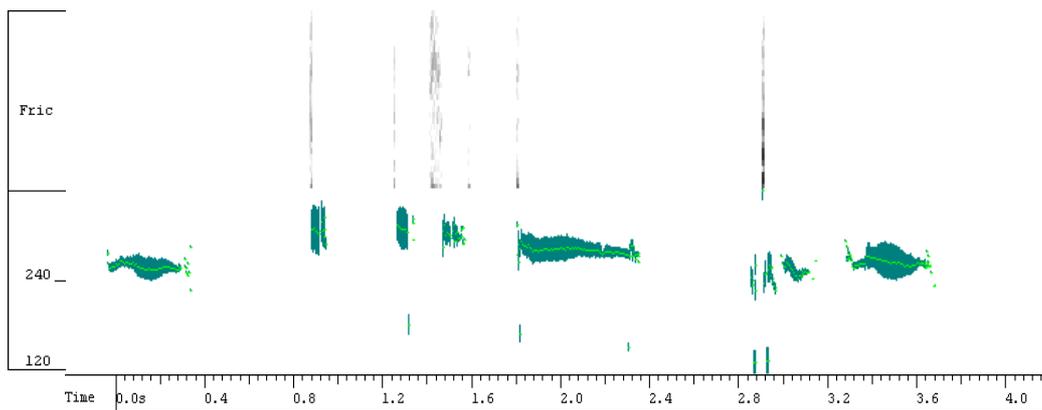


Figure 8(b) Speaker B Congenitally deaf boy – connected speech

Note:

The upper half of each trace is for frication; the lower half for voiced sounds, two octaves from 120Hz to 480Hz and 4s duration, these Fx traces are controlled in width by the acoustic amplitude for each period.

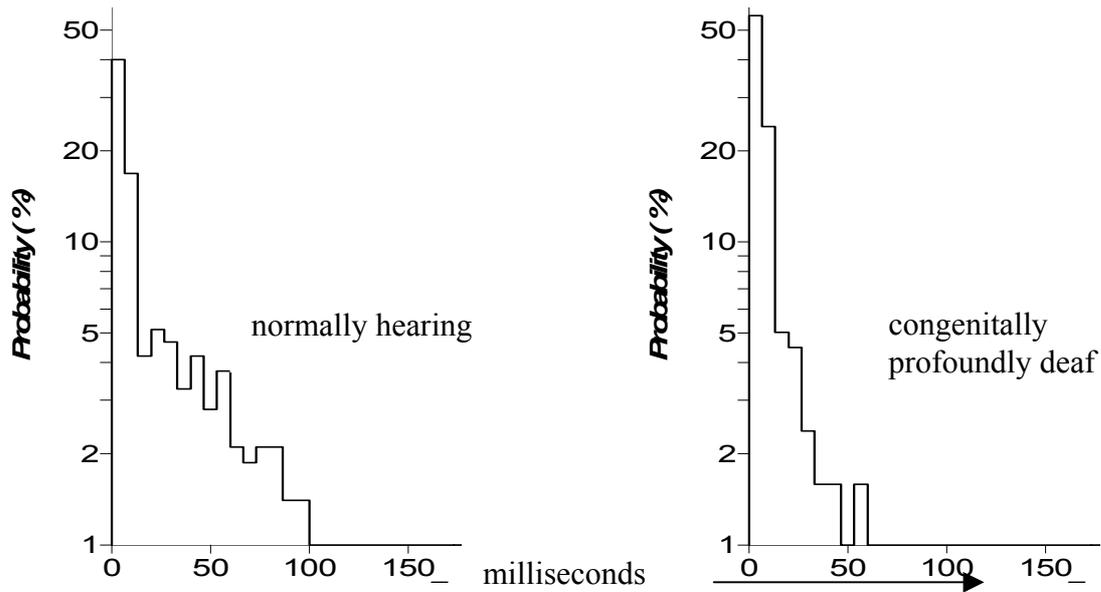


Figure 9 Distribution of intervals of frication in long samples of connected speech Speaker A on the left; Speaker B on the right

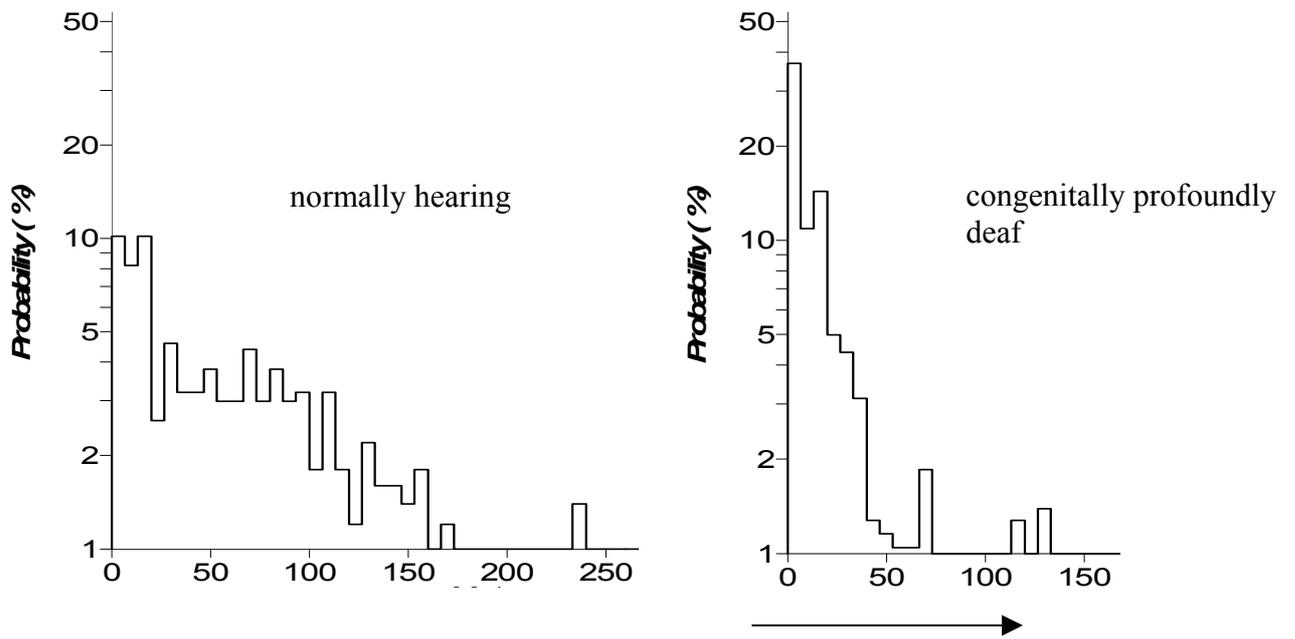


Figure 10 Distribution of voicing intervals in long samples of connected speech Speaker A on the left; Speaker B on the right

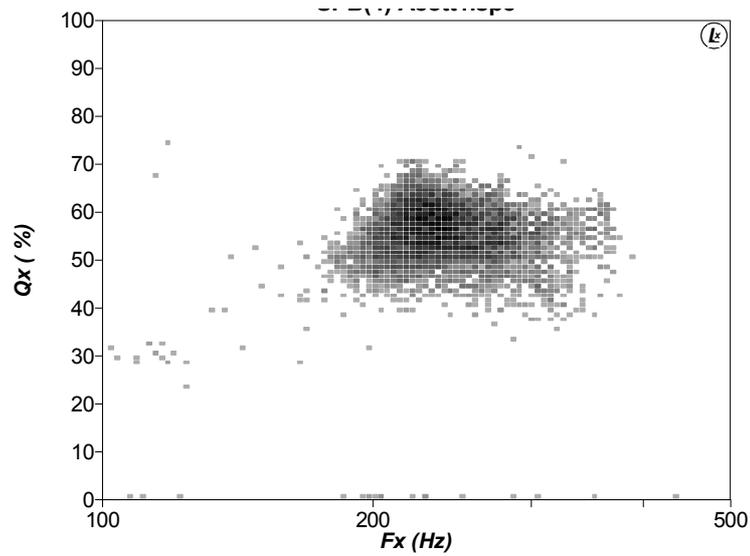


Figure 11(a) QxFx Distribution of vocal fold contact intervals
 Speaker A – normally hearing boy

