SOME AIRFLOW AND GLOTTOGRAM DATA ON DANISH WHISPER

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1. Introduction[1]

In Mansell (1973) I reported on some experiments designed to look for evidence of segmental articulatory reorganization from normal speech to whisper, where such reorganization would be seen as paralleling the reorganization found at the suprasegmental level (see Trim (1973) for a review and some experimentation). What was of particular interest in the above paper was the segmental behaviour of the glottis in phonologically voiced and voiceless stops in English and the corresponding aspirated/unaspirated series in Danish.

It was expected that in the English data the three parameters measured, airflow out of the mouth, air pressure drop across the articulatory constriction, and photo-electric glottograph traces of the gross opening/closing movements of the larynx, would be sufficient to enable all relevant physical differences between voiced and voiceless cognates and between normal and whispered speech to be characterized. Any problems in the physical interpretation of the Danish data, where only airflow and glottographic traces were sampled, were to be referred to the English data for possible explanations. However, the finding

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1) The recordings on which this paper is based were made at the Institute of Phonetics in the University of Copenhagen while the author was a visiting researcher in the Summer Term of 1971. The assistance of Prof. E. Fischer-Jørgensen and her staff, especially of B. Frøkjær-Jensen, who acted as subject, is gratefully acknowledged.

both that glottographic registration was poor during whispered speech and that in any case no great reliance could be placed upon the quantitative aspects of the glottographic traces lead inevitably to a good deal of uncertainty about the time-varying behaviour of the individual components of the sound production in both languages and for both normal and whispered speech.

The stops examined in Mansell (1973) exhausted neither the English nor the Danish material, however, and it is the purpose of this paper to present a more complete account of the Danish data. This comprises utterance medial, syllable initial [p, b, m, f, v]. It will be of great interest to discover whether those aspects of the stop traces which led to the tentative conclusion that segmental articulatory activity was to some extent reorganized during whisper will also be evidenced on the extra data considered here. Where the findings below have been reported on previously this will be noted; the great majority of the material below, however, is reported for the first time.

2. Method

A single adult male native speaker of Danish repeated the nonsense words[1] [pil], [bil], [mil], [fil], [vil] in the frame:

en lille ____ igen

The words were repeated in the order given above, each one being first spoken normally, then whispered. In the event thirteen error-free repetitions of each word were obtained.

Both the linguistic nature of the stimulus items and the experimental method were to some extent determined by the instrumentation used. Airflow out of the mouth was sampled *via* a 2-channel Frøkjær-Jensen Aerometer. Back vowels in combination with

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1) The required pronunciation of these words was without stød. It has not been possible in the preparation of this paper, however, to check for this in the original tapes, and the possibility exists that the stød is at least occasionally manifested under the influence of the normal Danish pattern for such words. It is thus possible that the measure C described below is unreliable.

the front consonants of interest were excluded in order to avoid large tongue movements which might introduce volume changes in the Aerometer mask, and consequently errors in the traces. The audio was picked up by a microphone in the Aerometer mask. Glottis movements were registered via a Frøkjær-Jensen photo-electric glottograph. The mode of operation of this device excludes low vowels from the corpus since pharyngeal narrowing interferes with the photocell above the larynx.

It was found advisable to have the subject produce normal voiced/whispered pairs immediately after each other, thus making sure that the position of the light source against the neck, a potent source of artefacts with this device, was as similar as possible for both members of the pair. (For these points and a general technical description of the device, see Frøkjær-Jensen et al. 1971.)

All three experimental parameters were registered simultaneously on a Mingograph ink-jet recorder, running at 100 mm/sec, the audio being at the same time recorded on tape. The airflow channel for normal speech was low-pass filtered with a time constant of 40 msec to remove the voicing ripple. This filter was left in the circuit for the whispered cases so that the maximum amount of comparability could be maintained.

2.1 Measurement parameters

The two aspects of the traces which are of theoretical interest are:

(a) how the (phonologically) "same" units are variously manifested in normal speech and in whisper

(b) how the linguistic contrasts[1] are manifested in normal speech and in whisper.

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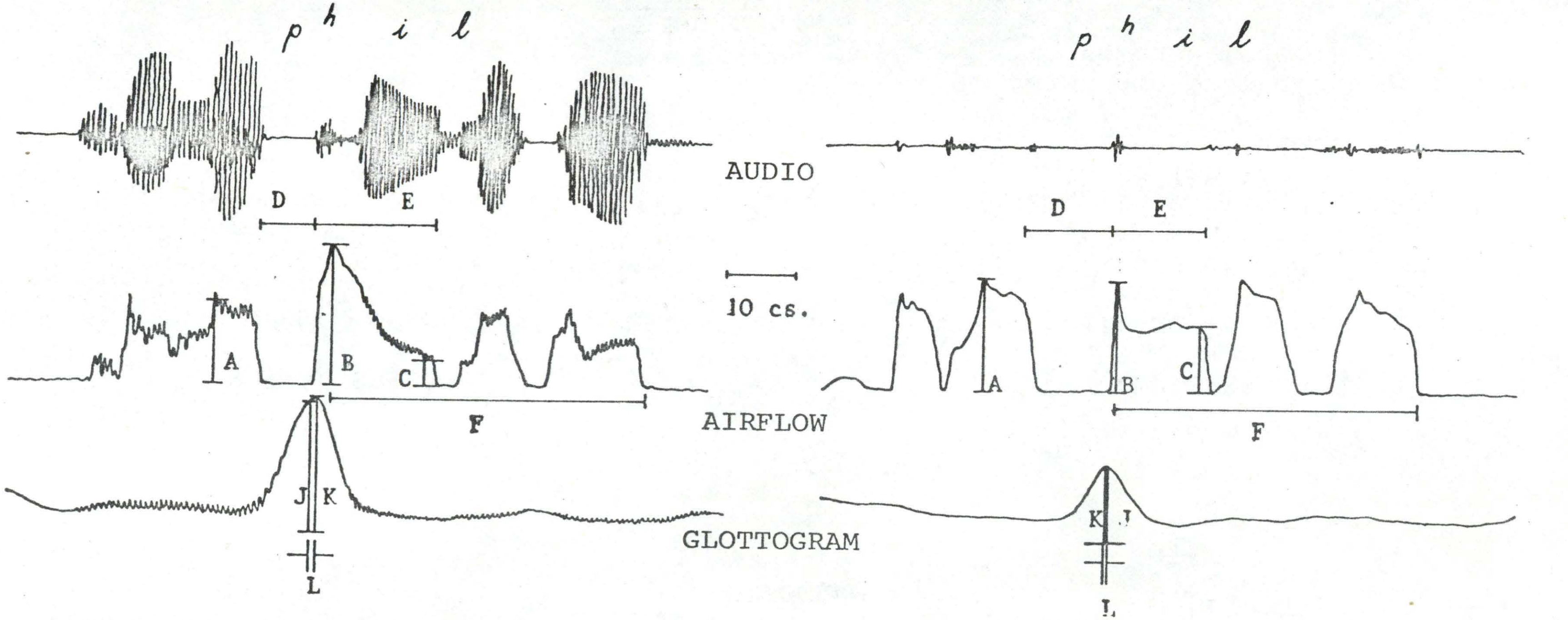
1) Aspirated vs. non-aspirated ([p]/[b]); nasal vs. non-nasal ([p,b]/[m]), voiced vs. voiceless ([f]/[v]).

