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BREATHINESS IN NORMAL FEMALE SPEECH: INEFFICIENCY VERSUS DESIRABILITY

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1. Introduction

In articulatory terms, the production of the type of phonation known as breathiness involves a mode of vibration of the vocal folds which is inefficient compared with that for modal ('ordinary') voice. The vibration is accompanied by slight audible friction. Laver (1980) states that muscular effort is low, so the glottis is kept somewhat open along its length, and the folds never meet along the mid-line. Catford (1977, p. 99) described the vocal folds as 'flapping in the breeze' of the high velocity air-flow, with the effect produced as being 'somewhat like that of sighing'.

This breathy phonation, arising from an incomplete adduction of the vibrating vocal folds, is used to form linguistic contrasts in numerous languages. These include many Indo-Aryan languages such as Gujarati (Pandit, 1957), Nepali, Marathi and Hindi; Niger-Kordofanian languages such as Igbo and Tsonga; Sino-Tibetan languages such as Newari (Ladefoged, 1983); Mazatec of Mexico (Kirk *et al.*, 1984); and !Xóõ of Southern Africa (Traill, 1981).

However, this is not the only role of breathiness in speech. As remarked by Ladefoged (1983, p. 351), 'One person's voice disorder is another person's phoneme'. He expands this with the claim that breathy voice 'would be considered strongly stylistically marked or pathological if used by speakers of English' (p. 351). Undoubtedly, breathiness in speakers of English can indeed be identified as a perceptual marker of pathological speech (Perkins, 1971; Hanson and Emanuel, 1979), where it is symptomatic of a wide range of laryngeal disorders. But Ladefoged's claim is insufficient in an important respect: as this paper will show, breathiness in speakers of English is not just a marker of style or of vocal pathology, but of (normal) female speakers as opposed to males. If, as seems to be the case, breathiness is a regular concomitant of the speech of non-pathological British English women, then it may have a socially-determined, communicative origin. There are, moreover, substantial implications for the perceptual diagnosis of vocal pathology, in particular what counts as 'normal', and what does not.

2. Previous experimental findings

On the assumption that breathy phonation plays some functional role, whether linguistic or paralinguistic, then we would expect to find some evidence of it when speech is analysed acoustically. What, precisely, would we be expecting to find? What are the acoustic correlates of breathiness?

The incomplete vocal-fold adduction which accompanies breathy phonation allows

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considerable leakage of voiceless air through the glottis. In the acoustic spectrum of a vowel this produces a random pattern of noise interspersed among the separate voicing harmonics.

One possibility which was therefore considered for an acoustic measure of breathiness was the ratio of harmonic energy to noise energy in the speech signal. Such a measure was used for example by Yumoto *et al.* (1982), although for the measurement of hoarseness and not specifically of breathiness in the pathological voice.

We opted, however, for an acoustic measure which has the advantage of being more directly derivable from conventional spectrographic instruments, with no special processing. This measure is the amplitude relationship between the voicing harmonics of lowest frequency. Its use in quantifying breathiness has been validated by Bickley (1982). She explored Gujarati, in which, as was mentioned above, breathy voice is used to make linguistic contrasts. She established that the amplitude of the first (fundamental) harmonic was consistently enhanced compared with that of the other low harmonics, and that this constituted a reliable acoustic correlate of breathiness. Figure 1 is adapted from her paper and shows the effect in two /ɑ/ vowels: the modal (non-breathy) vowel at the top and the breathy /ɑ̤/ at the bottom. Compare the relative heights of the first two harmonic peaks. It is easy to see how the first harmonic in the modal vowel is some 5 dB lower in amplitude than the second harmonic, whereas in the breathy vowel the first harmonic is about 5 dB higher than the second harmonic—a total difference in amplitude of about 10 dB.

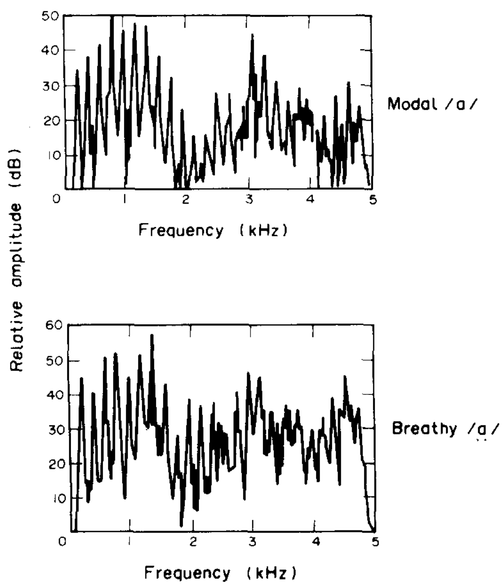

Fig. 1. Spectra of a Gujarati modal /ɑ/ (top) and breathy /ɑ̤/ (bottom). Figure adapted from Bickley (1982).

