Ann.Bull.RILP(1985)No.19, 111-132

F_0 DECLINATION: THE SETTING AND RESETTING OF THE BASELINE

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1. INTRODUCTION

Intonation is an abstract phonological structure that manifests itself as a succession of perceptually salient pitch changes. These changes have their acoustic basis in the varying fundamental frequency (F_0) of the speech wave, which, in turn, reflects the changes in the rate of vocal fold vibration. Any production model of intonation will therefore have to explain which physiological mechanism(s) can be held responsible for the changes in the periodicity of the laryngeal pulsing.

It has been repeatedly demonstrated that an increase in F_0 can be brought about most efficiently by the contraction of the cricothyroid muscles (CT). On the other hand, most F_0 falls can be explained in terms of CT relaxation, while some others -especially in the speaker's mid to low register- may require the activity of the strap muscles of the neck, e.g. the sterno-hyoid muscles (Atkinson 1978, Ohala 1978). The general picture that emerges is, that intonational features are implemented by laryngeal muscle activity. The phonetic properties of the resulting F_0 changes (their direction, magnitude, timing, etc.) are determined not only by the nature of the intonation pattern that is being realized, but also by the syntactic and accentual structure of the sentence on which this pattern occurs. Therefore, the production of an intonation pattern requires a certain amount of preplanning.

The perceptual characterisation of a pitch contour requires one more ingredient than the specification of the perceptually obtrusive rises and falls. It appears that these conspicuous changes relate to a reference line that is not strictly horizontal, but gradually drifts down over the entire course of an utterance: the so-called "declination line" (Cohen and 't Hart 1967). The perceptual relevance of declination is such that it cannot be omitted in intonation synthesis-by-rule without making the utterance sound less natural. Consequently, any account of intonation production has to incorporate a physiological explanation for the declination phenomenon, too.

There has been some speculation that F_0 declination can be explained for the greater part in terms of the gradual decrease of subglottal air pressure (P_{sg}) in the course of the utterance (Collier 1975, Collier and Gelfer 1984). If declination is viewed as the automatic by-product of the expiratory activity during phonation, its (psycho-)linguistic status is rather

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low: the speaker need not care about actively producing the declination effect and no preplanning is involved.

Recently, however, this view has been challenged. It has been shown that the slope of the declination line varies with utterance length and with syntactic category, and that the declination ramp is "reset" at certain types of syntactic boundary (Maeda 1976, 't Hart 1979, Cooper and Sorensen 1981, Thorsen 1983). These findings suggest that the status of declination has to be elevated and that the phenomenon is of linguistic importance. A review of the issues that surround declination is presented by Cohen, Collier and 't Hart (1982).

This paper deals with some physiological factors that may determine the F_0 value at the beginning of an utterance (i.e. the onset or "setting" of the declination baseline) and the F_0 value at the beginning of a clause that follows a syntactic boundary (i.e. the possible "resetting" of the declination line). The data to be presented concern the relationship between F_0 values at the onset and at the end of clauses on the one hand, and measures of P_{sg} variation and EMG activity in the CT muscles on the other.

2. DECLINATION (RE)SETTING

In publications by Cooper and Sorensen (e.g. Cooper and Sorensen 1981) declination is defined in terms of F_0 maxima rather than minima: they introduce the concept of Topline declination as opposed to Bottom line (or Baseline) declination. With regard to the former, they present a limited amount of data to suggest that a new declination ramp may be (or has to be) started at certain types of clause boundaries, viz. if two main clauses are adjoined. This resetting of the declination line therefore takes into account the location and the nature of the syntactic boundary and requires a certain amount of preplanning on the side of the speaker.

In the experiment to be discussed I wanted to investigate (a) whether there is (baseline) declination resetting at the syntactic boundary between a main clause and a subclause; (b) if so, how this resetting is brought about by the physiological mechanisms that can influence the rate of vocal fold vibration.

2.1. Linguistic variables

The utterances to be produced by the subject were Dutch and were of the main clause+subclause and subclause+main clause type. The two constituent clauses were both "short" or both "long" (some five or ten syllables, respectively). Each combination of subclause and main clause was read with four partly different pitch contours. There was a brief pause at the syntactic boundary, and in one half of the materials there was a breath intake during that pause. The utterances were syntactically and prosodically so designed that exactly the same clause could occur either before or after the syntactic boundary. The complete set of utterances with their stylized pitch contours is listed in Table I.

2.2. Physiological variables

Simultaneous recordings were made of the electromyographic activity in the left and right side cricothyroid muscles and of the subglottal air pressure. The EMG signals were picked up using bipolar hooked-wire electrodes, prepared according to the technique described by Honda et al. (1983). For the measurement of P_{sg} use was made of a miniature pressure transducer (Gaeltec, model 12D-104, 4F). The device has a diameter of 1.32 mm. It is inserted through the nose and reaches down between the vocal folds.

The physiological signals were analog-to-digital converted before being stored on video tape. The audio signal was recorded separately. The EMG and pressure data were computer processed, using techniques similar to those described by Harris (1981). F_0 extraction was done by means of the algorithm of Duifhuis et al. (1982).

The author, a native speaker of (Southern) Dutch, served as the subject. He read all the utterance types twice, in semi-randomized order.

3. RESULTS

We will first examine whether there is resetting of the F_0 declination line at the syntactic boundary. Then we will attempt to relate this acoustic phenomenon to the physiological variables that are supposed to cause it.

3.1. F_0 declination resetting

We will concentrate on baseline declination resetting, with occasional attention to what happens to the topline. To this end we will compare the F_0 values at the beginning of the second clause (B2) to those at the beginning (B1) and at the end (E1) of the first clause. Since the two clauses are of approximately equal length, there is resetting if F_0 is significantly higher at the beginning of the second clause (B2) than at the end of the first (E1). In such a case the F_0 onset value of the second clause (B2) may still be lower than that at the beginning of the first (B1), or it may be equal to it. This difference is one of degree and, following Sorensen and Cooper (1980), one may make a distinction between "partial resetting" (if B2<B1) and "complete resetting" (if B2=B1). We will examine the F_0 data from this double point of view. In doing so, we will analyze the data in a token by token fashion and compute average values for comparable

utterance types.

