TEMPORAL AND TONAL CONTROL IN GERMAN

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ABSTRACT

A fundamental issue for a model of prosody is whether or not the phonological features expressed by time (duration) and pitch (fundamental frequency) are independent variables. Vowel duration in Central Swedish has been said to be dependent on the fundamental frequency change associated with that segment. However, there is evidence that an Fo-dependent model for duration does not adequately account for data on Swedish and Danish. This report examines the relationship between fundamental frequency change and duration in German. Two statistical tests clearly indicate that time and pitch should be treated independently in German prosody. Finally, a model for German prosody is sketched based on these findings.

1. INTRODUCTION

In every model that generates speech utterances, be it articulatorily or acoustic-auditorily oriented, the two dimensions time and fundamental frequency (Fo) play an important role. To produce an utterance takes a certain length of time. Furthermore, every utterance has its own temporal structure and a tonal structure as well which, as it seems, exists in parallel.

Up to now a number of models for duration and intonation in several languages have been developed (see references). These models attempt to generate either the durational or the tonal structure of an utterance to be observed in the signal. The question that then arises is how to arrive at a more complete utterance containing both structures. Assuming the independent generation of the temporal and tonal features of an utterance, this goal can be reached by simply adding both structures together. This, however, leads to problems of coordination which have to be solved. It should be quite obvious that these two structures generated independently of each other will have to be changed or adjusted when put together. Tonal adjustments of the basic Fo-contours as a consequence of factors of time and sentence position were described by Bruce (1977, 74 ff.).

Recently Lyberg (1981) made an attempt to handle these two prosodic dimensions simultaneously. Taking up an idea of, among others, Öhman et al. (1979), he presented an Fo-dependent model for segment duration where segment durations are the automatic result of Fo-movements. The more complex such a movement, i.e. the larger the Fo-change or the Fo-difference over the segment, the larger the segment duration has to be. The alleged causal relationship between Fo-change and segment duration is expressed by the formula $D = k \cdot \Delta Fo$, where D = segment duration, k = constant, and Δ Fo = Fo-difference. Comprehensive counter evidence against an Fo-dependent model for duration, however, has been presented by Bruce (1981) and Bannert (1982).

The aim of this paper[1] is to answer the crucial question from the outset as to which relationship exists between the temporal and tonal dimension in a model of prosody[2] for German. It is of course decisive to know whether segment duration must be treated independent of intonation or not. The answer to this question will have fundamental consequences for the design of any model of prosody.

2. MATERIAL AND ANALYSIS

In order to be able to answer the question formulated above, the following strategy was chosen. In a sentence with three accents the tonal structure was varied while the temporal structure (the segments) was kept constant. The temporal structure was also varied while the tonal structure was kept constant. This was done in the following way:

(1) Tonal variation (segments constant)

The statement

Der *Lahme* (1) hat die *Maler* (2) *gemahnt* (3).

("The limping man reminded the painter.") containing three accent positions (underlined and numbered) was embedded in four different prosodic contexts. By this procedure, a tonal difference as large as possible between the four contexts (versions) of the test sentence was to be produced. The starting or neutral version (1) of the sentence contains three equivalent accents. In the other three versions, the sentence accent would be moved by focusing to the first (version 4), second (version 2), and third (version 3) accent position. The third accent position served only as a dummy, in order to be able to move the sentence accent away from positions 1 and 2. Only these two positions were investigated. The sentence presented above served also as a means of calibration throughout the recording session. As the calibration sentence is semantically quite natural, it served as a pattern for the rest of the material, and the validity of the measurements in the test material could be checked against this sentence.

Two versions were added where the test word appears in isolation: affirmative statement (version 5) and echo question (version 6). These isolated versions further increased the tonal and temporal variation within the test material.

(2) Segmental variation (intonation constant)

In each tonal version, two bisyllabic word pairs, containing the stressed vowel /a/, were used. In order to achieve temporal variation, different segmental features were introduced: consonant type (voiced nasal sonorant vs. voiceless obstruent), quantity (long vs. short vowel), and number of initial consonants. The test words and the distribution of the segments were as follows:

	consonant type	
	sonorant (nasal)	obstruent (voiceless)
vowel quantity	C1 V1 C2 V2	CØ C1 V1 C2 V2
V:	M ah n er	S p a t er
	[m a: n ɐ]	[ʃ p a: th ɐ]
V	M a nn er	S p a tt er
	[m a n ɐ]	[ʃ p a th ɐ]

The test words, except Mahner ('admonisher'), are semantically void, although they pertain to a very common word structure (in English e.g. singer). Each test word appears both in the first and second sentence position, yielding a doubling of the words to be investigated. This arrangement was also necessary due to semantic reasons. Each sentence contained test words with either sonorants or obstruents respectively, but always a long and a short vowel. Thus the following five sentences were used:

Der Lahme hat die Maler gemahnt. (calibration sentence)
Der Mahner hat die Manner gemahnt. (sonorants)
Der Manner hat die Mahner gemahnt. (sonorants)
Der Spater hat die Spatter gemahnt. (obstruents)
Der Spatter hat die Spater gemahnt. (obstruents)

As each sentence appeared in 6 versions, the material consisted of 30 sentences in all. They were arranged in random order and spoken by four speakers[4] from Northern Germany seven times in randomised series with a buffer sentence at the beginning and at the end of each series. In a dialogue-type situation, the author spoke the context sentences during the recording which was made in the studio of the Department of Phonetics at Kiel University. Two signals were recorded simultaneously on a Revox tape recorder, speed 7 ips, the audio signal from a microphone and the Fx-signal from a laryngograph (Fourcin and Abberton 1971). The speakers were well acquainted with the recording situation and produced the sentences with satisfactory naturalness and consistency.

The acoustic analysis rendered an oscillogramme and an Fo-contour, recorded on a Siemens Oscillomink with a paper speed of 100 mm/s. Segments could be defined easily. The following parameters were measured by hand:

(1) Duration:	sentence (S), word (W), segments (CØ = ʃ ; C1 = m, p, l; V1 = a (:); C2 = n, t, m, l; V2 = ɐ, ə; the sequence V1C2.
(2) Fo (test words with sonorants only):	Fo-value at each segment boundary, starting with the beginning of C1 and thus yielding five Fo-values. If there was an Fo-maximum or Fo-minimum within a segment, the number of Fo-measurements increased. Thus the course of the Fo-movement throughout the word is unequivocally determined.

These basic values were used to calculate the mean, standard deviation, the VC-ratio (section 4.2), and the Fo-change (ΔFo) (section 5.2.2).

The results will be presented below. First, as an orientation, the tonal structures of the six versions will be shown in section 3. Second, some central aspects of the temporal structure of the material under the varying prosodic conditions is treated in section 4. Third, the central question concerning a possible relationship between the duration of segments and the Fo change is investigated by statistical methods in section 5.

3. TONAL STRUCTURE

By varying the prosodic context in the different versions, the tonal contours in sentence positions 1 and 2 were expected to be different. This was the case with all four speakers. Representative tonal contours of the four sentence versions (1-4) and the two isolated versions (5, 6) for two speakers are shown in Figure 1. The curves for each accent position are superimposed with the beginning of the accentuated vowel as the line-up point. The third position is included just for the sake of completeness and will not be treated.

Comparing the tonal contours of the speakers, it can be seen that all the contours, except for version 1 (neutral), are very similar. The tonal differences in version 1 may be the result of not giving equal weight to the accents by each speaker. While speakers U (and M) manifest the accent in all three positions, speakers R (and C) de-accentuate the word in the third position.

In this paper I do not want to treat the tonal features of the Fo-contours. A more detailed report on the tonal aspects of the German accents in statements and two kinds of questions, including also syntactic variation, is being prepared (Bannert forthcoming 2).

4. TEMPORAL STRUCTURE

Primary data on the temporal structure of the test material will not be presented due to limitation of space. Nevertheless, to concentrate on a central issue, the relations within the accentuated syllable will be examined. While the durations of the vowel and the following consonant are presented in the temporal space, the relative temporal relations are shown in the VC-ratios.

4.1 The temporal space

Within accentuated syllables, temporal relations of a certain kind seem to exist. One can think of the relationship between two successive segments as being confined to a temporal field or space and expressing a characteristic pattern of rhythmic structure (Bannert 1976, 1979). A special instance of temporal relationships, the pattern of complementary length (Lehiste 1970), exists in, among other languages, Central Bavarian, a High German variety (Bannert 1976). This pattern is also found in