Of further interest is the evidence provided by this larger corpus on the reliability of glottographic traces, a question already examined, as noted above, in Mansell (1973).

These points will be examined below in terms of the parameters depicted in figure 1 (for stops) and figure 2 (for fricatives). These parameters require some comment, since the considerations which prompted their choice are not always self-evident.

In the first place, a general measure of the effect of whisper on airflow was needed that would be independent of the consonants of direct interest. The obvious choice lay in measuring the airflow amplitude in the vowels [ə] and [i] which flank the consonants in each case (measurements A and C on figures 1 and 2). For [ə] the point chosen for measurement was the amplitude achieved immediately after the [l], rather than at the highest point, the measure which is used in Mansell (1973; see table 3.6 there). The reason for this is that this latter measure is required for other purposes in the fricative traces. Here, since in whisper the fricative cannot be segmented reliably from the preceding vowel, the highest point of pre-consonantal airflow is taken to be a measure of the airflow at the start of the fricative constriction; this measure was hence not available for vocalic purposes. For [i] the point chosen was the amplitude before the sudden drop in the trace for the following [l]. Here the difficulty of establishing any other point reliably, or once again of segmenting in the whispered traces such that measurement could be made at the onset of [i] should be evident.

The validity of this measure is, however, in some doubt, given the remarks in section 2. above about stød manifestation, since the amplitude of the airflow at this point would be greatly dependent upon the occurrence of a following stød. Since the



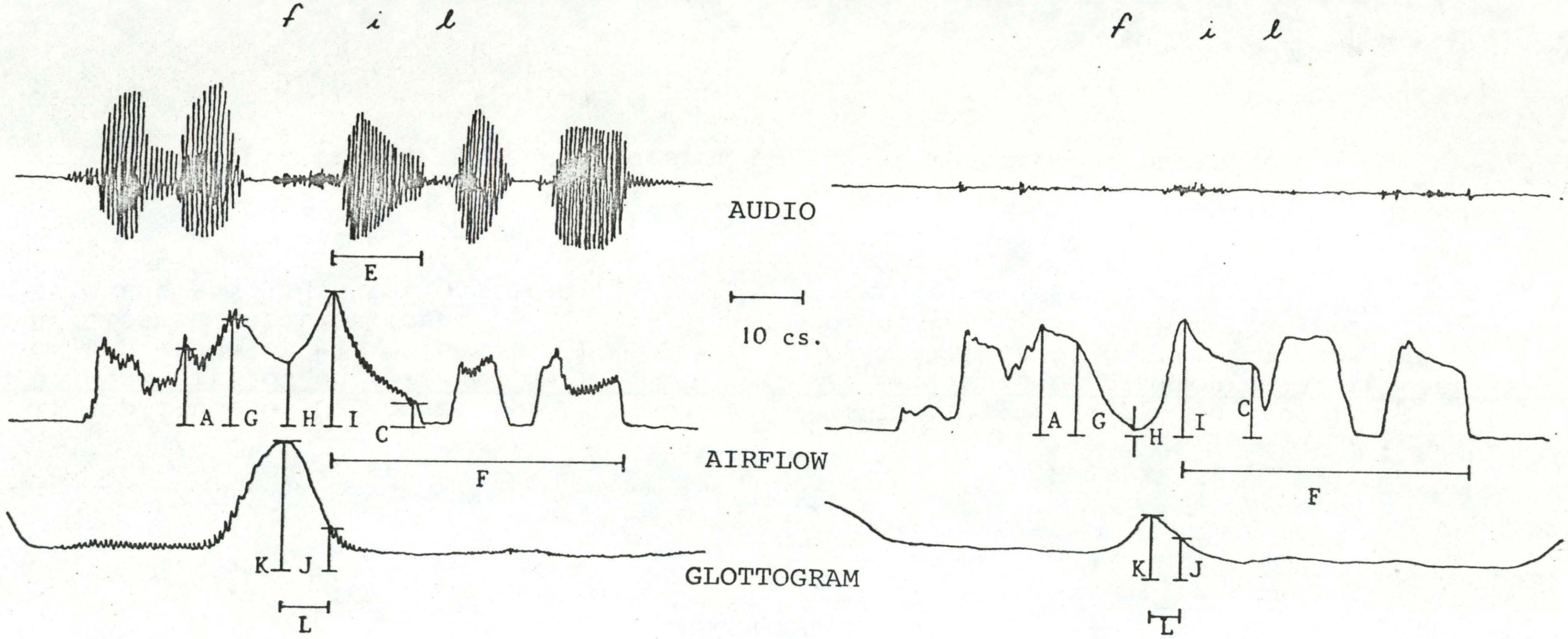
NORMAL SPEECH | WHISPER

A: Amplitude of [ə] onset (mm)
B: Peak airflow on release (mm)
C: Amplitude of [i] offset (mm)
D: Closure duration (csec)
E: Burst and [i] duration (csec)

F: "Total duration" (in csec)
J: Amplitude of glottogram at release (mm)
K: Amplitude of glottogram peak (mm)
L: Distance from glottogram peak to release (csec)

Figure 1

PIL traces illustrating stop consonant measurement parameters



NORMAL SPEECH

A: Amplitude of [ə] onset (mm)
C: Amplitude of [i] offset (mm)
E: [i] duration from 2nd. peak (csec)
F: "Total duration" (in csec)
G: Amplitude of 1st. consonantal airflow peak (mm.)

WHISPER

H: Amplitude of consonantal air-flow trough (mm)
I: Amplitude of 2nd consonantal airflow peak (mm)
J: Amplitude of glottogram at release (mm)
K: Amplitude of glottogram peak (mm)
L: Distance from glottogram peak to release (csec)

Figure 2

FIL traces illustrating fricative consonant measurement parameters results on this parameter do not in the event show great variation on the normal voiced traces, though, and since the theme of stød realization in normal speech vs. whispered speech cannot be gone into on the basis of the present limited material, the measure is allowed to stand.

The measures B (amplitude of airflow at release) and D (duration of the closure phase) require no particular comment beyond the acknowledgement that in B explosion and aspiration are confounded.

The measure E gives us the duration of the post-consonantal vowel in the syllable of interest, but with the duration of the explosion plus aspiration phase counted in with the vowel in the case of [p]. In part, of course, this practice is again dependent upon the difficulty of segmentation in the whisper case, but there are a number of authors (see Lehiste (1970) for a review) who would argue that such a procedure was in any case meaningful. F, labelled "total duration", is the most ad hoc parameter because the most completely tied to segmentation difficulties. What was required was some general means of estimating whether whispered speech was longer or shorter in duration than normal speech. It seemed most sensible to try to measure this on the frame rather than on any stretch including the consonants of interest, and the problem was simply to find a demarcatable stretch long enough. In the end measurement was made, as shown in figure 1, from the peak airflow on release to the point where the trace dips to the low level for the final [n] of igen.

The fricative traces shown in figure 2 share with the stop set the measures A and C for the amplitude of frame vowels. Total duration, F, is also measured as in the stop traces, the second peak of the airflow being taken, as before, as signalling the release. The measure E, duration of the post-consonantal vowel, could only be taken for the normal voiced FIL and VIL traces, and was here defined as the period when the vocal folds are vibrating for the vowel, since there was no period definable between release and onset of the vowel in the whispered cases.