3.1.1. Partial resetting

In order to verify the hypothesis that there is at least partial resetting in the data, we have to differentiate utterances that have low pitch before and after the pause and those that have high pitch in that location (see the stylized contours in Table I). Table II lists the two relevant subsets of the data (viz. the "low-low" and "high-high" utterance types). The F_0 values are presented in two ways: as averages computed over an entire syllable, and as extreme values, i.e. lowest F_0 in E1 and highest F_0 in B2.

In the first subset of the data, in which F_0 is low before and after the boundary, there is evidence of partial resetting: F_0 is systematically higher in B2 than in E1. The average amount of resetting is 9 Hz or 10.2% of E1 if we compare the average values, and it is 15 Hz or 17.4% of E1 if we look at the extreme values, which -of course- enhance the resetting effect. Perceptually these differences amount to 1.7 and 2.7 semitones, respectively. This amount of resetting is probably large enough to be perceived easily. Indeed, Isačenko and Schädlich (1970) have found that (monotonous) adjacent syllables audibly differ in pitch if they are about 5% or somewhat less than 1 semitone apart. Notice that the tendency for baseline resetting is consistently present in all the individual utterances of the first subset and must therefore be considered an integral feature of the speaker's intonational plan.

In the second subset of the data F_0 is high before and after the pause. With two exceptions (viz. nos. 3 and 17), F_0 is always lower after the pause than before. Consequently, for these cases of topline declination there is no evidence of partial resetting in the sense of the definition given above (viz. B2>E1). On the average F_0 is 9 Hz or 4.5% lower after the boundary than before if based on syllable averages and it is 5.5 Hz or 4.4% lower in terms of extreme values. These differences amount to less than 1 semitone and are not likely to be perceived. These perceptually irrelevant F_0 differences may reflect the speaker's plan to suspend declination during the pause and to start the second clause at the same pitch as at the end of the first. This suspension of declination may be considered a weak form of partial resetting.

Notice, finally, that the characteristics of the first four utterances in each subset are not different from those of the last four. This means that the presence of inspiration during the pause does not affect the F_0 value at the onset of the second clause.

3.1.2. Complete resetting

We will now examine the question whether the established resetting of the baseline in "low-low" contours leads to F_0 onset values for the second clause that approximate the onset values of the first. In other words, is there "complete resetting"? The relevant data are presented in Table III. They concern all the utterances that have low pitch both at the beginning of the first clause (B1) and at the beginning of the second (B2), irrespective of their other intonational features (see the stylized contours in Table I). The first subset of the data are utterances without inspiration during the pause, the second subset is with inspiration.

In both subsets we notice some variability from one utterance to the other: B2 may be higher or lower than B1, or be equal to it. But in at least half of the instances the difference between B1 and B2 is small. If we pool the utterances of each subset together, there appears to be complete resetting in the first group (nos. 1 through 11), but that is less clearly the case in the second group (nos. 13 through 24). Indeed, in the latter case the F_0 value in B2 is on the average about 6 Hz or 6% lower than in B1. If we overlook the relatively small difference between the two subsets and pool the data together, the following picture emerges: at the beginning of the second clause F_0 remains some 4 Hz below the onset value of the first, but perceptually this difference is so small (less than one semitone) that it is likely to result in an impression of equal pitch, i.e. of "complete resetting".

3.1.3. Conclusion

The data in Tables II and III combined suggest that the speaker aims to start the declination (base-)line of the second clause at an F_0 that is perceptually higher than that at the end of the first clause. In his effort to do so he raises F_0 to a level that may or may not be equal to that at the beginning of the first clause, but is perceptually not distinguishable from it. The fluctuations in the F_0 relation between the two clause beginnings may simply be experimental noise or may be taken as an indication that the speaker does not actually intend to achieve complete baseline resetting, but rather selects the starting pitch level of the second clause independently of that of the first: to start a new clause is like to start a new utterance. This conclusion may seem paradoxical: while resetting highlights the syntactic bracketing of the utterance, it disrupts the prosodic continuity and the integration of the clauses. However, resetting -as defined here- is a very local phenomenon that is limited to the F_0 relation between clause-initial syllables. There certainly are other ways of prosodically integrating the clausal constituents of an utterance or the sentential components of a paragraph (Lehiste 1979, Thorsen 1984). For instance, in our own data there is a tendency for the F_0 range to be narrower in the second clause than in the first: comparable pitch accents have lower F_0 peaks in the second utterance half.

3.2. Physiological correlates

The subtsantial partial resetting, which often amounts to complete resetting, can in principle be caused by at least two physiological variables, viz. increased CT activity and heightened P_{sg}, since both are known to increase the rate of vocal fold vibration.

We will first examine whether P_{sg} alone can account for the observed amount of resetting.

3.2.1. Subglottal air pressure

P_{sg} was measured in the middle of the vowel of the first syllable of the two clauses (in B1 and B2, respectively) and in the last syllable of the initial clause (E1). Table IV presents the data that are relevant for the cases of partial resetting. Remember that if F_0 is low before and after the pause, there is resetting of 15 Hz on the average (for extreme values).

P_{sg}, however, appears to be increased by an average of less than 1 cm aq only. Therefore, this variable cannot be held responsible for the full extent of F_0 resetting in these instances.