From perceptual tests which Bickley then conducted, she showed that listeners are sensitive to this balance between the amplitude of the first harmonic and that of the second.

3. British English data

In the course of a preliminary examination of a number of narrow band spectral analyses of vowels spoken by women speakers of British English, we had been struck by how often the same acoustic correlate as shown by Bickley for Gujarati was present in the spectra. Could one then suspect that women speakers of British English systematically produce more breathy vowels?

Extensive evidence to investigate our hypothesis was therefore collected from female and male speakers. A large database for two dialects of British English for speakers of both sexes has been assembled in Oxford. At the time of this study this database was not quite complete, and so the number of speakers studied was 36 for Received Pronunciation (twenty females, sixteen males), and 25 for a northern accent (twelve females and thirteen males). For a more detailed description of the careful criteria for selection and recording of the subjects in this database, see Henton (1983).

Narrow band spectral analyses were made from 80 ms steady-state portions of citation-form vowels. Figure 2 is an example of a female / ʌ / vowel displayed on a Brüel and Kjaer Type 2031 Narrow Band Spectrum Analyzer, where frequency in kHz is displayed along the *x*-axis, and relative amplitude in decibels (dB) up the *y*-axis. From displays such as these, it is easy to quantify the relative heights of the first and second harmonics.

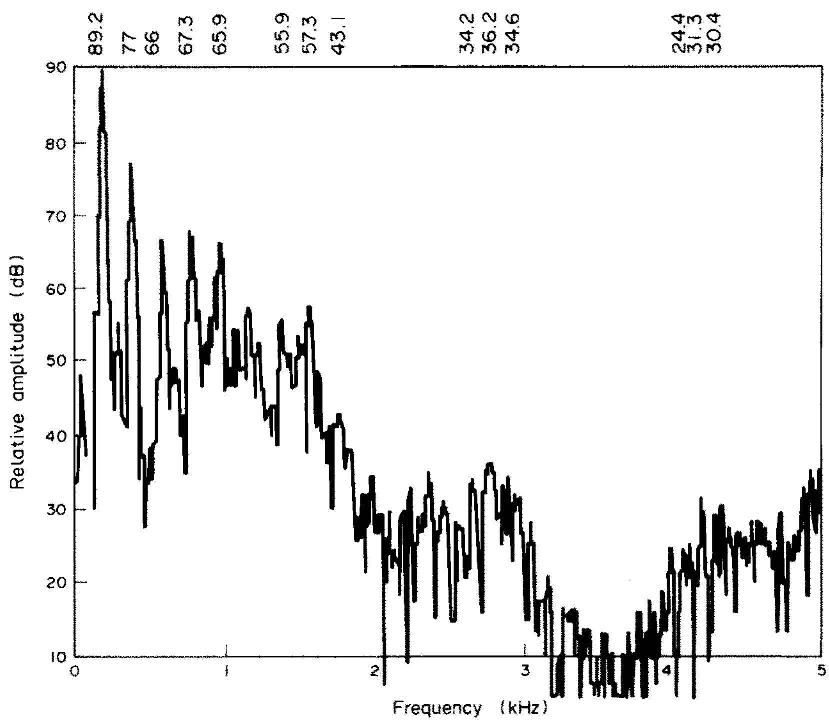

Fig. 2. Narrow band spectrum analyzer representation of an /ʌ/ vowel spoken by a female. The figures at the top of the chart are readings of intensity level in dB. Full scale level: 90; F.S. frequency: 5000. Speaker: female, DP. Token 3/1; Trig. No: 1.0. Accent: RP.

For the purposes of this investigation, we selected for study the open vowels /æ, ʌ, ɑ, ɒ/. There is an important reason for this decision. It is only in the open vowels that the frequency of the first formant is sufficiently high not to interfere with the lowest harmonics and thus increase their level: the first and second harmonics are in this way easily distinguishable from any first-formant influence.

Table 1. Average difference in amplitude (dB) between the first and second harmonics in male and female speakers of (a) Received Pronunciation and (b) Modified Northern

(a)	Vowel	/æ/	/ɑ/	/ʌ/	/ɒ/
RP	Females	8.4	6.4	6.2	3.3
	Males	0.98	0.77	0.16	0.39
Difference	(F–M)	7.42*	5.63*	6.04*	2.91*

Difference in amplitude across all vowels (mean of means) = 5.5 dB.