This segmentation problem is also encountered when airflow behaviour in the fricative consonants is in question. It happens, however, that all traces, normal voiced as well as whispered, could be segmented into a first peak of the airflow, followed by a trough, followed by a second peak. The amplitudes of the two peaks and of the trough (G, H, I) were taken accordingly as the airflow measures for the fricative consonants. The possibility of segmentation here may have imposed more unity than actually exists. Thus in VIL, for instance, the amplitude of airflow drops sharply at the end of the pre-consonantal vowel to an extremely low level, rising again only at the onset of the post-consonantal vowel. This low level was registered as nil on the aerometer, though in all probability a complete occlusion was not reached. Such traces <u>can</u> be segmentally measured like the FIL trace shown in figure 2. There is no immediate indication in the results below that such measurements are illicit, but the possibility nonetheless exists.

For all the above-discussed traces tests of central tendency will be carried out, both between the normal voiced and the whispered traces, and between the linguistic types in normal voice and in whisper. In this way it is hoped to provide a fairly detailed picture of aspects (a) and (b) above of the material.

The only glottographic measure which could be automatically made for all traces was the height of the glottogram above a constant arbitrary baseline at the moment of release (J), where release is defined as for measures B and I in the above paragraphs. The reason for this lies partly in the difficulty of segmentation in whisper, partly also in the fact that in some types there is no appreciable segmental movement of the glottal curve in the consonant, and hence no means of locating a point for measurement within the occlusive or constriction stage. The above is true of MIL and VIL traces in both normal speech and whisper. The results on parameter J will be used for tests of central tendency, as with the other traces, as well as for correlation tests with the stop and fricative airflow measures B and I.

The glottographic traces for PIL and FIL both voiced and whispered, and to a lesser extent BIL also, however, do show clear segmental activity in the form of peaking during the occlusive or constriction stage of the consonant. Moreover, inspection of the traces reveal that there are certain apparently systematic distinctions between the types in normal speech with respect to this peaking. Thus, for example, PIL peaks are larger than BIL peaks, while PIL peaks occur later than FIL peaks - in fact, as Mansell (1973) showed, the PIL peaks are more or less coincident with the release; for FIL, though, the glottogram peaks much more in the middle of the constriction phase. These points form the initial justification for the measurements K, height of glottogram peak in mm of trace above the same arbitrary baseline as is used for J, and L, distance in csec between the peak and the release. K and L are measured only for the types PIL, BIL and FIL, voiced and whispered.

It is planned to carry out tests of similarity of central tendency across types and voicing conditions, in order to provide a further set of comparisons between the glottal traces for normal voice and whisper. The measures are expected to be of greater interest in the case of the timing of the peak than in the case of the amplitude, where a great diminution from normal voice to whisper has already been noted as a major finding.

It is intended also to carry out tests of correlation between the peak measures and the peak airflow on release (measures B and I) in order to test the hypothesis that it is not only the instantaneous area of the glottis (as is to be investigated in the

J/B and J/I correlation tests mentioned above) which accounts for the amplitude of the release airflow, but also the amount by which the glottis has been opened during the consonant. The examination of this aspect of the traces will be completed by correlation tests between the amplitude of the peak and the timing of the peak, this latter test looking for some internal structure to the glottograph curves which, it is hoped, might be clearly repeated or deviated from in whisper.

3. Results

It should be noted that the shorthand "voiced" is employed in the tables below to stand for "normal voiced" in contrast to whispered speech.

3.1 A note on statistical measures:

The non-parametric tests of correlation and differences in central tendency used below do not assume a linear relationship between the measured traces and reality, although, of course, the assumption that the relationships "greater than" and "less than" holding between measurements is a true representation of some aspect of reality is made. The weak assumptions of these tests seem appropriate to an exploratory investigation of this sort. In the tables of results reported on below, however, mean values for the sets of raw scores on all parameters have been included for the reader's convenience.

3.2 Glottograph results

The glottograph scores in mm of trace for the parameter J, common to all types, are shown in table 1. Mann Whitney tests for differences in central tendency across the distinctions inherent in the material are shown in table 2.

TABLE I

Height of glottogram at release constriction (J) (in mm of trace)

	PIL voice	PIL whisper	BIL voice	BIL whisper	MIL voice	MIL whisper	FIL voice	FIL whisper	VIL voice	VIL whisper
1.	18.5	8	6	4.5	2.5	2.5	4.5	4.5	3.0	5.0
2.	19	12	4	4	3	3.5	5	5.5	3.5	6.5
3.	25.5	15	4.5	3.5	3	3.5	7	7	4	5
4.	25	9.5	4.5	5.5	2.5	3	4	5.5	3.5	3.5
5.	23	11	4	6	2.5	2.5	4.5	3.5	4	3.5
6.	25	10.5	4.5	4.5	2.5	3.5	4.5	5.5	3	2.5
7.	19.5	11	5	5	3.5	3.5	5	5.5	3	4
8.	17	6.5	4.5	4.5	3	3.5	5.5	6.5	4	7.5
9.	18.5	7	4.5	4.5	2.5	3	5.5	5	3.5	5
10.	17.5	9	3.5	5.5	3	3.5	6	6.5	4	5
11.	17.5	10.5	4	5	2.5	4	5.5	5.5	3.5	4.5
12.	18.5	8.5	4.5	4.5	3	3.5	6.5	3.5	4	5.5
13.	18.5	6.5	4.5	6.5	3.5	4	6.5	6.5	4	4.5
<u>Means</u>	20.2	9.6	4.5	4.9	2.8	3.3	5.4	5.4	3.6	4.8

TABLE 2

Mann-Whitney tests over stop and fricative types on glottographic measure (J)

Comparison			Comparison		
PIL_v/PIL_w	U	non-overlapping	FIL_v/FIL_w	U	78.5
	sign	dists.		sign.	NS
	dir.	v > w		dir.	--
BIL_v/BIL_w	U	9.5	VIL_v/VIL_w	U	32
	sign.	.001		sign.	.01
	dir.	w > v		dir.	w > v
MIL_v/MIL_w	U	36			
	sign.	.01			
	dir.	w > v			
PIL_v/BIL_v	U	non-overlapping	FIL_v/VIL_v	U	3
	sign.	dists.		sign.	.001
	dir.	p > b		dir.	f > v
PIL_v/MIL_v	U	non-overlapping			
	sign.	dists.			
	dir.	p > m			
BIL_v/MIL_v	U	1			
	sign.	.001			
	dir.	b > m			
PIL_w/BIL_w	U	1	FIL_w/VIL_w	U	54
	sign.	.001		sign.	NS
	dir.	p > b		dir.	--
PIL_w/MIL_w	U	non-overlapping			
	sign.	dists.			
	dir.	p > m			
BIL_w/MIL_w	U	6.5			
	sign.	.001			
	dir.	b > m			

In the tests between normal voicing and whisper with the consonants held the same, the clear relationship voice > whisper shown for PIL and BIL and reported on in the previous paper is not maintained on MIL or VIL, where whisper is shown to be significantly greater than voice, or on FIL where no significant difference can be found (but see the results on parameter K below).