Moreover, the correlation of ΔF_0 and ΔP_{sg} for this subset is not only small, but negative (-.16). The same negative correlation holds for the second subset of the data, where F_0 is high before and after the pause. Here we notice an average P_{sg} increase of about 1 cm aq, whereas the F_0 value at the onset of the second clause is 5 Hz lower on the average (extreme values). It can only be concluded that the speaker habitually increases the P_{sg} level after the pause, but that this increase does not explain the observed F_0 differences, neither in individual tokens nor on the whole.

As far as the cases of (nearly) complete resetting are concerned, we can infer from Table V that, despite its increase after the pause, P_{sg} is systematically lower at the beginning of the second clause (B2) than at the onset of the first (B1). The average difference amounts to 2.44 cm aq if there is no inspiration during the pause, and to 1.13 cm aq if there is. Although this seems a logical state of affairs, it has to be noticed that this reduced difference between B1 and B2 is not due to higher P_{sg} levels in B2, but to (unexplainable) lower P_{sg} levels in B1. In any case, the systematically lower P_{sg} values in B2 refute the hypothesis that this variable alone can account for the observed almost complete resetting in the F_0 data. The limited increase of P_{sg} cannot even explain (part of the) resetting in individual tokens: if we correlate ΔF_0 and ΔP_{sg} in the first subset of the data, the coefficient is .26, in the second subset it is .25 and for the ensemble of the data it is only .10.

It thus seems to be the case that the speaker only cares to raise P_{sg} to a level that will allow for adequate phonation, without taking into account the syntactic make-up of the utterance or the order of the constituent main and subclauses. It may be added that the onset value of P_{sg} does not show any dependence upon the anticipated clause length either: the longer utterances in Table V (viz. nos. 7 to 11 and 19 to 24) have no higher P_{sg} levels at their clause onsets than the shorter ones.

3.2.2. Cricothyroid activity

From what precedes it is apparent that P_{sg} primarily provides the driving force for phonation and cannot explain the momentaneous F_0 values in any detail. This conclusion merely confirms the results of many other experiments (Ohala 1970, Collier 1975). Indeed, the same peak of F_0 can be reached with different levels of P_{sg}, even the highest F_0 values can be attained when P_{sg} is actually strongly decreasing, as in the case of a continuation rise on the last syllable of a clause. In all reported cases, F_0 correlates most directly with laryngeal muscle activity, particularly with that of the CT muscles. Therefore, one may expect that this pair of muscles is also actively involved in the setting and resetting of clause-initial F_0, i.e. in establishing the onset level of the declination line.

However, this onset level may require only a fairly low F_0 value, especially if the intonation pattern prescribes low pitch at the beginning of the clause. In such a case little or no CT activity may required to start phonation in the mid to low portion of the speaker's range (e.g. at about 100 Hz in the case of our subject). This state of affairs makes it difficult to examine the role of the CT muscle in (re-)setting the declination line, especially in the present data, in which the maximum amount of CT contraction corresponds to about 100 microvolts only. Consequently, the measuring accuracy is rather low.

We will first discuss the difference between the clause-initial CT values in this experiment and will supplement these findings with data from another experiment with the same subject. Table VI lists the EMG values of CT for the first syllable of each pair of clauses (B1 and B2). The difference in the level of CT activity is then compared to the corresponding difference in F_0 and P_{sg} at the clause onsets. Qualitatively the correspondence between ΔF_0 and ΔCT is quite good: if F_0 is lower in B2 than in B1, CT activity is lower, too; if F_0 is higher in B2 than in B1, CT activity is higher or the same. There is only one counterexample, viz. utterance no. 24.

The correlation between ΔF_0 and ΔCT produces a coefficient of .78 for the syllable averages of F_0 and .74 for the extreme F_0 values ($p < .005$ in both cases). The significance of this correlation strongly supports the hypothesis that the onset frequency of the declination line is dependent upon the level of CT activity. Furthermore, the absence of any correlation between ΔP_{sg} and ΔCT indicates that the two variables do not compensate each other in setting the initial F_0 level (r=.006).

Other CT data on the same subject provide additional evidence on the role of the CT muscle in this matter. They were recorded during an experiment by Gelfer et al. (1983).

Fig. 1A shows CT averages of five repetitions of the same utterance type, i.c. a sequence of [ma] syllables of about 1, 2 and 3.5 s, respectively. The utterances all have a rise-fall F_0 change on their second syllable (see Fig. 1B). It can be seen that a major burst of CT activity corresponds to this F_0 inflection (immediately after time 0). But notice that there is also a smaller peak of CT activity associated with the first syllable. This peak may be considered as a contribution of CT to setting the utterance-initial F_0 level (i.e. the onset of the declination line) at an average of 110 Hz.

Fig. 2A presents CT averages for utterances that have a rise-fall inflection on their penultimate syllable, as illustrated in Fig. 2B. The utterances are Dutch and their duration increases in three steps: 1.5, 2.5 and 3.5 s, respectively. The CT tracings are averages over five repetitions. Notice again the CT burst near time 0, i.e. for the pitch accent on the penultimate syllable. But also notice the important increase of CT activity at the beginning of the utterance. This initial CT peak does <u>not</u> result in a local inflection in the F_0 curve. In our opinion, it rather contributes to raising F_0 to a level that is appropriate to start the declination line from (here on the average 125 Hz). In the three cases of Fig. 2A, CT relaxation proceeds rather gradually after the initial burst and certainly less abruptly than at the end of the utterance. The time course of this relaxation may reflect the speaker's rather accurate laryngeal control over the declination slope during the first few syllables of the utterance. Once CT has become inactive, the remaining portion of the declination line is likely to be controlled by decreasing P_{sg}.

These two sets of data lead to the following conclusion: depending on the F_0 value that the speaker wants his utterance to start from, he activates his CT muscles to a corresponding degree (unless the amount of laryngeal tension that results from the activity of other muscles is sufficient to reach the intended level). In other words, some amount of CT activity may be required to set or reset the declination baseline. Furthermore, the pattern of CT relaxation may influence the rate at which F_0 slowly declines.