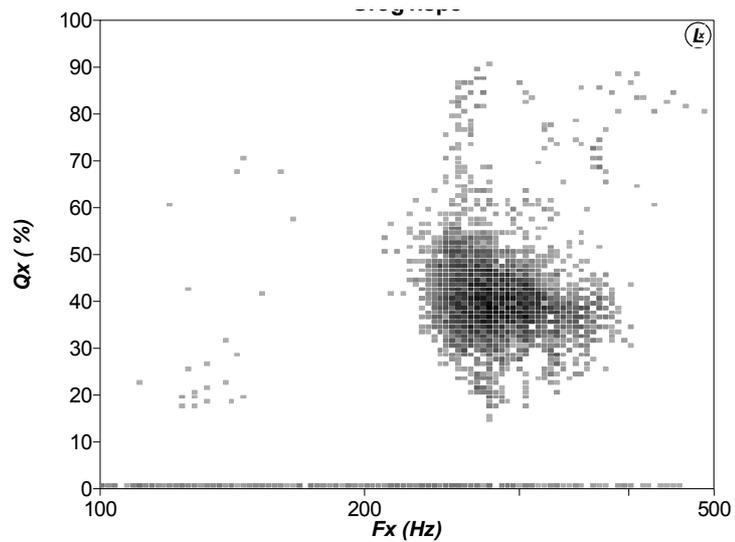


Figure 11(b) QxFx Distribution of vocal fold contact intervals
 Speaker B – congenitally profoundly deaf boy

Note the lower average value and greater irregularity and spread of Qx for the deaf speech

Finally, the important aspect of voice quality, QxFx, used for example in Figure 6(c) above for the examination of pathological speech, is measurable by analysing the distribution of contact phase intervals in the voicing segments of the two recordings. These Qx distributions, Figure 11(a) & (b), once more show that there are striking quantifiable differences between the voices of the two children. The voice of **B** has a tendency to considerably lower values of Qx – an indicator of breathy voice quality, and a smaller range of control across the span of larynx frequency. On the other hand speaker **A** is already producing a patterning of Qx control which tends (by its uniformity across Fx) to be like that of the adult male.

6. In Conclusion

The main contributions to voice quality analysis which are presently made possible by Laryngograph type approaches come from the special physical properties of the equipment and the very close relation between the signal and the processes of voice generation and control.

- Non-invasive sensing gives acceptable access to a wide range of speaker populations
- Response primarily only to vocal fold contact provides an effectively unrivalled accurate basis for larynx frequency measurement.
- Acoustic noise immunity is a special advantage for data gathering in many work environments (including the hospital voice clinic), and in the quiet this facility gives an extremely useful basis for frication detection.
- The duration of vocal fold contact is represented in the laryngograph waveform with sufficient accuracy to give a basis for closed quotient comparison.

The particular examples discussed above have tended to concentrate on the links which can be made between objective measurement using Lx type signals and the use of auditory dimensions of voice quality description. This is an increasingly important area of development. The measurement techniques described are able to provide one way of escaping from the current clinical bias towards the utilisation of data [sustained vowels for example] not so much because it is important in real life as because it is convenient in use for the investigator. The two-minute speech samples (of Sp & Lx) used are easy to obtain and representative of major speech factors such as onset, offset, register change and vocal tract/larynx interactions which are largely absent from sustained samples.

Acknowledgements

In addition to Mr Julian McGlashan and Beverly Towle and their colleagues at QMC Nottingham and Dr Elisabeth Fresnel of the Laboratoire de la Voix, Paris, it is a pleasure to acknowledge the laryngograph, stroboscopic and analytic resources which have been developed by Colin Bootle, Xinghui Hu and David Miller at Laryngograph Ltd. and used for the figures and discussions of this chapter.

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Appendix

The appendix contains nine figures which have been included in order to provide supplementary information relating to the relation between sustained vowel analyses and those, as in the main body of the text, based on connected speech.

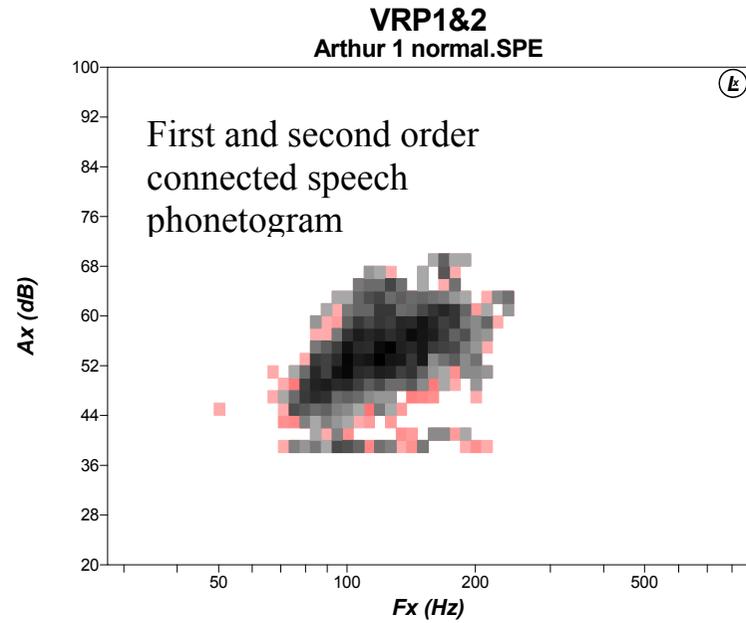
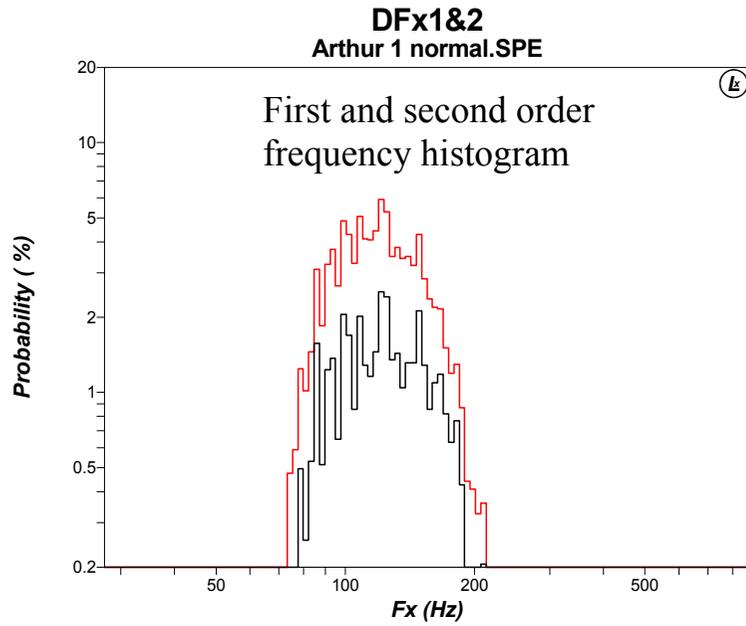
The first page of figures is for a normal man, VW. In these distributions the previously discussed analyses are here applied to this normal voice and show how very clearly defined are the basic pitch, regularity, loudness and closure ratio distributions.

The second page gives the results of analyses of a sustained vowel produced by the previously discussed patient CW; whilst the third page summarises the analyses of her connected speech. Whilst the sustained vowel analyses were not very informative the connected speech analyses give a profoundly different overview – which is of value in many surgical and therapeutic aspects of management.