For the tests across consonant types, the glottograph traces show the relationships which would be expected, however, namely [p] > [b], [f] > [v], non-nasal > nasal. The latter result is given as the expected one since, at least in normal speech, the presence of an open nasal port above the glottal constriction renders unnecessary any major adjustment of the vocal folds, active or passive, such as may be seen for [b], for example, in order to assure the continuance of voicing. For the comparison MIL with PIL, on the other hand, the contrast is simply between a configuration during which voicing is to be maintained and one in which it has to be interrupted. These results hold true for both normal voicing and whisper, with the single exception that no significant result is shown for [f/v] in whisper; the value of U on this test, however, only just falls short of significance at the 5% level. The data show a trend in the expected direction ([f] > [v]).

Following the practice of the previous paper, Spearman Rank correlation tests between the glottographic measures and the peak airflow measures on release were undertaken. The results are given in table 3. It will be seen that the results fail to cluster along any physical (normal voicing versus whisper) or linguistic dimension of the data. Of the three significant results (but only at the 5% level) two are for whispered speech (PIL, BIL) while the third is for normal speech (FIL). In the whispered pair, however, while r_s for BIL is positive, for PIL it is negative.

TABLE 3

Spearman rank correlation tests between glottographic measure J and peak airflow on release (B + I)

Type	r_s	sign.
PIL_{voiced}	- 0.188	NS
$PIL_{whisper}$	- 0.62	.05
BIL_{voiced}	+ 0.235	NS
$BIL_{whisper}$	+ 0.625	.05
MIL_{voiced}	+ 0.24	NS
$MIL_{whisper}$	+ 0.14	NS
FIL_{voiced}	+ 0.56	.05
$FIL_{whisper}$	+ 0.30	NS
VIL_{voiced}	+ 0.07	NS
$VIL_{whisper}$	+ 0.19	NS

Within the insignificant results there is no trend for the results on whisper to be more significant than those for normal voice.

The results on measurements K and L, carried out for only some of the linguistic types (see section 2.1 above) are given in tables 4 and 5. Two points should be noted. First, a peak was only locatable in some of the traces for $BIL_{whisper}$. Secondly, in the measurement L, the distance from peak to release, the convention has been adopted that those traces where the peak was observed to fall before the release have been designated as "+" values, while those with a peak after the release are given "-" values. "O" means that the peak is coincident with the release. Thus, while for PIL_{voiced} the mean value on L is -0.1 csec , implying that the peak is in general coincident with or even slightly after the release, that for FIL_{voiced} is +5.8 csec , showing the peak to occur well before the release.

Mann-Whitney tests across types and conditions for measures K and L are reported on in table 6. Taking the peak measure (K) first, it will be seen that on all voiced/whisper contrasts for the linguistic types the relationship "voiced greater than whisper" is shown. The relationship between the linguistic types shown for normal speech, namely [p] > [f] > [b] is modified in whispered speech to ([p] = [f]) > [b]. It should be observed, however, that the finding [p] > [f] in normal speech is evidenced at a lower level of significance (.025) than either the finding [p] > [b] or [f] > [b].

On parameter L, which concerns the timing of the peak relative to the release, it can be seen that whereas there is no significant difference in peak position between normal voicing and whisper for PIL, for BIL and FIL a highly significant difference is found. In both cases the voiced scores are higher

TABLE 4

Raw values and illustrative means for glottogram peak (K) for selected traces (in mm of trace)

	PIL voiced	PIL whisper	BIL voiced	BIL whisper	FIL voiced	FIL whisper
1.	19.5	8.5	9.5	4.5	18	7.5
2.	19	12	7.5	-	27	9
3.	25.5	15	8	-	22	8.5
4.	25.5	9.5	6	-	16	8
5.	22.5	11	5.5	-	18.5	7.5
6.	25	10.5	6	4.5	17.5	8.5
7.	19.5	11	7	5	26	9
8.	18.5	6.5	6.5	6	16.5	11.5
9.	18.5	7.5	7.5	4.5	16	8.5
10.	18.5	9	6	6	18	10
11.	18	10.5	7	-	12.5	7.5
12.	18.5	9	8	-	16	5.5
13.	18.5	6.5	7.5	6.5	16	9.5
<u>Means</u>	20.5	9.7	7.1	5.3	18.5	8.5

TABLE 5

Raw values and illustrative means for distance from glottogram peak to release L (in csec)

	PIL voiced	PIL whisper	BIL voiced	BIL whisper	FIL voiced	FIL whisper
1.	-1	-1.5	3.5	2.5	7	5.5
2.	0	0	3.5	-	5.5	6
3.	0	-1	5	-	6.5	3.5
4.	1.5	1	4	-	5.5	3
5.	0.5	0	5	-	7	4
6.	0	0.5	4	0	7	2.5
7.	0	0	4.5	1	5	4
8.	-1	0	3.5	1.5	6	3
9.	-0.5	1	4.5	0	6	3.5
10.	-1.5	-0.5	4.5	0	5	2.5
11.	0.5	0.5	3.5	-	6	2.5
12.	-0.5	1	4	-	4.5	4.5
13.	1	0	3.5	0	4.5	3.5
Means	-0.1	+0.1	4.1	+0.7	5.8	3.7

TABLE 6

Mann-Whitney tests across types and conditions for measures K and L

	K		L	
	U	sign.	U	sign.
$PIL_{voiced}/PIL_{whisper}$	non-overlapping v > w		73	NS
$BIL_{voiced}/BIL_{whisper}$	9.5 v > w	.01	non-overlapping v > w	
$FIL_{voiced}/FIL_{whisper}$	non-overlapping v > w		13.5 v > w	.001
$PIL_{voiced}/BIL_{voiced}$	non-overlapping P > B		non-overlapping B > P	
$PIL_{voiced}/FIL_{voiced}$	39.5 P > F	.025	non-overlapping F > P	
$BIL_{voiced}/FIL_{voiced}$	non-overlapping F > B		9 F > B	.001
$PIL_{whisper}/BIL_{whisper}$	1 P > B	.001	46.5	NS
$PIL_{whisper}/FIL_{whisper}$	55.5	NS	non-overlapping F > P	
$BIL_{whisper}/FIL_{whisper}$	3 F > B	.001	non-overlapping F > B	

than the whisper scores. This is to be interpreted as showing a shift of peak positioning in whisper towards the release.

In normal voice the following significant relationships are shown between the linguistic types, [f] > (= peaks earlier than) [b] > [p]. In whisper, while again the FIL traces peak significantly earlier than those of BIL or PIL, we fail to find the expected distinction made between these last two types.

In table 7 are given the results of Spearman Rank correlation tests between glottogram peak (K) and peak airflow on release (B and I), and between glottogram peak (K) and distance to release (L). On the B/K tests, only the result for $FIL_{whisper}$ is significant, and then only at the 5% level. The value for r_s here is, moreover, positive, in common with that for $BIL_{whisper}$ while all the other results are negative. On the K/L tests there is likewise only one significant result, again at the 5% level, this time for FIL_{voiced}, where the r_s, in common with all results except that for PIL_{voiced}, is negative.

3.3 Results on stop parameters A-F

The raw scores on parameters A-F for the stop consonants are given in table 8. Amplitude measures are given in mm of the trace, duration measures in csec. The results of Mann-Whitney tests across whisper/normal voice and across stop types for these parameters are given in table 10. This table can be further analyzed in terms of three types of comparison, as presented in the following sections.