(b)	Vowel	/æ/	/ɑ/	/ɒ/
MN	Females	10.26	7.59	6.31
	Males	2.41	1.55	2.48
Difference	(F–M)	7.85*	6.04*	3.83*

Difference in amplitude across all vowels (mean of means) = 5.91 dB.
*Significant according to a *t*-test, $p < 0.01$.

Let us consider the Received Pronunciation (RP) data first. The four open vowels of twenty female speakers were compared with those for sixteen males. The results of this comparison are shown in Table 1a.

The first harmonic of the female vowels, when averaged across speakers, was higher in amplitude than the second harmonic by a value ranging from 3.3 to 8.4 dB, suggesting considerable breathiness. For the males, by contrast, the average enhancement was as little as 0.16–0.98 dB. All of these male–female differences are highly significant statistically, as can be seen from Table 1a. The mean enhancement of the first harmonic above the second for all four vowels is 5.5 dB more for women than for men.

Of these results, that for the /ɒ/ vowel is the least dramatic. This can be explained by the fact that, in current RP, the /ɒ/ vowel is no longer really an open vowel (see Henton, 1983, Fig. 2). In fact it is noticeably closer than the other three vowels examined. The acoustic effect of this behaviour is for the first formant to be lower in frequency and thus have a greater interfering effect on the lower harmonics. It therefore comes as no surprise to find that the amplitude difference between the first and second harmonics for /ɒ/ was indeed somewhat diminished.

The general picture emerging from these results supports the view that, in RP at least, women speakers' vowels are physically more breathy than males'. But is this pattern limited to one dialect alone? As a step towards determining this, we turn next to a comparison of the open vowels of male and female speakers of Modified Northern British English (MN). This accent is defined for our purposes to be the accent of speakers who grew up and were educated in or near Leeds, but who have substantially moved away for substantial periods (e.g. to go to university or work) and have thus modified their native features.

One slight incommensurability with the RP data is that MN does not have a native /ʌ/ vowel: this is realized with a variety of degrees of openness ranging from [ʊ] through [ə] to [ʌ]. Very few of these realizations can be considered as a sufficiently open vowel, as would meet our experimental requirements. For MN therefore we investigated the first and second harmonics for only the three vowels /æ, ɑ/ and /ɒ/. The results, however, were not unencouraging, as Table 1b shows. The MN results can be summarized as showing the same significant trend as in RP, this time with a mean difference between the females and the males of 5.91 dB. This mean difference between the sexes is clearly very similar in the two dialects. As before, the higher female value suggests greater breathiness.

4. Experimental conclusions

We can conclude from this experiment, then, that there is evidence of breathiness in female speakers of two accents of English; that it is consistent and that it is present to a much greater extent than in the male vowels from both accents.

A crucial question is whether the observed breathiness difference in British English, averaging out at 5.5 and 5.91 dB in the two accents, is sufficient to be perceptible? Indeed it is: the magnitudes of the male/female breathiness difference are such that, in a language in which breathy voice is used contrastively such as Gujarati, they would be sufficient to carry the perceptual contrast between breathy and modal vowels. This can be determined from a comparison of our results with those of Bickley for Gujarati. From Bickley's Table 2, the mean difference between breathy and modal vowels is an enhancement of the first harmonic by 5.3 dB.

Could we infer from these findings in British English, then, that if a female English speaker attempted to learn a language in which breathiness is employed contrastively, her first efforts would be interpreted as breathy vowels, even when she was intending modal versions?

5. Inefficiency versus desirability: a paradox

Why should women be exhibiting such degrees of breathiness when it is not used contrastively in British English? Breathy phonation is, after all, inefficient in production (as was indicated in the Introduction). Together with the leakage, breathiness gives rise to other communicative limitations. Because the degree of longitudinal tension of the vocal folds is rather low for breathiness to occur, high-pitched breathy voices are unlikely. Breathiness also frequently induces limited vocal intensity and low pitch, giving rise to greater possible monotony in the speaker's overall delivery.

Alternatively then, is breathiness conceivably used because it is perceptually efficient, an aid to intelligibility? Although to our knowledge this conjecture has not been investigated *per se,* it is a hypothesis which cannot be entertained seriously. From all the studies (e.g. Kalikow *et al.,* 1977) of speech perception against a background of noise (which is essentially what is happening when voiced speech is overlaid on a breathy background), a degradation of intelligibility is inevitably attested. In addition, there is a somewhat technical reason why a breathy spectrum would pose a perceptual problem for the ear. The problem is at its most severe in close rather than open vowels, where the frequency resolution in the auditory system is such that the first harmonic component is integrated with the first formant into a single, auditory peak (Bladon, 1982). A breathy vowel whose first harmonic is of high amplitude will 'unbalance' the perceived first formant, inducing an impression of a shift in the vowel's quality in the openness dimension. This would be predicted to have a detrimental effect on the identification of vowels.