4. GENERAL DISCUSSION AND CONCLUSION

The pitch contour of an utterance may be considered as the sum of two ingredients: localized rises and falls, super-imposed on a baseline that gradually drifts downward. To a first approximation these two components have separate physiological origins: the pattern of CT activity explains the perceptually salient rises and falls, while the slowly decreasing P_{sg} is responsible for the declining baseline (Collier and Gelfer 1984). This simple model can cope with the production of a variety of intonation patterns in fairly short utterances, which (therefore) start at a moderately low pitch level. However, for longer utterances a more complex model is needed, since they show a tendency to start from proportionally higher pitch levels. In such cases the beginning of the utterance or the clause has to be produced with a certain amount of CT contraction, sufficient to raise F_0 to the required onset level. Then the relaxation of this muscle, in combination with decreasing P_{sg}, accounts for the initial portion of the declination line and, as soon as CT activity ceases, the remaining stretch of the declination line is controlled by falling P_{sg} only.

In the introductory paragraphs of this paper it was pointed out that declination can no longer be seen as the automatic by-product of expiratory activity: some of its features are determined by linguistic variables and the speaker has to incorporate the appropriate declination values into his mental plan, when programming the production of an intonation pattern. This production plan may be seen as the implementation of an ensemble of perceptual (melodic) targets. Having computed these melodic targets, the speaker knows which physiological means will meet his perceptual ends. More specifically,

(a) In order to <u>set</u> the starting level of the declination baseline, the speaker has to estimate whether the current degree of laryngeal tension (in the prephonatory stage) is sufficient to attain the intended frequency of vocal fold vibration. If not, he increases this tension by an appropriate amount of CT contraction;

(b) In order to control the <u>slope</u> of the declination line, the speaker regulates the time course of CT relaxation, or the rate at which P_{sg} decreases, or both;

(c) In order to <u>reset</u> declination, e.g. at a syntactic boundary, the speaker proceeds in a way that is not basically different from the utterance-initial setting of the baseline.

The physiological data reviewed in this paper provide evidence in favor of a laryngeal component in the control of declination and argue against the exclusive role of P_{sg} in this matter. This laryngeal component deserves further investigation and in future experiments the EMG data sampling should include other muscles that can influence slow variations in overall laryngeal tension. Needless to say that observations on more subjects are needed: all that was said above about "the" speaker may only be valid for "this" speaker.

Acknowledgements

This research was carried out while the author was a guest at the Research Institute of Logopedics and Phoniatrics, University of Tokyo (Japan), in the summer of 1984. The hospitality and the help of the colleagues in the Institute is gratefully acknowledged. The author is also much indebted to H. Fujisaki (Dept. of Electrical Engineering, Univ. of Tokyo) for several stimulating conversations on the subject of this paper. Finally, the author wishes to thank J. 't Hart and L. Leroy for their very helpful comments on an earlier draft of this text. The research was funded in part by the Belgian National Science Foundation (NFWO).