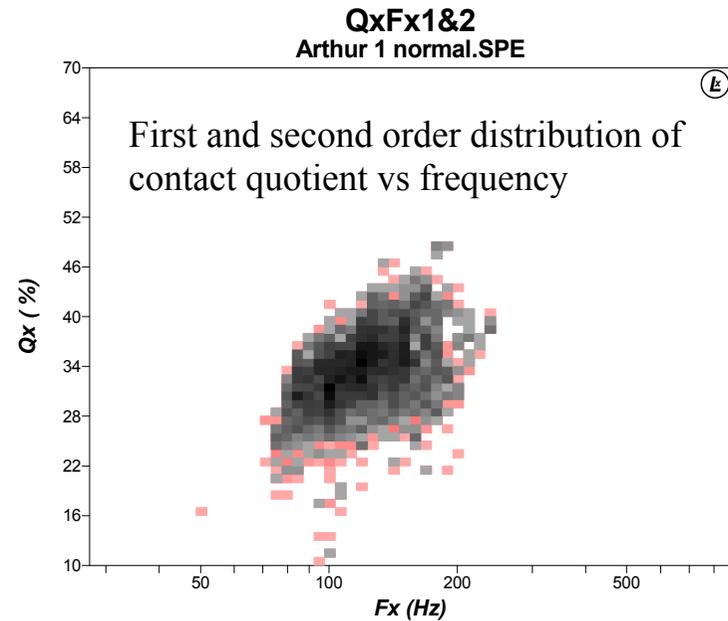
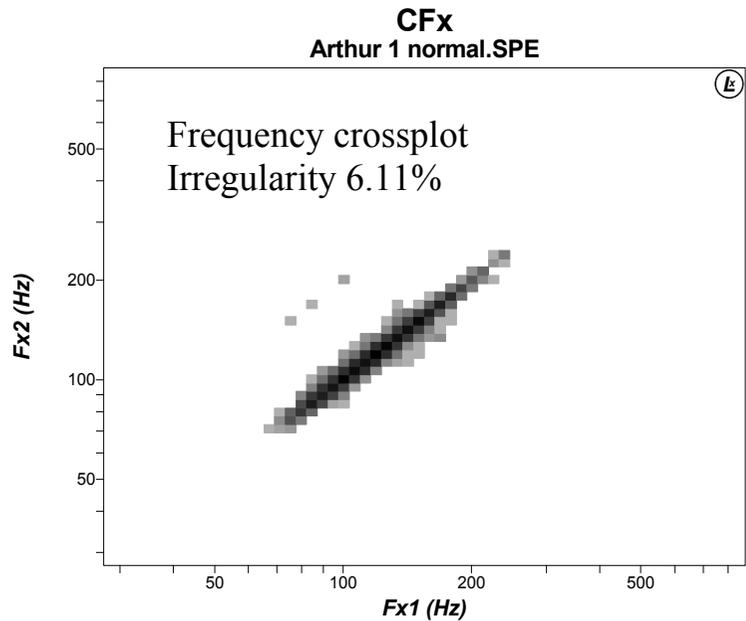
The fourth page of analyses is again based on the use of a sustained vowel but this time for patient DC. Once more in comparison with the set of connected speech analyses shown on the following fifth page the sustained sound is seen to be a poor indicator of pathology.

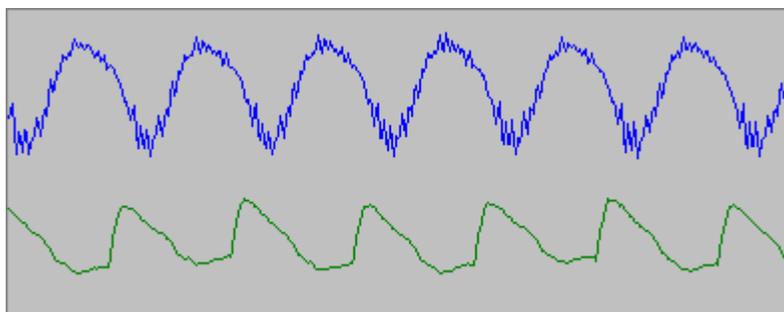
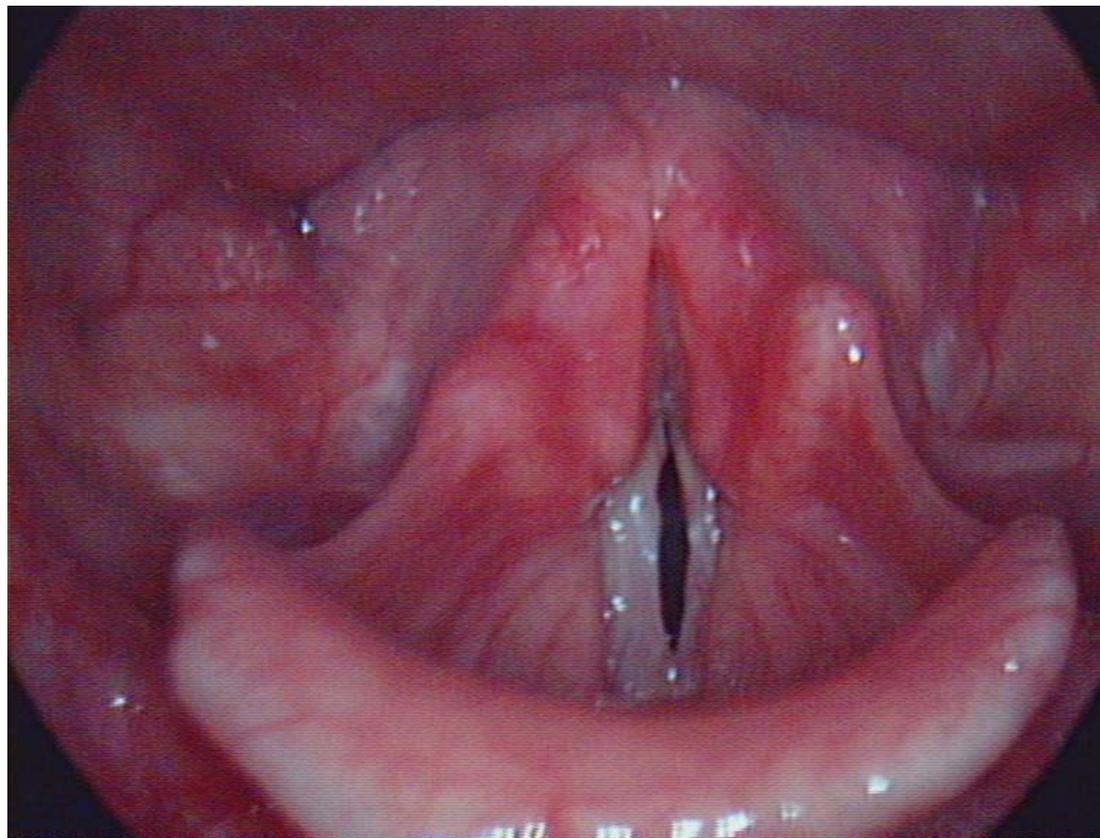
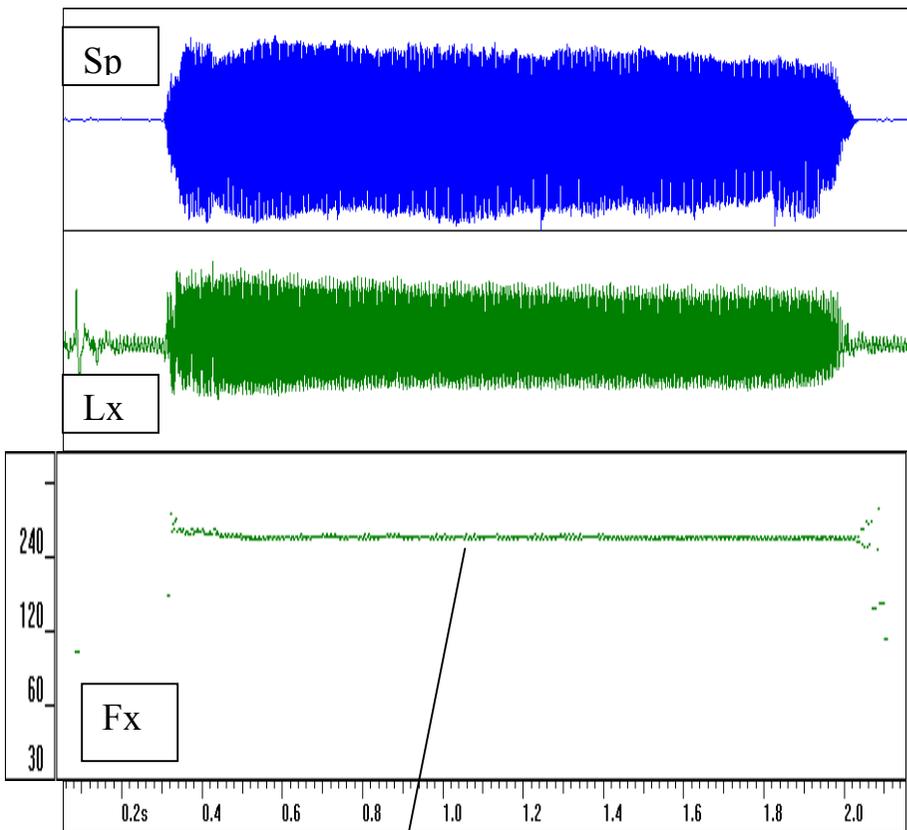
The sixth and seventh pages apply these same procedures to data from patient MF and the eighth and ninth pages are for patient SK – both previously presented in the main body of the text.

These very brief comparisons of the two approaches – sustained vowel and connected speech – show how very powerful is the use of connected speech when appropriately analysed.