3.3.1 Whisper versus normal voice tests

There is unanimity over the stop types about the significant differences between normal voice and whisper on the vowel airflow parameters A and C, where, at high levels of significance in all cases, whisper is shown to be greater than voice, and on

TABLE 7

Spearman rank correlation tests between glottogram peak (K) and airflow on release (B + I) and between glottogram peak (K) and distance to release (L)

	B/K		K/L	
	r_s	sign.	r_s	sign.
PIL_{voiced}	-0.35	NS	+0.08	NS
$PIL_{whisper}$	-0.46	NS	-0.18	NS
BIL_{voiced}	-0.04	NS	-0.04	NS
$BIL_{whisper}$	+0.29	NS	-0.5	NS
FIL_{voiced}	-0.01	NS	-0.61	.05
$FIL_{whisper}$	+0.58	.05	-0.44	NS

TABLE 8

Raw scores and illustrative means for stop consonants (for description of parameters, see figure 1).

		A	B	C	D	E	F
PIL_{voice}	1.	11.5	20	4	12.5	18.5	55
	2.	9.5	18	3	8.5	17	55
	3.	9.5	20	2.5	8.5	18	57.5
	4.	10.5	20.5	2.5	9.5	17	56.5
	5.	9	20	3.5	8.5	16.5	55.5
	6.	9.5	18.5	3	8	16.5	58
	7.	10	20	3.5	8	17	56
	8.	10.5	19	3	7.5	17.5	57
	9.	11.5	21.5	3.5	8.5	16.5	56.5
	10.	10.5	20.5	4	8.5	18	58
	11.	10.5	20.5	4	9	15	55.5
	12.	9.5	21	4	8	15.5	53.5
	13.	11	20.5	3.5	9.5	16	56
Means		10.2	20	3.4	8.8	16.8	56.2
$PIL_{whisper}$	1.	16.5	17.5	12	11	16	55.5
	2.	16.5	14	10	9	14	52
	3.	18	16.5	9.5	9.5	14.5	55
	4.	16	15.5	8	10.5	15	55.5
	5.	15	15.5	8	11.5	13.5	54.5
	6.	15.5	16	7	10	14.5	54
	7.	16.5	16	9.5	10	15	54.5
	8.	13.5	16.5	10.5	10	14.5	54.5
	9.	14.5	17.5	8	9.5	15	52
	10.	16	16.5	5	9	15	52.5
	11.	15.5	17.5	6.5	10	14	54.5
	12.	14	14.5	4	11	14.5	55
	13.	14	17	10.5	10.5	12.5	53.5
Means		15.5	16.2	8.3	10.1	14.5	54.1
BIL_{voice}	1.	12	17	2.5	10	14	54.5
	2.	10.5	15.5	2.5	9.5	13.5	52.5
	3.	13	15.5	3.5	10.5	16	55.5
	4.	11	16	3.5	9.5	15.5	57
	5.	10	16.5	2	9.5	14.5	54.5
	6.	11	16.5	3.5	10	14.5	55
	7.	10.5	16.5	3.5	10.5	14	55.5
	8.	13	16	3	9	14.5	55.5
	9.	11.5	16.5	3.5	10	14.5	55
	10.	12	16.5	2.5	9.5	14	54
	11.	11.5	17	2	10.5	14.5	55.5
	12.	10.5	14.5	2.5	9.5	14	53
	13.	12	17	2.5	10	14.5	55
Means		11.4	16.2	2.8	9.8	14.5	54.8

TABLE 8
(continued)

		A	B	C	D	E	F
$BIL_{whisper}$	1.	18	16.5	10.5	8.5	14.5	54
	2.	18.5	15	9	8.5	14	52
	3.	14	14	4	9.5	15	52.5
	4.	19.5	16.5	11	8.5	13.5	53.5
	5.	18	15.5	9	10	12.5	53
	6.	17.5	16	6	10	14.5	55
	7.	17	15	8.5	11	13.5	55.5
	8.	14.5	15.5	9.5	10.5	13.5	55.5
	9.	15.5	15.5	5.5	10	12	52
	10.	15.5	16.5	8.5	9.5	14	52
	11.	18	16	7	9	12.5	52.5
	12.	15	14	6	10.5	13.5	53.5
	13.	16	16.5	4	12	14	55
Means		16.7	15.6	7.6	9.8	13.6	53.5
MIL_{voice}	1.	10	6.5	2	8	13.5	52
	2.	10	7.5	3	10	12.5	53
	3.	8	8.5	2	9	12.5	52.5
	4.	9	9	2.5	8	13.5	53
	5.	10.5	11	2.5	8	13	51.5
	6.	10	9	3	9	13.5	54
	7.	9	12	2.5	9.5	13.5	54.5
	8.	9.5	10.5	3	7.5	13.5	53.5
	9.	12	11	2.5	8.5	13.5	53.5
	10.	10	12	2.5	7.5	14.5	51.5
	11.	8	11	3.5	8.5	13	52.5
	12.	8.5	9	1.5	8	13.5	51
	13.	9.5	10.5	2.5	8.5	13.5	55
Means		9.5	9.8	2.5	8.5	13.3	52.9
$MIL_{whisper}$	1.	17	8	7.5	8.5	14	54
	2.	16	10	3.5	8.5	13	57
	3.	15.5	11	5	7.5	13	53
	4.	16	14.5	5.5	7	13	50.5
	5.	14.5	12	6.5	7.5	12.5	50.5
	6.	16.5	11.5	8.5	8	13	50
	7.	16	13.5	7	7.5	12	51
	8.	15.5	16.5	5.5	7.5	13	52
	9.	15	13	4	7.5	12.5	49
	10.	18.5	13.5	8.5	7	11.5	49
	11.	15.5	9.5	6.5	7.5	12	49.5
	12.	14	12.5	6.5	6.5	11.5	50
	13.	14	13.5	3.5	6.5	13.5	49
Means		15.7	12.2	6	7.5	12.7	51.1

the durational parameters E and F, where normal voice is shown to be of significantly greater duration than whispered speech.

On parameter B, the peak airflow on release, normal speech is shown to be greater than whisper (in contrast to the vowel findings above) for PIL and BIL, although for BIL this finding is only marginally significant even at the 5% level.[1] In MIL, the whispered values are shown on this parameter to be greater than those of normal speech. No pattern at all is revealed on parameter D, the closure duration. Whisper is greater than normal voice for PIL, the opposite result holds for MIL, while for BIL there is no significant difference.

3.3.2 Normal voice differences between stops

On the amplitude measures a consistent pattern is revealed only for B, the amplitude at release. Here the relationship [p] > [b] > [m] is shown extremely clearly. On parameters A and C, concerning the amplitude of the frame vowels, it would seem that the results reflect in each case the presence of unusually high amplitudes for one stop type. On A the [b] traces are of greater amplitude than either [p] or [m] while these latter are not distinguished. On C it is the [p] set that is greater than the [b] and [m] traces.

The consistent pattern [p] > [b] > [m] is revealed on both the durational parameters E and F, while on D the [b] closures are longer than those of either [p] or [m] with these not being distinguished from each other.

3.3.3 Whispered speech differences between stop types

On the amplitude parameter A, no significant differences between stop types are observed, while on C the amplitude of the [m] traces is significantly below those of either [p] or [b],

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1) In Mansell (1973) this result was indeed over-conservatively given as non-significant.

these being indistinguishable from each other. This latter analysis also holds true for three other parameters, airflow on release (B), closure duration (D), and total duration (F). The relationship [p] > [b] > [m], however, is shown on parameter E.

3.4 Results on fricative parameters A,C,E,F-I

The raw scores on the fricative parameters A,C,E,F - I are given in table 9. Mann-Whitney tests across normal voicing/ whisper and fricative type are given in table 11.