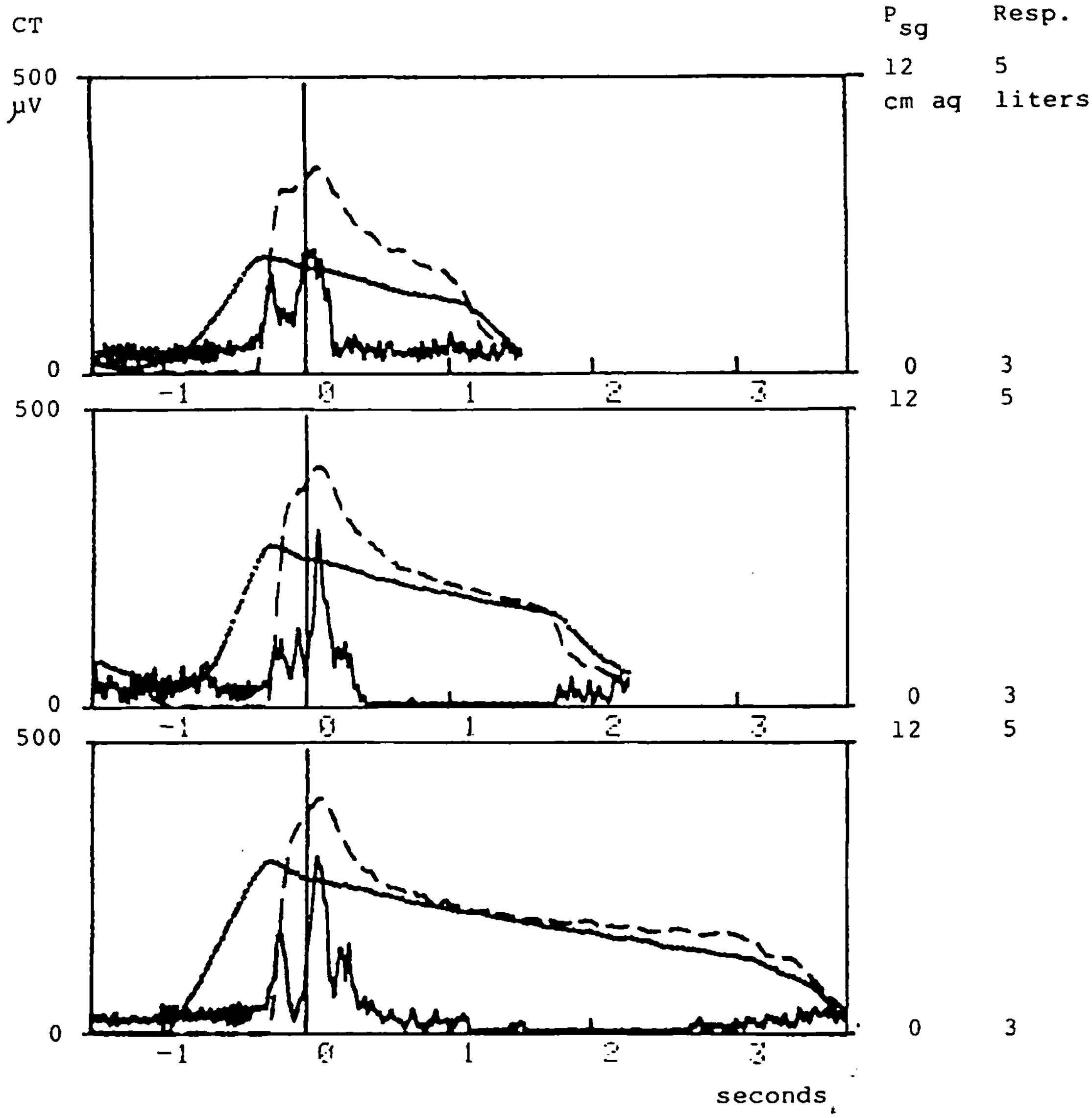


Fig. 1A. Three sequences of [ma] syllables of increasing length, with stress on the second syllable. In each plot the dashed line is P_{sg}, the dotted line is relative lung volume and the solid line is CT activity. The data are averaged over 5 repetitions.

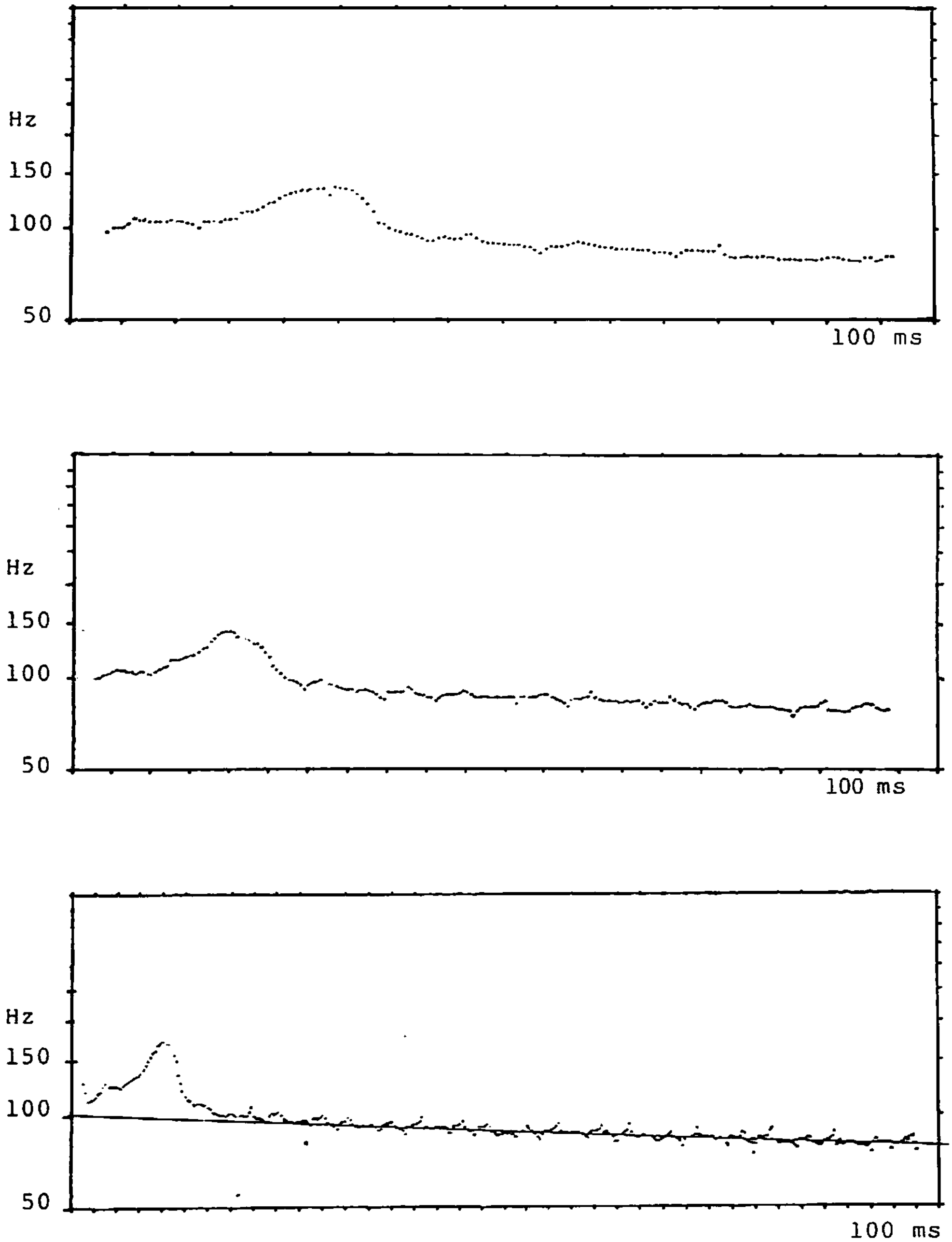


Fig. 1B. F_0 curves corresponding to the second of the five repetitions of the [ma] syllable sequences in Fig. 2A.