Normal connected speech VW

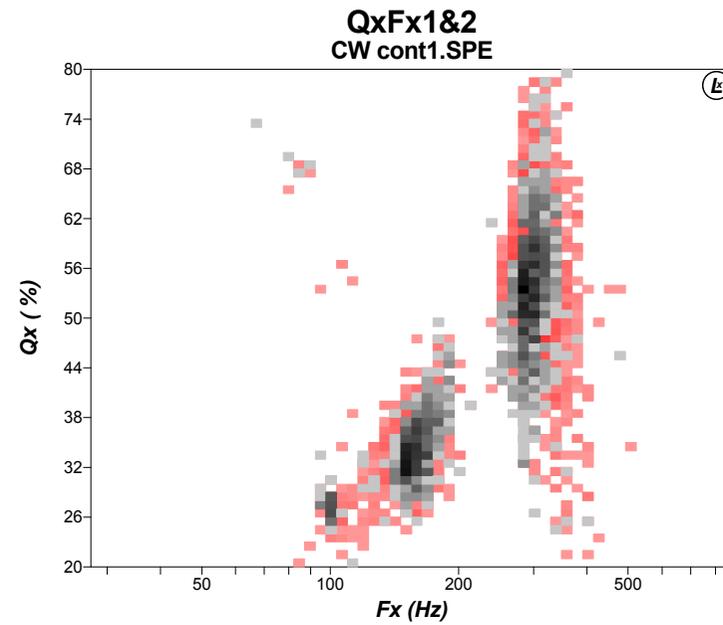
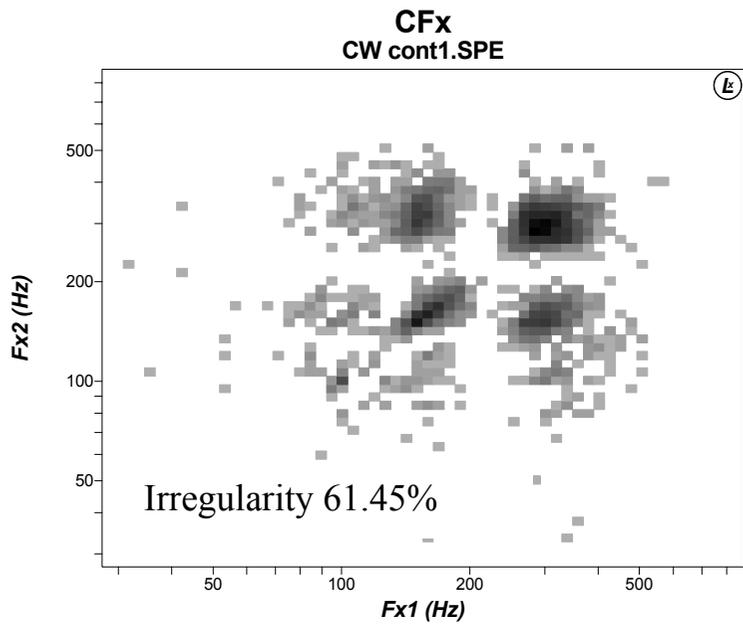
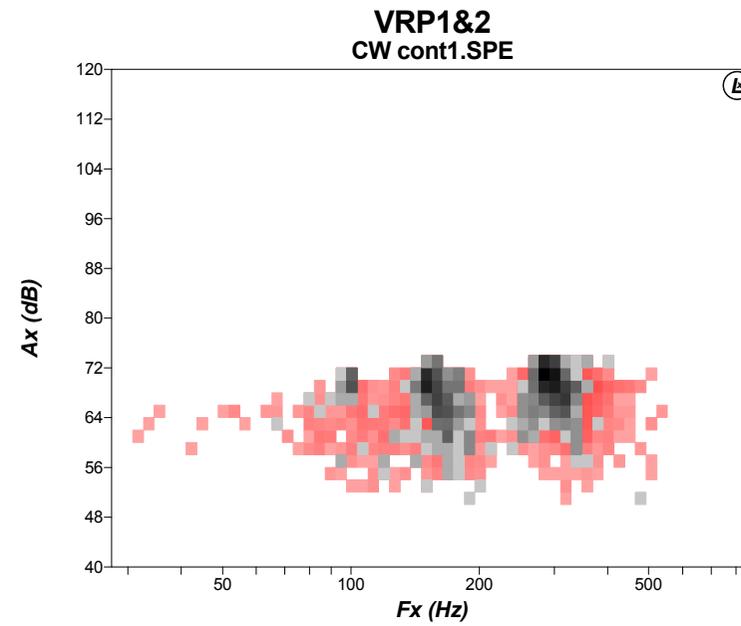
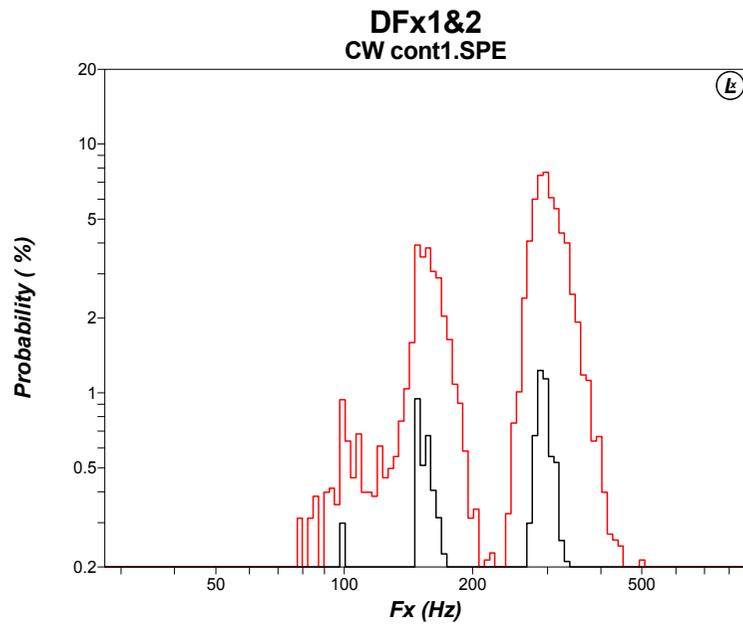




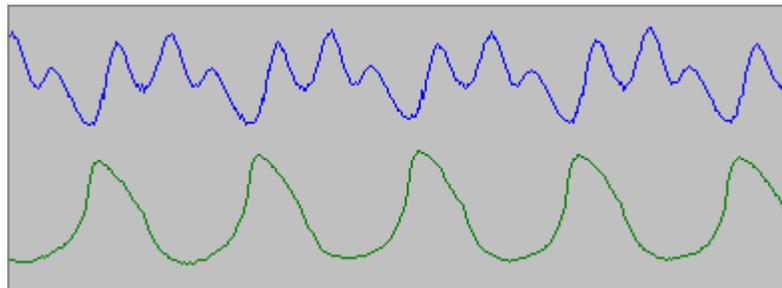
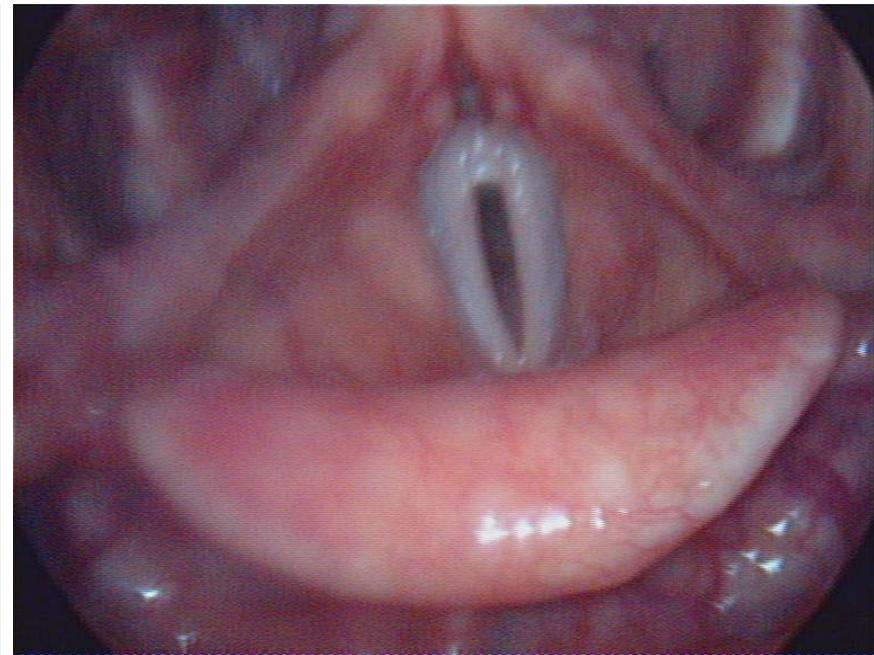
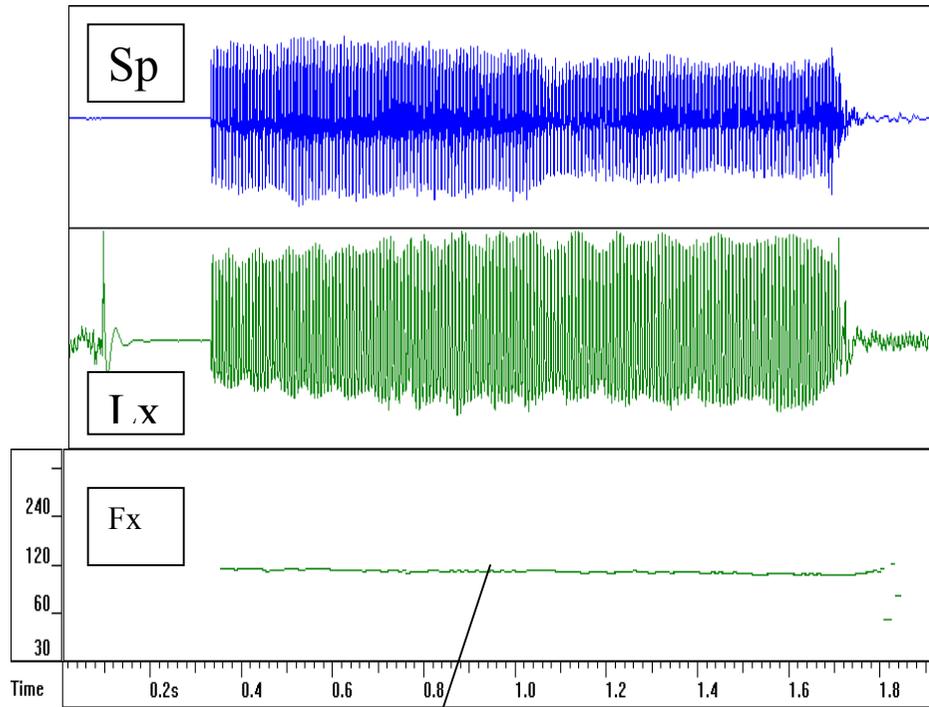
CW – sustained vowel analysis