3.4.1 Whisper versus normal voice tests

On the amplitude of the frame vowels (A and C) whispered speech is shown to be significantly greater than normal speech for both fricatives. On F, total duration, normal speech is, again in both cases, shown to be significantly greater than whispered speech.

On the consonantal measures, only on the amplitude of the second airflow peak (I) is there agreement on the effects of whisper over the two fricative types. Here the normal traces are shown to be greater than the whispered. This relationship is also shown at the trough (H) for FIL, but on VIL no significant difference can be found. At the first peak, however, while VIL shows the relationship whisper > normal voice, no significant difference can be seen with FIL.

3.4.2 Fricative differences in normal speech and whisper

On the frame vowel amplitude measures there is agreement between normal speech and whisper. While there is a tendency (5% level) for [ə] to be higher in amplitude for VIL than for FIL (A), no significant difference is found for the post-consonantal vowel (C). On the total duration measure there is a

TABLE 9

Raw scores and illustrative means for fricative consonants (for description of parameters, see figure 2)

		A	C	E	F	G	H	I
FIL$_{voice}$	1.	11	3	11.5	43	14	9	19
	2.	11	4.5	13	44.5	12	1.5	19.5
	3.	10	2.5	12.5	42.5	11	2	19
	4.	9	3	11	43	9.5	2.5	17.5
	5.	10	3.5	13	44	14	3	18.5
	6.	9	3	12	43.5	11	3.5	18.5
	7.	9.5	4.5	12.5	43.5	15.5	3.5	22.5
	8.	11.5	3.5	11.5	43.5	12	4.5	19
	9.	10	3	11.5	43	12.5	5.5	21.5
	10.	11.5	4	12.5	44	14	5.5	20.5
	11.	11.5	3.5	11.5	43.5	10.5	4.5	19.5
	12.	9.5	3.5	11.5	43	8	0	20
	13.	11	4	12	43.5	11.5	2.5	21
Means		10.3	3.5	12	43.4	12	3.7	19.7
FIL$_{whisper}$	1.	16.5	8	-	43	13.5	0	15.5
	2.	14.5	10.5	-	40.5	14	2.5	15.5
	3.	16.5	8.5	-	42	13.5	1	14.5
	4.	12.5	10	-	40.5	12.5	1.5	15.5
	5.	14	8	-	41	11.5	0	15.5
	6.	17	8	-	40.5	15.5	0	17.5
	7.	15.5	10	-	42	13.5	0.5	16.5
	8.	15.5	6	-	42	10.5	0	19
	9.	12.5	8.5	-	40.5	11.5	0.5	17
	10.	14.5	6.5	-	41	13.5	0	17
	11.	15	5.5	-	41	12	1.5	16
	12.	12.5	9	-	40.5	11.5	0.5	16
	13.	16.5	10	-	43	13.5	0.5	17.5
Means		14.8	8.3	-	41.3	12.8	0.7	16.4
VIL$_{voice}$	1.	12	2.5	14	42.5	8.5	0	11.5
	2.	11.5	2.5	13.5	44.5	8	0	11
	3.	9.5	3	14.5	44.5	8	0	10
	4.	9.5	3	13.5	45	8	0	10.5
	5.	10	3.5	14	43	8	0	11
	6.	11	3.5	14	46	8.5	0.5	11.5
	7.	10.5	3	13	44	7.5	0	11.5
	8.	13.5	3.5	12.5	44.5	9	0	13.5
	9.	13.5	3	13	44.5	9.5	0	12.5
	10.	10.5	4.5	14.5	44	10.5	0	13.5
	11.	12.5	3	13	42	9	0	14
	12.	11.5	3.5	12.5	44.5	10.5	0	14
	13.	12	4	13.5	43.5	9.5	0.5	12
Means		11.3	3.3	13.5	44	8.8	0.1	11.9

TABLE 9
(continued)

		A	C	E	F	G	H	I
$VIL_{whisper}$	1.	14.5	9	-	43	14	0	14.5
	2.	18	9	-	41	15.5	0	13.5
	3.	15.5	9.5	-	42.5	14.5	0	15
	4.	15	9.5	-	41	13	0	12.5
	5.	16.5	9.5	-	42	14	0	13
	6.	13.5	6.5	-	42.5	10.5	0	14
	7.	18.5	7.5	-	40	15	0	14.5
	8.	15.5	10.5	-	43.5	14	0	13.5
	9.	17.5	8.5	-	41	14.5	0	15
	10.	16.5	9.5	-	40.5	14	0	14.5
	11.	16.5	3.5	-	40.5	15	0	12.5
	12.	16.5	4.5	-	41	14.5	0	14
	13.	16.5	5	-	43.5	15.5	0	15.5
Means		16.2	7.8	-	41.7	14.2	0	14

TABLE 10

Mann-Whitney tests across stop parameters

		A	B	C	D	E	F
	U	non-	non-	2	20	45	17.5
PIL_v/PIL_w	sig.	overlapping	overlapping	.001	.001	.001	.001
	dir.	w > v	v > w	w > v	w > v	v > w	v > w
	U	non-	46	non-	80.5	38	42
BIL_v/BIL_w	sign.	overlapping	.05	overlapping	NS	.01	.025
	dir.	w > v	v > w	w > v	-	v > w	v > w
	U	non-	31.5	1	25	11	34.5
MIL_v/MIL_w	sign.	overlapping	.01	.001	.001	.001	.01
	dir.	w > v	w > v	w > v	v > w	v > w	v > w
	U	29.5	non-	43.5	20.5	4	34.5
PIL_v/BIL_v	sign.	.01	overlapping	.025	.001	.001	.01
	dir.	b > p	p > b	p > b	b > p	p > b	p > b
	U	56	non-	23.5	72.5	non-	5
PIL_v/MIL_v	sign.	NS	overlapping	.001	NS	overlapping	.001
	dir.	-	p > m	p > m	p - m	p > m	p > m
	U	14	non-	62	12.5	12	21
BIL_v/MIL_v	sign.	.001	overlapping	NS	.001	.001	.001
	dir.	b > m	b > m	-	b > m	b > m	b > m
	U	51.5	54	61.5	67	38	66.5
PIL_w/BIL_w	sign.	NS	NS	NS	NS	.01	NS
	dir.	-	-	-	-	p > b	-
	U	79.5	9	35	non-	10.5	21.5
PIL_w/MIL_w	sign.	NS	.001	.01	overlapp.	.001	.001
	dir.	-	p > m	p > m	p > m	p > m	p > m
	U	57.5	13	48.5	3	33.5	28.5
BIL_w/MIL_w	sign.	NS	.001	.05	.001	.01	.01
	dir.	-	b > m	b > m	b > m	b > m	b > m

TABLE 11
Mann-Whitney tests across fricative parameters

Type		A	C	E	F	G	H	I
FIL_v/FIL_w	U	non-overlapping	non-overlapping	-	6	71	14.5	5.5
	sign.			-	.001	NS	.001	.001
	dir.	w > v	w > v	-	v > w	-	v > w	v > w
VIL_v/VIL_w	U	non-overlapping	4.5	-	13	non-overlapping	71.5	16
	sign.		.001	-	.001		NS	.001
	dir.	w > v	w > v	-	v > w	w > v	-	v > w
FIL_v/VIL_v	U	47	66	10	47.5	14	7.5	non-overlapping
	sign.	.05	NS	.001	.05	.001	.001	
	dir.	v > f	-	v > f	v > f	f > v	f > v	f > v
FIL_w/VIL_w	U	47	78	-	68.5	31.5	32.5	6.5
	sign.	.05	NS	-	NS	.01	.01	.001
	dir.	v > f	-	-	-	v > f	f > v	f > v

tendency (5% level) for VIL traces to be longer than FIL traces in normal speech; this tendency is not shown in whisper, however, where no significant difference is found. On the consonantal amplitude parameters agreement is seen between normal and whispered speech on the trough (H) and second peak (I) measures, where in both cases [f] is significantly greater than [v]. While [f] is likewise significantly greater than [v] for normal speech on the first airflow peak (G), the opposite relationship is found on this parameter in whispered speech. On the parameter (E), only measured in the normal speech cases, VIL traces are shown to be significantly greater than FIL traces.