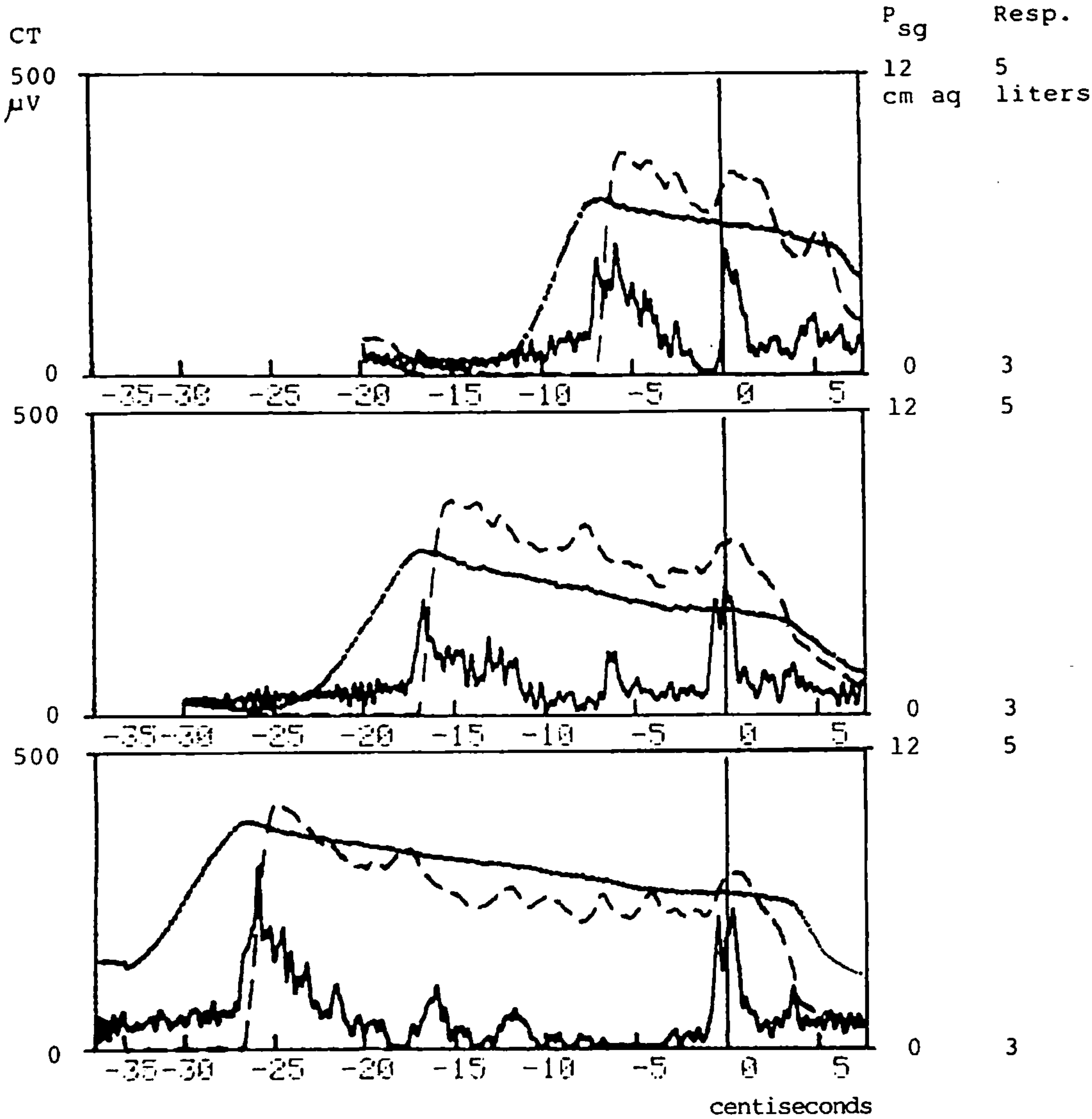


Fig. 2A. Three Dutch sentences of increasing length, with stress on the penultimate syllable. In each plot the dashed line is P_{sg}, the dotted line is relative lung volume and the solid line is CT activity. The data are averaged over 5 repetitions.

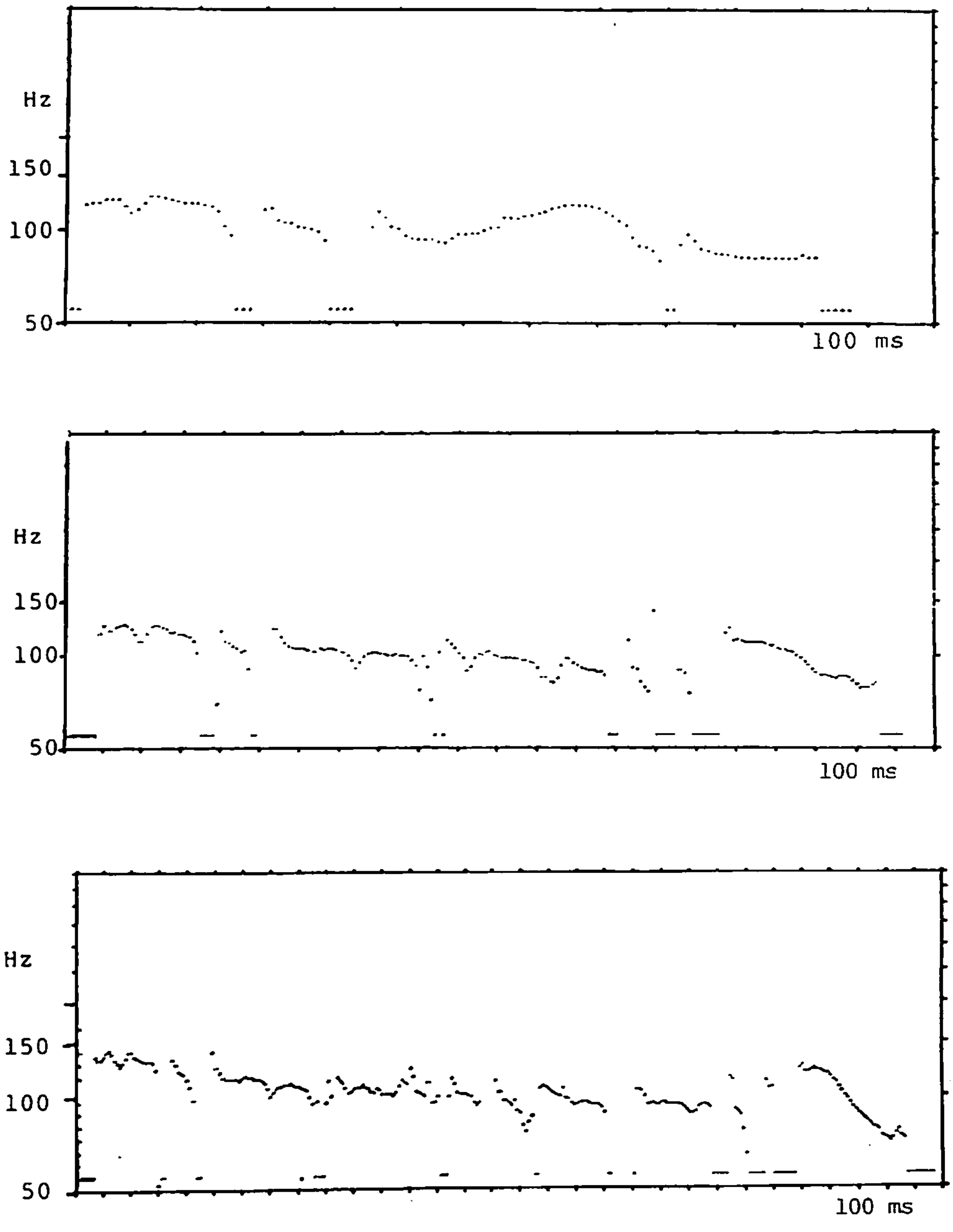
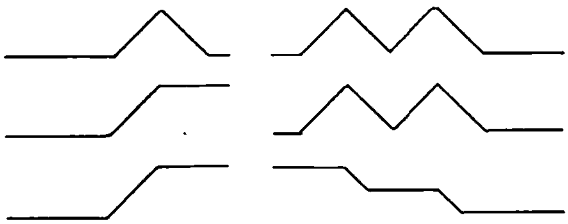