Report – Vocal Profile Analysis

No. Samples	440	Duration	1.347 s
Minimal Fx	276.19 Hz	Maximal Fx	294.13 Hz
Average Fx	287.42 Hz	S.D. Fx	3.20 Hz
Minimal Qx	43.33 %	Maximal Qx	53.22 %
Average Qx	48.95 %	S.D. Qx	0.13 %
Jitter First	1.72 %	Jitter Second	0.84 %
Shimmer+	3.48 %	Shimmer-	-4.01 %



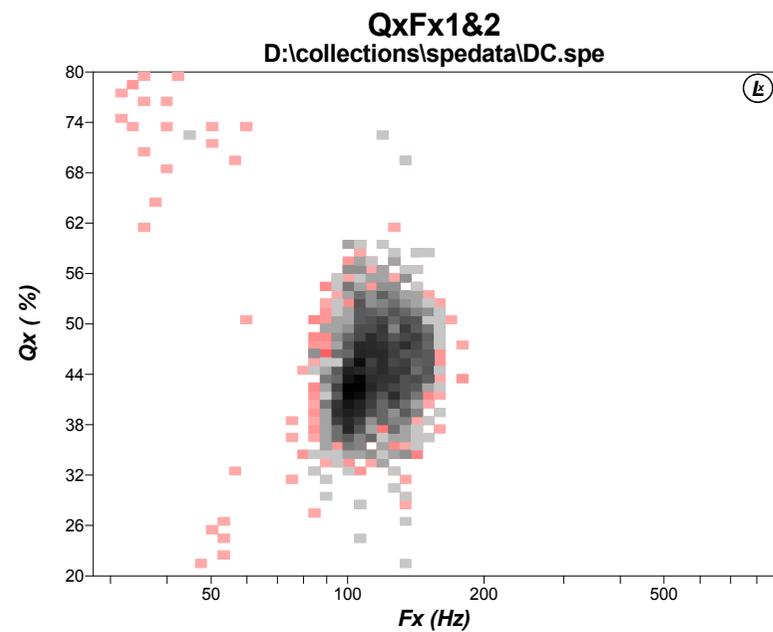
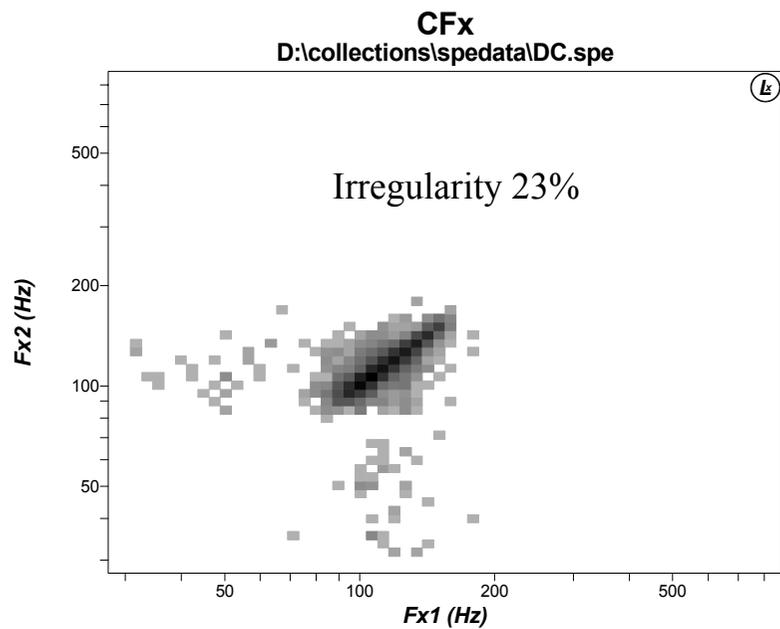
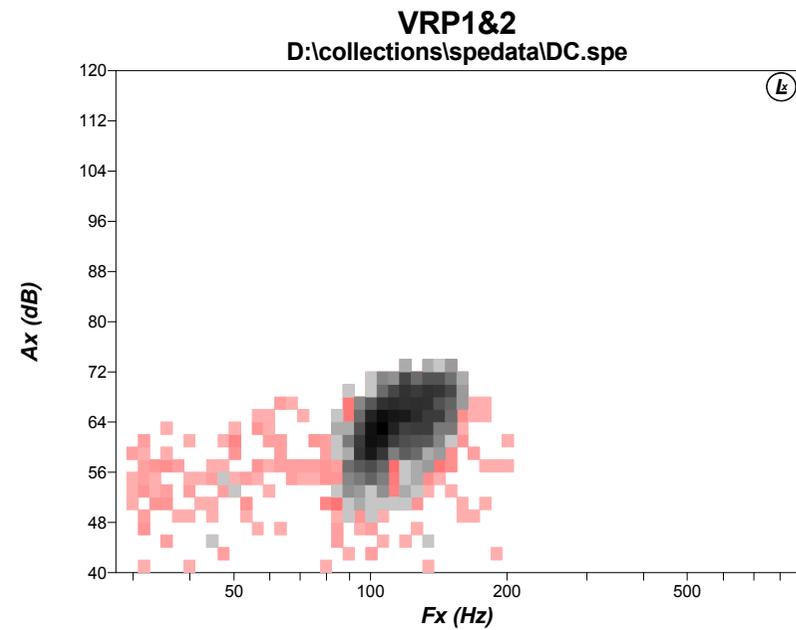
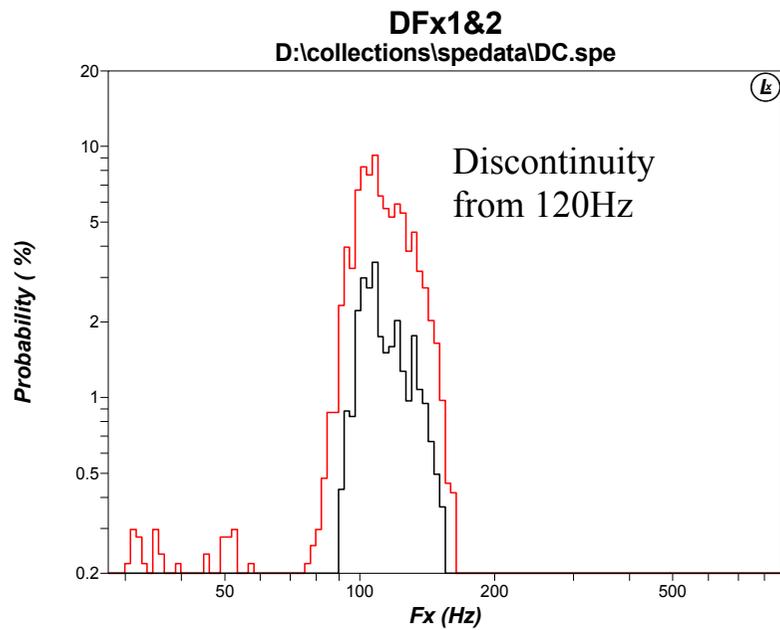
CW - connected speech analysis