4. Discussion

It would, I think, be fair to characterize conventional assumptions about whisper in the following terms: the glottis is throughout more open than in normal speech, and the airflow consequently, in both vowels and consonants, higher. With respect to timing in whisper, one can expect general agreement with the words of Slis and Cohen (1969) when they claim:

> "It seems justified to consider whispered speech as normal speech minus voice, leaving the time structure and probably transitional cues intact."

It will be the main task of this section to isolate those aspects of the results which cannot be accomodated under this model, or separately accounted for in ways which do not require modifying it. Having isolated them it has to be decided whether there is a consistent pattern observable in the data and a reasonable explanation available, or whether these data are better considered to be aberrant in some way. It will be seen below that glottal behaviour during consonantal constriction in whisper is possibly implicated in all traces that cannot be accomodated without alteration to the simple model above. Hence one would normally expect the glottograph records to be decisive in the evaluation of the data. Unfortunately, the arguments for and against placing reliance on the glottographic traces are quite finely balanced in the present case. This point is so central that it will be dealt with first, in 4.1 below. Those traces explainable without modification to the simple model of this section will be enumerated in 4.2, while in 4.3 the question of the exceptional traces will be considered.

4.1 The glottographic evidence

In Mansell (1973), where only the results from PIL and BIL were analyzed, the possibility of pharyngeal narrowing, as reported for some varieties of whisper by Ohala and Vanderslice (1965) was invoked to explain the fact that glottographic traces were much lower in amplitude for whisper than for normal voice. It was hypothesized that this narrowing was sufficient in the English data to extinguish the trace altogether, since the photocell had not been anchored, while in the Danish case attenuation only was the result, some light being passed to the photocell by means of the anchoring tube passing into the oesophagus. It is unfortunately the case, however, both that the airflow results from MIL, to which I return in the following section, make it unlikely that any single factor like pharyngeal narrowing is available to explain the present data, and that the relationship voiced > whisper, observed in PIL and BIL, fails to show up on any of the extra traces examined here. It is further far from clear why VIL and MIL should group together in showing whisper voice on Table 2, although the lack of any significant difference between FIL_{voice} and $FIL_{whisper}$ on glottogram height at release is probably attributable to the inappropriateness of the measurement parameter in this case, the peak of the fricative glottal movement having already been reached some time before. Note that where the peak is considered (table 6) the relationship voiced > whisper is found for all types examined.

The second aspect of the glottographic traces which causes some concern is the lack of a notable increase in amplitude in the carrier vowels in whisper as against normal speech, despite the fact that all types show marked airflow increase in these vowels in whisper.

Finally, on the negative side, there is the evidence of tables 3 and 7; the extra traces and parameters examined here serve to strengthen the conclusion from similar tests in Mansell (1973), that no reliable correlation was to be expected between glottographic traces and airflow. It would seem that neither for normal voice or whisper is either instantaneous area, as shown by parameter J, nor the maximum area reached by the glottis (K) correlated with the airflow at release. These results are so far removed from conventional assumptions about glottal action and aerodynamic results as to necessarily throw doubt on the validity of the traces. It should be noted here also that the correlation tests between amplitude and timing scores for the glottogram peak failed to show up any pattern of internal organization for the traces, and hence could not be used to look for distinctions between normal and whispered speech.

There are aspects of the glottographic results, however, which would lead us to suppose that these traces were providing a proper reflection of reality. In the first place distinctions between linguistic types which are shown at the glottis in normal speech are likewise in general shown in whispered speech. The only exceptions are for J on $FIL_{whisper}/FIL_{voice}$, where, as has been previously noted, the measurement parameter may not be appropriate, $PIL_{whisper}/FIL_{whisper}$ for parameter K, where, however, the distinction found in normal speech between PIL and FIL may be regarded with some suspicion, the finding being at a fairly low level of significance, and $PIL_{whisper}/BIL_{whisper}$ for parameter L, where a general shift of glottographic peaks towards the release can be seen in whisper, involving the collapse of BIL and PIL timing scores in whisper (see below). Further, despite the fact that significant correlations are not shown between the individual values of glottograph amplitude and airflow on release, it is nonetheless the case that the relationships shown between types on the glottograph measure J ([p] > [b] > [m], and [f] > [v]) are reflected exactly in the airflow on release results for normal speech, and in a closely approximate form in whisper (([p] = [b]) > [m], [f] > [v]). Again, despite the general amplitude diminution it can be repeated that, as the scores for K on table 4 show, there is a marked peaking of the glottographic trace for the consonants in both PIL and FIL, voiced and whisper, and also in BIL voiced and in some whispered cases too.

Furthermore, on the durational parameter E for the stops, the relationship [p] > [b] is shown for both normal and whispered speech. This result has relevance to the glottographic traces in that scores on parameter E in normal voicing at least contain a period of aspiration. If we measure the duration only of the voiced portion of the post-consonantal vowel in normal voiced PIL and BIL we find a range of 9.5 - 11.5 csec for PIL, and a range of 12.5 - 14 csec for BIL. This echoes the result VIL > FIL found on the same measurement for the normal voiced fricatives. It is thus seen that for normal speech the aspiration is the all-important factor in making [p] greater than [b] on parameter E. It is difficult to avoid the conclusion that the E measurements in whisper also contain an "aspiration" phase.

If this were so, it would be an argument on the one hand for the validity of the glottographic traces, since these - whatever the reason for the overall drop in amplitude - show greater opening for $PIL_{whisper}$ than for $BIL_{whisper}$, greater opening being by conventional assumptions associated with aspiration. On the other hand, it would also be an argument for the validity of the simple model for whisper outlined in section 4. above. For if we believe that the laryngeal gestures in whisper are essentially the same as in normal speech, and if we believe, as, for example, Rothenburg does, that the timing of stops is related principally to a glottal cyclic movement, then the results on parameter E are only what would be expected. If, on the other hand, it is believed that the laryngeal consonantal gestures in whisper are different from those in normal speech, it is a formidable problem to explain why these different gestures should have produced the same durational result as in normal speech on the post-consonantal vowel.

The only point which counts against the above is the fact that whereas in normal speech the closure phase (parameter D) for BIL is longer than for PIL, this distinction is neutralized in the present data for whisper. The results on this parameter are discussed in 4.3 below.