If, as one can infer from these factors, the listener's brain prefers a relatively 'clean' image to analyse, why are women appearing to make that analytic task more difficult by producing a 'messy' signal?

So we encounter an interesting paradox: British women are apparently adopting articulatory postures which not only undermine the perceptibility of their speech, but also tend to make it less varied and more monotonous. Why, so to speak, should they wish to queer their own pitch?

Laver starts to provide an answer to all these questions, but then fails to follow up the implications. He concludes his section on this particular voice quality by saying (1980, p. 135) that:

> . . . breathy voice does not seem to be used phonologically as often as it might be. Paralinguistically, however, breathy voice is exploited in English for the communication of intimacy.

Now we begin to get a glimmering of why women should exploit this quality of breathiness. . . .

A breathy voice is a 'sexy' voice (Crystal, 1975, p. 85; Daniloff *et al.*, 1980, p. 175) and a sexy voice is associated with arousal. It may not be too speculative to assume a physiological basis for the association between breathiness and arousal. An accompaniment to the release of sex hormones by the hypothalamus is the release of other secretions—lubrication to the body as a whole, and the larynx does not escape this effect. If the larynx receives extra lubrication, then this may inhibit the ability of the vocal folds to adduct fully, resulting in an inefficient phonation and producing breathy voice.

This is not to say, of course, that British women using a breathy voice are actually aroused; rather that they imitate the voice quality associated with arousal. If a woman can manage to *sound* as though she is sexually aroused, she may be regarded as more desirable or with greater approbation by a male interlocutor than if she speaks with an ordinary, modal voice. At an ethological level, breathy voice may be seen as apart of the courtship display ritual, as important as bodily adornment and gesture. A breathy woman can be regarded as using her paralinguistic tools to maximize the chances of her achieving her goals, linguistic or otherwise.

6. Implications and the issue of normativism

Several further questions arise immediately. For example, how much breathiness would be tolerated in women speakers of languages (such as Gujarati) where breathiness is used contrastively? At what age do girls start to acquire/employ breathiness? These are empirical questions to which we do not as yet have the answers.

How does this sex-linked characteristic influence British speech therapists' decisions about what is a 'normal' voice, and what is pathological and in need of treatment? Are 'normal' women speakers in danger of being classified as 'pathological' in their speech habits, when in fact they are merely exploiting a particular voice quality paralinguistically?

This dilemma is a particular, sex-based instance of a problem to which Crystal (1980, p. 129) has drawn more general attention:

> . . . a label should be supported by a set of criteria of analysis, which will systematically differentiate the disorder from others with which it is likely to be confused, and explain the internal variability which can be found within the disorder.

Laver and his research group (Laver *et al.*, 1981) have been working towards providing a set of criteria of analysis in the form of their Vocal Profile Analysis Protocols. However, in connection with this current discussion, we can see that immediate problems with normativism arise. If, in proposals such as those of Laver *et al.*, a perceptual norm for breathiness is established using male speech as the baseline, then, on the basis of the findings presented here, all the women in our data base would be described as abnormally breathy. Indeed, it is not out of the question that, similarly, degrees of nasality are used differentially by the sexes, or creak, or jaw movement and so on.

A solution to this problem, for the breathiness norm, can be proposed using the findings of section 3 above: it is necessary to define two separate breathiness norms for

British English speakers, according to their sex. On the acoustic parameter we have used, these norms are some 6 dB apart.

There are further practical implications of our study. For example, it would seem to be a requirement for the satisfactory synthesis of (British English) female speech for it to incorporate some breathiness. In addition, it would be communicatively desirable for transsexuals (male-to-female) to be taught to incorporate a degree of breathiness in their adopted voices.

Finally, and as a pointer to further work, the inherent variability in the definition of normal versus pathological speech is not limited to the dimensions we have already discussed. Crystal (1980, p. 128) once more draws attention to this. (The reader may like to note the exact use of the so-called generic pronoun in this quotation.)

> Let us imagine an 'abnormal' child turning up at a clinic. As assessment must be carried out, and the nature of the abnormality pinpointed. But with what norm should he be compared? How should he be speaking? The therapist will need to know the dialect the child comes from, in case there are differences between the way she speaks and the way the child will be expected to speak by his parents and peers.

Heaven help the 'abnormal' child if she also happens to be female!

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