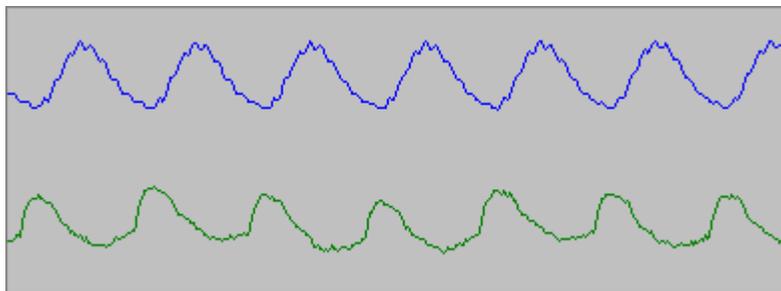
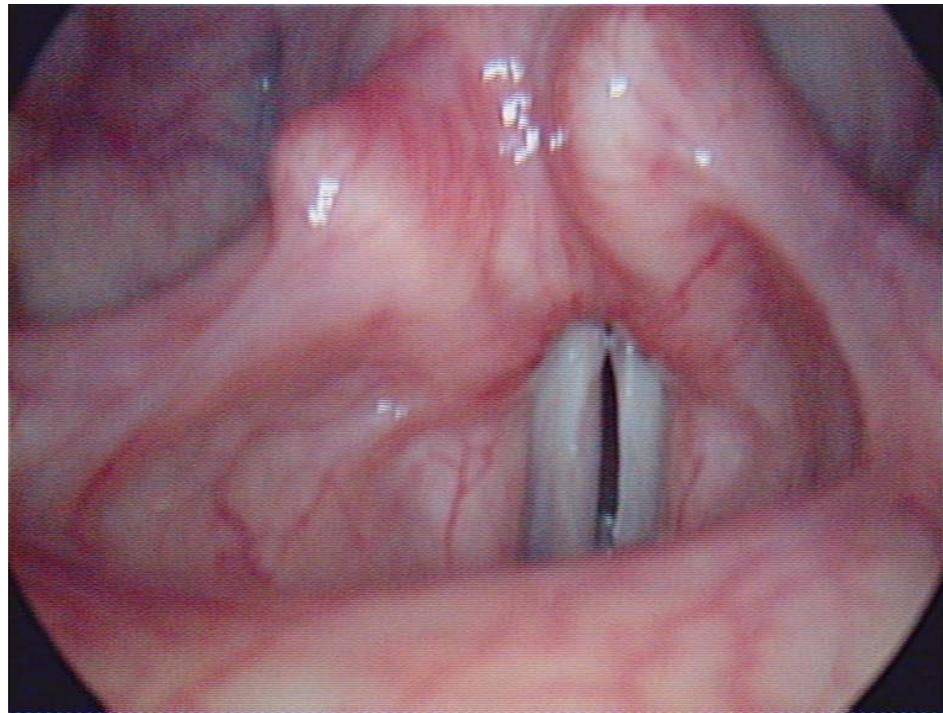
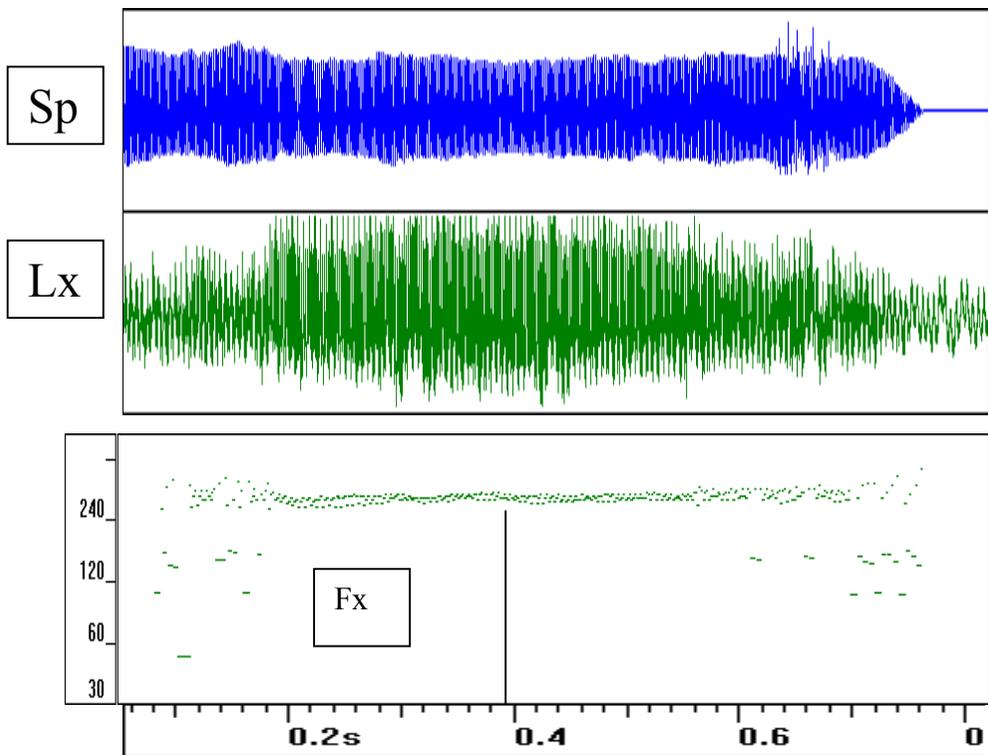
Report – Vocal Profile Analysis

No. Samples	154	Duration	1.242 s
Minimal Fx	104.23 Hz	Maximal Fx	113.95 Hz
Average Fx	108.76 Hz	S.D. Fx	2.42 Hz
Minimal Qx	35.36 %	Maximal Qx	44.31 %
Average Qx	39.67 %	S.D. Qx	0.31 %
Jitter First	0.70 %	Jitter Second	0.39 %
Shimmer+	5.81 %	Shimmer-	-5.12 %