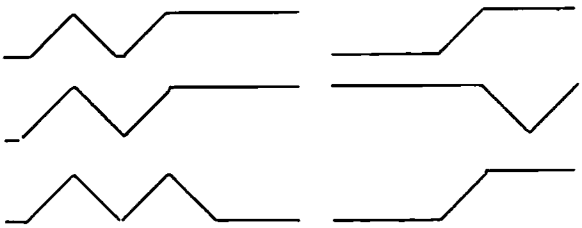
Fig. 2B. F_0 curves corresponding to the second of the five repetitions of the Dutch sentences in Fig. 3A.

Omdat hij ziek is , wil Jan in bed blijven
(Because he sick is, wants John in bed to stay)



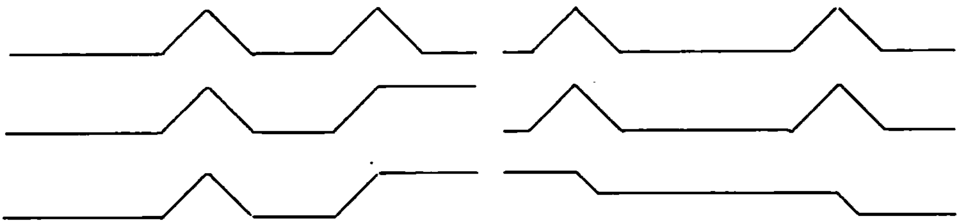
1,13
2,14
3,15

Wil Jan in bed blijven, omdat hij ziek is?
(Wants John in bed to stay, because he sick is?)



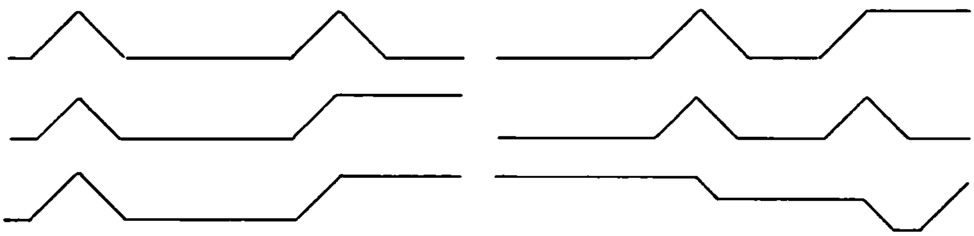
4,16
5,17
6,18

Omdat hij zo vreselijk verkouden is, wil Jan maar liever in bed blijven
(Because he such a terrible cold has, wants John rather in bed to stay)



7,19
8,20
9,21

Wil Jan maar liever in bed blijven, omdat hij zo vreselijk verkouden is?
(Wants John rather in bed to stay, because he such a terrible cold has?)



10,22
11,23
12,24

Table I. The set of test utterances and their stylized pitch contours (declination omitted). Nos. 1-12: without inspiration during the pause; nos. 13-24: with inspiration. Stressed syllables are underlined.

FUNDAMENTAL FREQUENCY (in Hz)

I (low-low)	SYLLABLE AVERAGE				EXTREME VALUES			
utt.#	E1	B2	ΔF_0	ST	E1	B2	ΔF_0	ST
1	98	103	-5	-.86	88	107	-19	-3.38
6	86	99	-13	-2.43	84	101	-17	-3.19
7	89	102	-13	-2.36	92	111	-19	-3.25
10	87	96	-9	-1.70	86	97	-11	-2.08
13	90	94	-4	-.75	86	99	-13	-2.43
18	81	90	-9	-1.82	81	91	-10	-2.02
19	92	96	-4	-.74	92	99	-7	-1.27
22	82	97	-15	-2.73	82	102	-20	-3.78
avg	88	97	-9	-1.70	86	101	-15	-2.68
s.d.	5	4	4	.80	4	6	5	.86
Δ%			10.2				17.4	
II (high-high)								
3	158	158	0	0	169	161	8	.84
5	140	132	8	1.01	147	138	9	1.09
9	162	152	10	1.10	166	153	13	1.41
12	160	141	19	2.18	161	153	8	.88
15	150	140	10	1.19	151	151	0	0
17	151	161	-10	-1.11	153	163	-10	-1.10
21	162	160	2	.22	166	166	0	0
24	154	138	16	1.90	156	140	16	1.87
avg	155	148	9	0.81	160	153	5.5	.62
s.d.	8	11	3	1.07	8	10	8	.94
Δ%			-4.5				-4.4	

Table II. F_0 values at the end of the first clause (E1), at the beginning of the second clause (B2), F_0 difference (ΔF_0) and difference in semitones (ST), for utterances having the same pitch (low or high) at either side of the syntactic boundary.