In summary, it will be evident that there is sufficient uncertainty about the factors involved to make it impossible without further research to decide on their validity. The addition of further data in this paper over Mansell (1973) has, it should be noted, added a number of facts to the data which make the glottographic findings more plausible. It can be suggested that a useful place to start with further research may well be in the investigation of glottographic registration in different kinds of whisper. In both the Danish case and the English case considered in the previous paper, the type of whisper used by the subjects was certainly very strong, perhaps even tending towards stage whisper. This may well have affected the results, since it is well-known that the glottis configurations for different types of whisper vary. Further, while the experimental design employed renders most of the artefacts listed in Frøkjær-Jensen et al. (1971) irrelevant here, the sensitivity of the photocell to activity at different parts of the larynx (point 2(3) in their paper) has by no means been catered for in research so far.

4.2 Results not requiring emendation of the simple model of 4.

On the whispered speech/normal speech comparisons the MIL traces, considered here for the first time, play a pivotal role in the evaluation of the other traces, for in MIL not only is airflow during the frame vowels larger in whisper, but also after the consonant, suggesting that the larynx was here held open at least at the configuration for the vowels during the consonantal closure. The results for MIL thus correspond fully with the predictions of the simple model for whisper outlined in 4. above. Further, for MIL, the duration results are maximally simple, in that the general shortening of durations observed in whisper is found on all three durational comparisons, D, E and F. Since the only suggestion I have to make about this general shortening is that it may be attributable to some relationship between air expended and duration of utterance, an explanation which does not cater for differential shortening of parts of the utterance, the MIL result is better viewed as correct than any of the other patterns observed in the results.

All stop traces share the direction of the MIL results on parameters A, C, E and F. Not falling under the MIL paradigm are the B measures of PIL and BIL, where normal voice airflow amplitudes are greater than in whisper, and the D measures for the same types, where the normal speech > whisper result is not shown. In the fricatives the only results on the normal speech/

whisper comparisons which do not fit into the MIL type model are G, H and I for FIL, and H and I for VIL. The result on the G parameter for FIL is probably attributable to the presence of a set of unusually low FIL whisper signals on this parameter. There is also the result $VIL_{whisper} > FIL_{whisper}$ on this parameter in table 11 which contradicts the finding $FIL_{voice} > VIL_{voice}$. This result can also be explained by postulating values for $FIL_{whisper}$ which are lower than to be expected.

In the contrast between stop types, it has already been noted in 4.1 that on the durational parameters the same relationships are approximately adhered to on the durational parameters E and F in normal speech and in whisper. The results on the carrier vowel amplitudes differ from normal voice to whisper, but it is probably unsafe to conclude anything from this. An explanation in terms of irregular results in one type such as was used in the presentation of results on these parameters in 3.3.2 and 3.3.3 is probably sufficient to account for the data. For the fricatives a tendency for the pre-consonantal vowel to be higher in amplitude before VIL than before FIL is shared by normal speech and whisper, while no significant difference is found for either condition in the post-consonantal vowel.

On parameter B the expected result [p] > [b] > [m] is shown in normal speech. In whisper, however, while the non-nasal stops are still greater than the oral stops, [p] and [b] are neutralized. This finding has no explanation within the simple model of 4.

On parameter D, in accordance with the findings of Fischer-Jørgensen (1966) the closure duration for [b] in normal speech is shown to be greater than for [p]. It is also found that [p] is not distinguished from [m]. In whisper, however, [b] and [p] are neutralized, with both being shown to be greater than [m]. Once again, there is no basis for this neutralization in the simple model of 4.

Finally, the only clear distinction between normal and whispered speech, besides the general diminution in amplitude, which emerges from the glottographic results is the shift in peak timing towards the release shown for BIL and FIL in whispered speech. The fact that PIL does not appear to show this trend can be perhaps simply accounted for by the fact that PIL peaks in normal voice are already coincident with or even subsequent to the release, and could not hence be shifted rightwards. This finding is not accomodated in the model of section 4.

It is thus claimed that the only results on tables 6 and 7 that require an extension of the simple model of 4, are:

PIL_v/PIL_w	:	B	D	
BIL_v/BIL_w	:	B	D	L
PIL_w/BIL_w	:	B	D	
FIL_v/FIL_w	:	H	I	L
VIL_v/VIL_w	:	H	I	

4.3 The exceptional results

First, the duration results on parameter D for the stops. MIL has normal voice > whisper on this parameter. For this pattern to be changed in the PIL_v/PIL_w comparison, the duration of the whispered PIL traces must be considerably longer than expected. This would explain also the non-significant result for the PIL_w/BIL_w comparison on this parameter. It is not unreasonable to suppose further that the non-significant result on the BIL_v/BIL_w comparison can also be explained via a lengthening of the whispered traces. I cannot at the moment, however, suggest any underlying cause for this lengthening. In the present context it is tempting, of course, to regard the durational measures as dependent upon glottal action; against this, however, speaks the fact that the same time relationships are observed in the post-closure phase (release and post-consonantal duration, parameter E) in both PIL and BIL traces in normal and whispered speech. The one set of results argues as stated in 4.1 above, for the same set of events at the glottis in normal speech and whisper, whereas the other demands that a different set be postulated. I am inclined to conclude that on the present evidence the durational results not covered by the simple model are in all probability artefactual in some manner.

Secondly, a minor point, concerning the symmetry of the amplitude results. The disagreement between the FIL_V/FIL_W comparison and the VIL_V/VIL_W comparison on parameter H arises, it seems from inspection of the raw scores in table 2, from the fact that in the normal speech traces the airflow registration sinks to the baseline during the trough, so that the possibility of there being a further diminution during whisper is ruled out.

We are thus left finally with a symmetrical set of airflow results which together suggest that the segmental activity of some part of the vocal tract may be different during these consonants in normal speech and whisper. It remains to be seen what possibilities there are for such alterations, and what arguments there are, on the other hand, to suggest that the results are artefactual. Mansell (1973), on the basis mainly of the English data, came to the conclusion that supraglottal manoeuvres were unlikely to be implicated, a view which is echoed here. This leaves subglottal or glottal parameters. Mansell (1973) was inclined to find adduction on the glottal level unlikely, and suggested that a subglottal explanation be sought. What this explanation might be was, and still must be, left vague. Note that the possibility of adduction at the glottal level is not ruled out in principle, since what is here labelled "adduction" may simply be a change in glottal configuration which happens to offer more resistance to airflow than that assumed during consonants in normal speech. Certainly, until an adequate analysis of the involvement of laryngeal muscles in forming the glottal configuration for whisper, this question cannot be decided. It is precisely at this point, however, that airflow and glottographic traces come into conflict, since, as noted above, the glottographic traces do show peaking in the constriction phase for both [p] and [f] in whisper. The only possibility of a resolution of this conflict lies in the timing of the glottal gesture; it may be that timing differences, such as those revealed here on parameter L could lead to effects such as have been observed. Consideration of this point, however, requires the context of further research.

If we add to the above the reminder that in the airflow on release data of Lehiste (1964; see p. 168ff) the whispered consonants follow by and large the simple model of 4. above, then it will be evident that the general validity of the results treated in this section is in some doubt, especially since so many of the other results achieved can be explained by a model requiring no reorganization of articulation from normal speech to whisper. Even given this doubt, however, no conclusion seems justified here other than that if there <u>is</u> segmental reorganization in whisper, it takes place in a very restricted context (during the constriction for consonants and apparently nowhere else) and in a restricted set of segments (not, for example, in nasal consonants). It remains an urgent task for further research to provide adequate direct measures of glottal activity in whisper.

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