DC – sustained vowel analysis



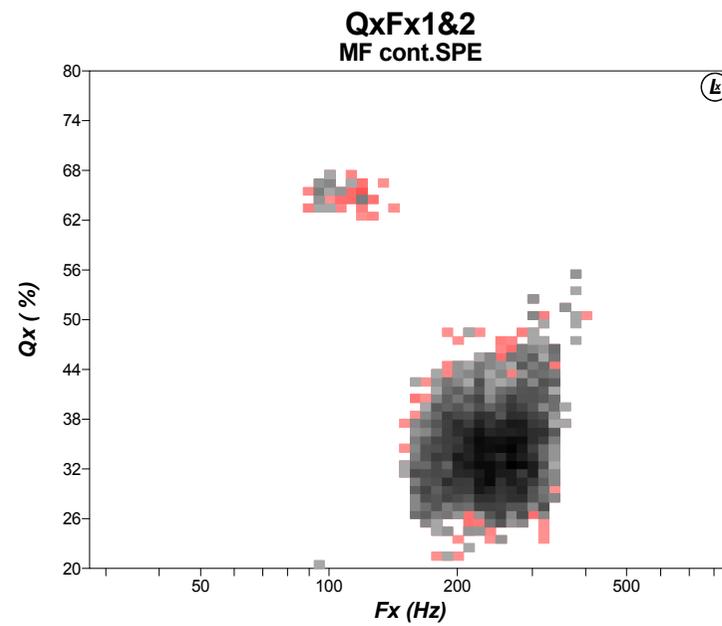
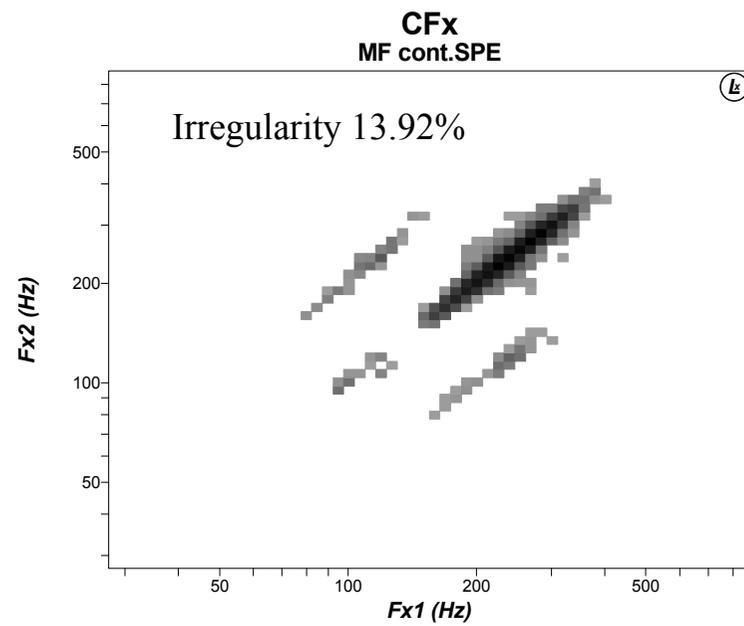
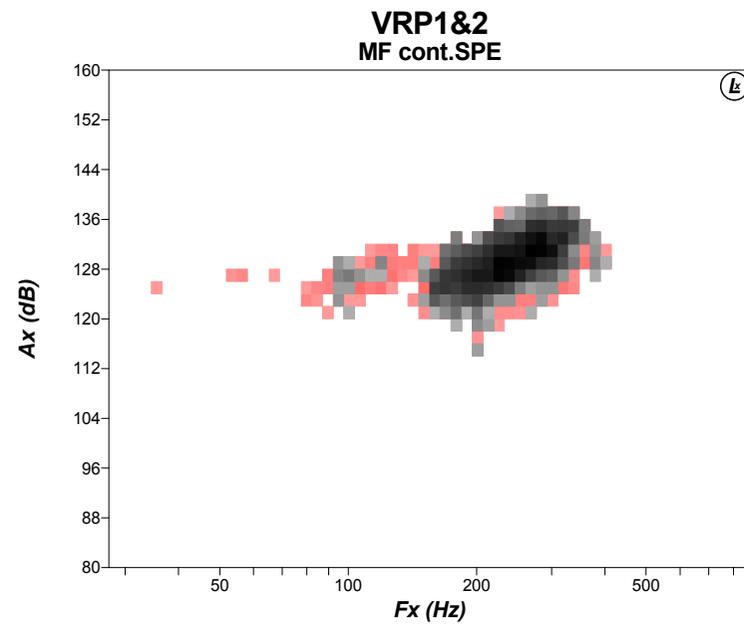
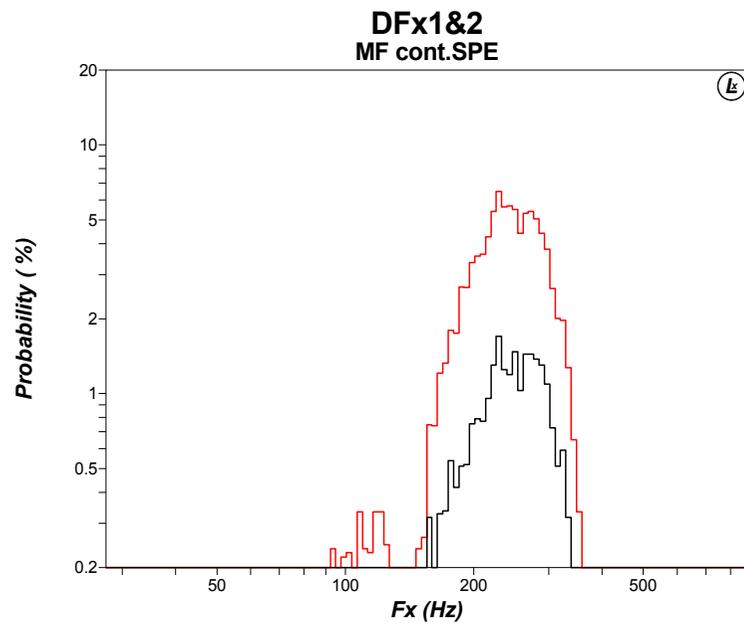
DC – connected speech analysis



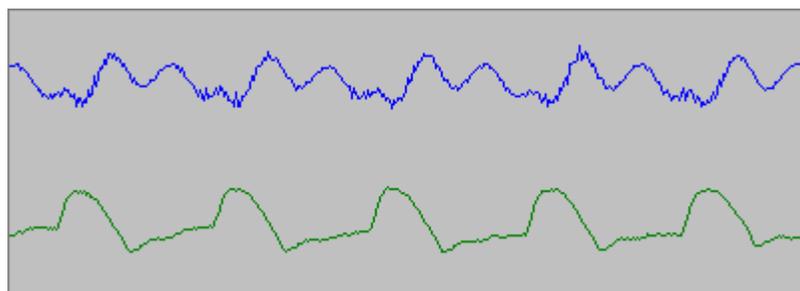
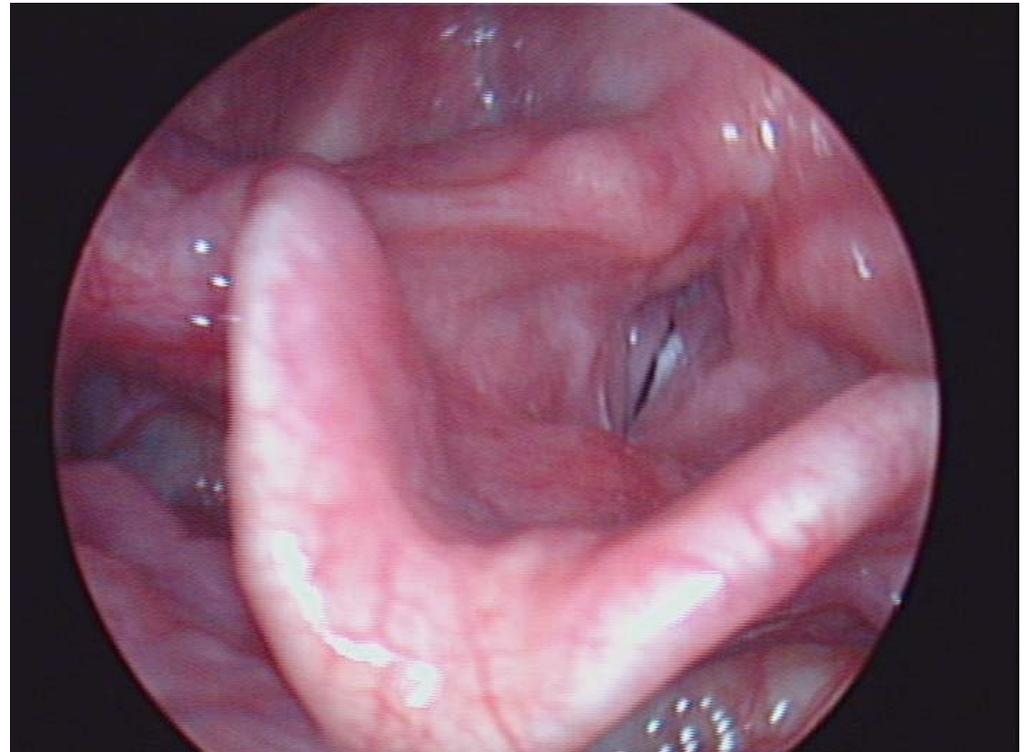
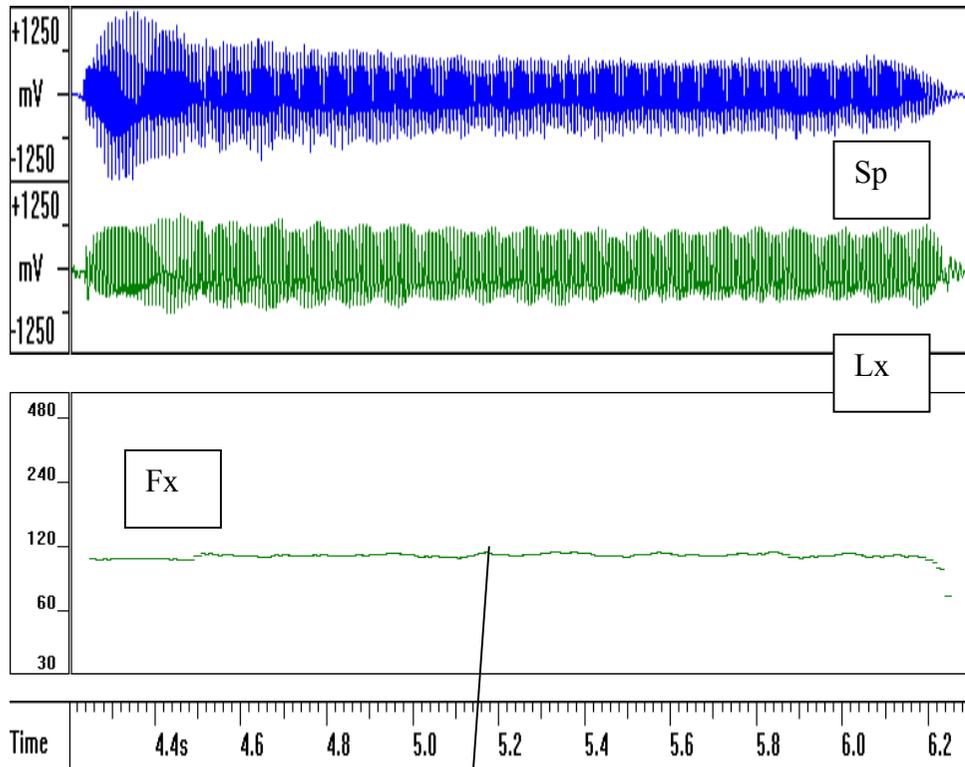
MF – sustained vowel analysis