FUNDAMENTAL FREQUENCY (in Hz)

I (no inspir.)

utt.#	SYLLABLE AVERAGE B1	B2	ΔF_0	ST	EXTREME VALUES B1	B2	ΔF_0	ST
1	109	102	7	1.14	117	107	7	1.55
2	102	99	3	.52	112	108	4	.63
4	100	104	-4	-.68	106	107	-1	-.16
6	102	99	3	.52	107	101	6	.99
7	103	102	1	.17	104	111	-7	-1.13
8	105	108	-3	-.49	111	111	0	0
10	105	96	9	1.55	111	97	14	2.33
11	98	105	-7	-1.19	101	106	-5	-.84
avg	103	102	1.1	.19	109	106	2.3	.42
s.d.	3	4	6	.93	5	5	7	1.18
Δ%			.97				2.75	

II (inspir.)

utt.#	SYLLABLE AVERAGE B1	B2	ΔF_0	ST	EXTREME VALUES B1	B2	ΔF_0	ST
13	105	94	11	1.91	108	99	9	1.51
14	95	93	2	.37	99	102	-3	-.52
16	95	97	-2	-.36	99	99	0	0
18	97	90	7	1.30	103	91	12	2.14
19	107	96	11	1.88	109	99	10	1.67
20	104	92	12	2.12	107	94	13	2.24
22	100	97	3	.53	105	102	3	.50
24	100	97	3	.53	105	100	5	.84
avg	100	95	5.9	1.04	104	98	6.1	1.05
s.d.	5	3	5	.90	4	4	6	1.01
Δ%			5				5.76	

I + II

	B1	B2	ΔF_0	ST	B1	B2	ΔF_0	ST
avg	102	98	3.5	0.61	106	102	4.2	0.73
s.d.	4	5	6	.99	5	6	6	1.11
Δ%			3.37				3.7	

Table III. F_0 at the beginning of the first (B1) and the second (B2) clause, F_0 difference (ΔF_0) and difference in semitones (ST), for utterances having low pitch at the onset of their two clauses, without and with inspiration during the pause.

utt.#	F_0 DIFF. (B1-B2) (in Hz) syll.avg.	extr.val.	P_{sg} DIFF. (B1-B2) (in cm aq)	CT VALUES (in μV) B1	B2	B1-B2
1	7	10	4	30	25	5
2	3	4	3	20	15	5
4	-4	-1	1.75	5	20	-15
6	3	6	2	15	8	7
7	1	-7	2.25	10	20	-10
8	-3	0	4.75	15	25	-5
10	9	14	1.75	15	10	5
11	-7	-5	0	8	12	-4
13	11	9	2.50	15	10	5
14	2	-3	1	5	5	0
16	-2	0	.50	15	15	0
18	7	12	.50	15	5	10
19	11	10	1	20	10	10
20	12	8	1.50	20	5	15
22	3	3	1	10	10	0
24	3	5	.50	12	18	-6

Table VI. F_0 and P_{sg} differences, CT values and CT differences between the beginning of the first and the second clause in utterances having low pitch at the onset of their two clauses.

I (no inspir.)	SUBGLOTTAL PRESSURE (in cm aq)		
utt.#	B1	B2	ΔP_{sg}
1	11	7	4
2	10.5	7.5	3
4	9.25	7	1.75
6	8	6	2
7	8.75	6.5	2.25
8	9.75	5	4.75
10	7.75	6	1.75
11	6	6	0
avg.	8.87	6.38	2.44
s.d.	1.62	.79	1.48
II (inspir.)			
13	8	5.5	2.5
14	7	6	1
16	7	6.5	.5
18	6.25	5.75	.5
19	7.5	6.5	1
20	7.5	6	1.5
22	7.5	6.5	1
24	7	6.5	.5
avg.	7.21	6.16	1.06
s.d.	.53	.40	.68
I + II			
avg.	8.04	6.27	1.75
s.d.	1.44	.62	1.32

Table V. P_{sg} values at the beginning of the first (B1) and the second (B2) clause and P_{sg} difference (ΔP_{sg}), for utterances without and with inspiration.

I (low-low) utt.#	SUBGLOTTAL PRESSURE (in cm aq) E1	B2	ΔP_{sg}
1	8	7	1
6	4.75	6	-1.25
7	5.75	6.5	-.75
10	4.50	6	-1.50
13	5.50	5.5	0
18	4	5.75	-1.75
19	6	6.6	-.50
22	4.75	6.5	-1.75
avg.	5.40	6.2	-.81
s.d.	1.25	.48	.91

II (high-high)	E1	B2	ΔP_{sg}
3	7	7.25	.25
5	5.50	6.75	-1.25
9	7.50	7.50	0
12	5.25	6	-.75
15	5.50	6	-.50
17	5.75	7.25	-1.50
21	6.75	8.50	-1.75
24	4.75	7.50	-2.75
avg.	6	7.09	-1.03
s.d.	.96	.83	.98

Table IV. P_{sg} values at the end of the first clause (E1) and at the beginning of the second (B2), P_{sg} difference (ΔP_{sg}), for utterances having the same pitch at either side of the syntactic boundary.

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