Report – Vocal Profile Analysis

No. Samples	169	Duration	0.478 s
Minimal Fx	286.80 Hz	Maximal Fx	346.26 Hz
Average Fx	311.74 Hz	S.D. Fx	10.34 Hz
Minimal Qx	32.07 %	Maximal Qx	49.15 %
Average Qx	39.89 %	S.D. Qx	0.08 %
Jitter First	4.29 %	Jitter Second	2.44 %
Shimmer+	2.75 %	Shimmer-	-2.88 %



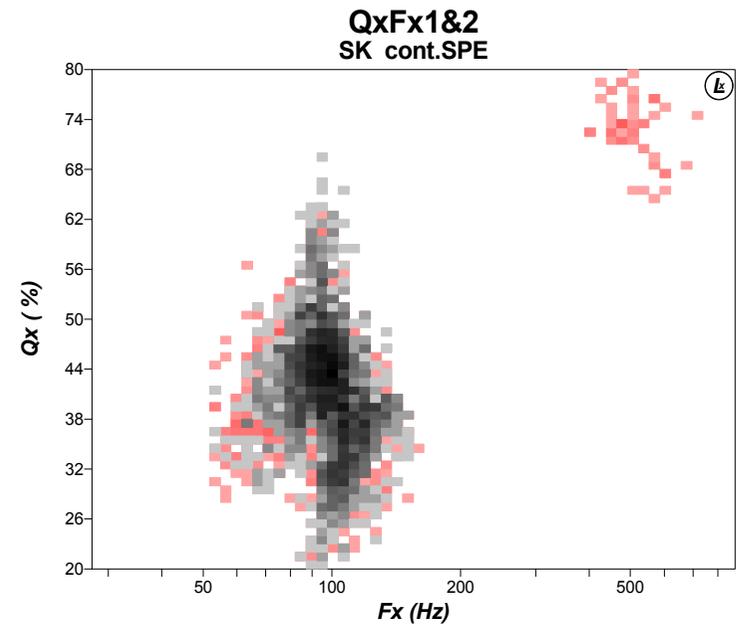
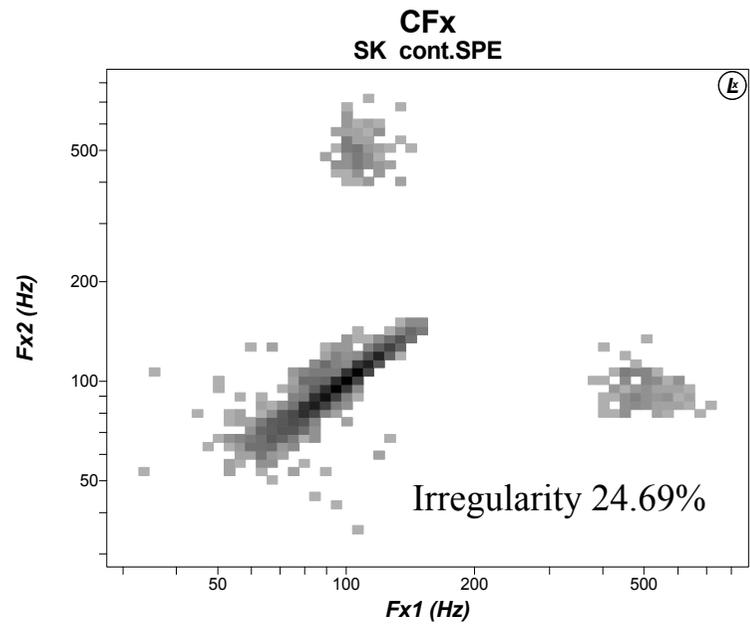
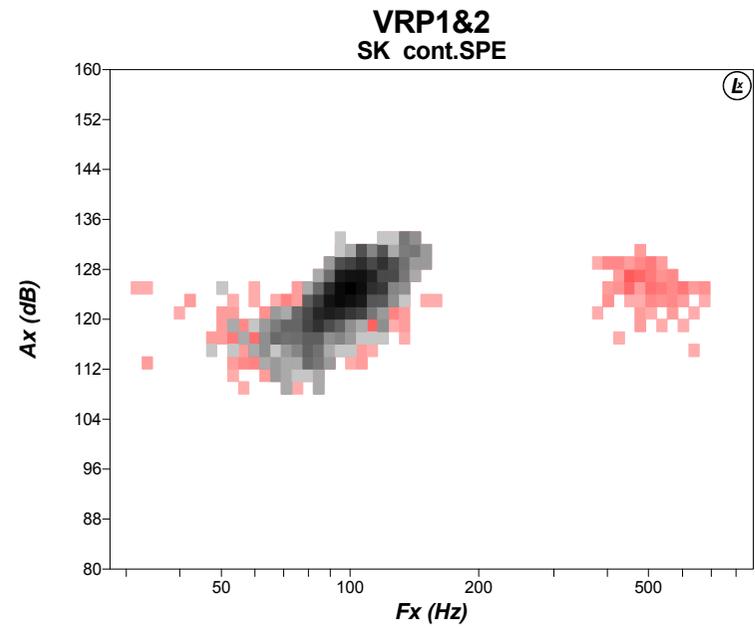
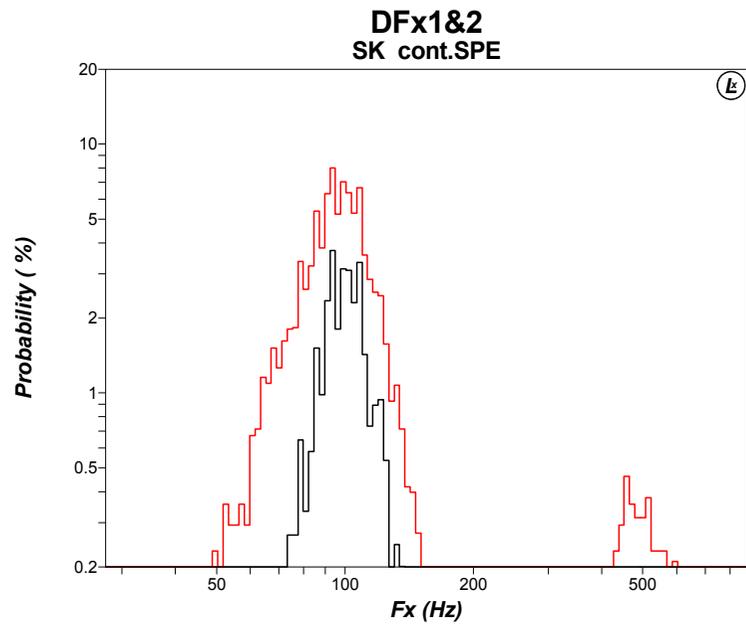
MF – connected speech analysis



Report – Vocal Profile Analysis

No. Samples	197	Duration	1.590 s
Minimal Fx	105.85 Hz	Maximal Fx	113.17 Hz
Average Fx	109.26 Hz	S.D. Fx	1.40 Hz
Minimal Qx	32.92 %	Maximal Qx	44.17 %
Average Qx	38.40 %	S.D. Qx	0.14 %
Jitter First	0.54 %	Jitter Second	0.17 %
Shimmer+	6.74 %	Shimmer-	-10.53 %

SK – sustained vowel analysis



SK – connected speech analysis