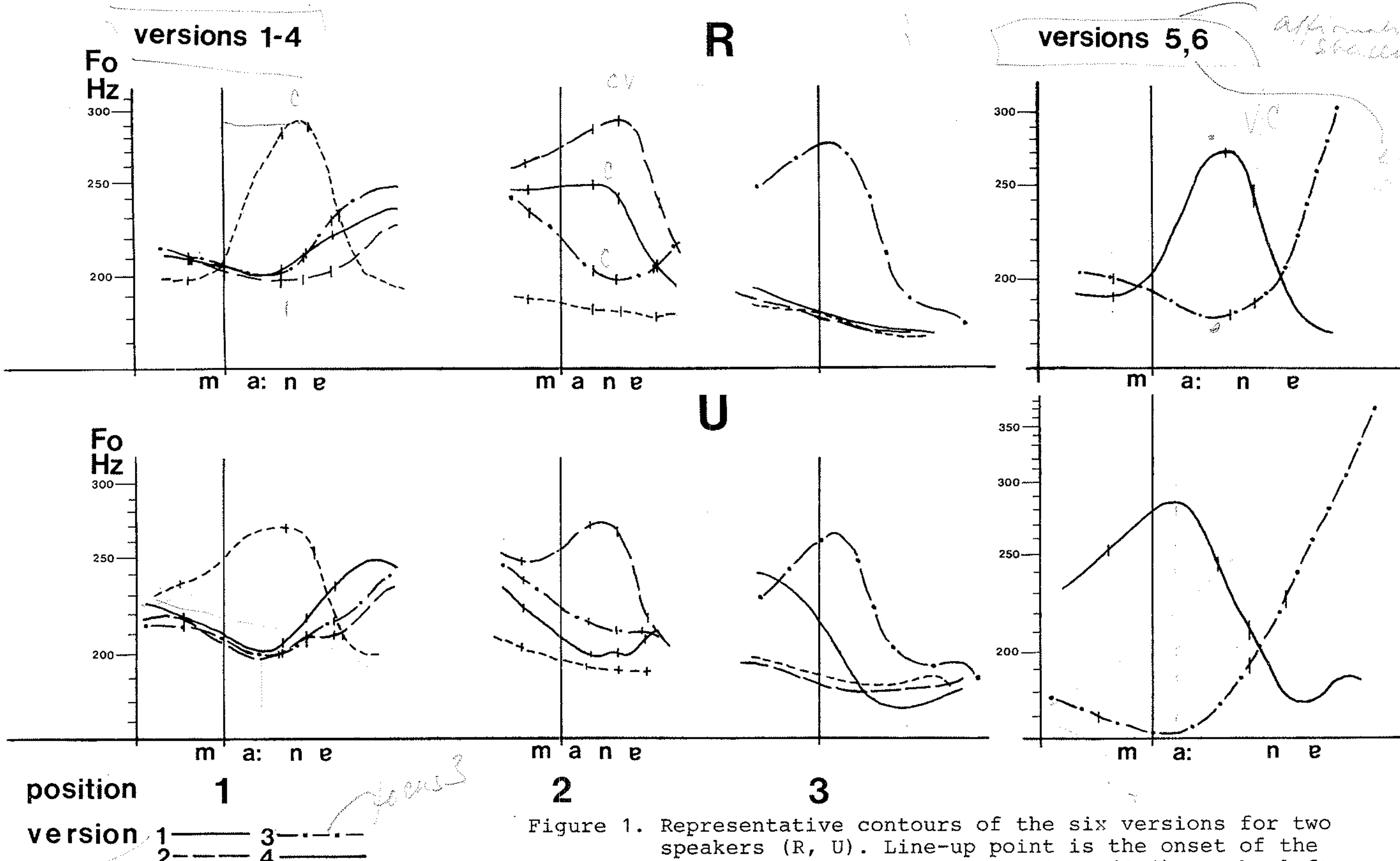

Figure 1. Representative contours of the six versions for two speakers (R, U). Line-up point is the onset of the stressed vowel. Sentence versions (1-4) to the left, isolated versions (5,6) to the right.

Standard German, although there it has been reported to function in a different way, namely in the contrast between voiceless (fortis) and voiced (lenis) plosives (Kohler 1979 a, b).

The temporal relations between the accentuated vowel and the following consonant can be shown in the vowel-to-consonant plot. The data points expressing the temporal relations are grouped into two clearly separated fields or spaces. Figure 2 depicts the temporal space of the two VC-sequences. The mean values of vowel duration V1 are plotted against the mean values of the duration of the following consonant C2 in all the versions (1-6), both positions, and for all four speakers, making a total of 120 points. Apart from the length contrast of the consonant, Figure 3 shows the same temporal picture, as was found in Central Bavarian. There, however, the duration of the consonant following the short vowel is much larger. Both fields, which are shown by the points of the VC-sequence with long and short vowels respectively, are clearly separated and expand in different directions with increasing segment durations. If the durations are increased drastically, e.g. in version 6, the field of the long vowels extends in the direction of the long vowel, the field of the short vowels, however, extends in the direction of the consonant. Thus the temporal relations between the long and short vowel and the following consonant in stressed syllables in North German, too, can be accounted for by using the pattern of complementary length.

4.2 The VC-sequence

Apart from expressing temporal relations between the stressed vowel and the following consonant in absolute terms, the temporal structure of the segments can also be represented in relative terms. The VC-ratio, i.e. the temporal relationship between the parts (vowel, consonant) and the whole (vowel + consonant = the sequence) was introduced in Bannert (1976). It is assumed that the VC-sequences constitute some temporal basic unit in languages with quantity and stress (Bannert 1976, 1979). Changes of the

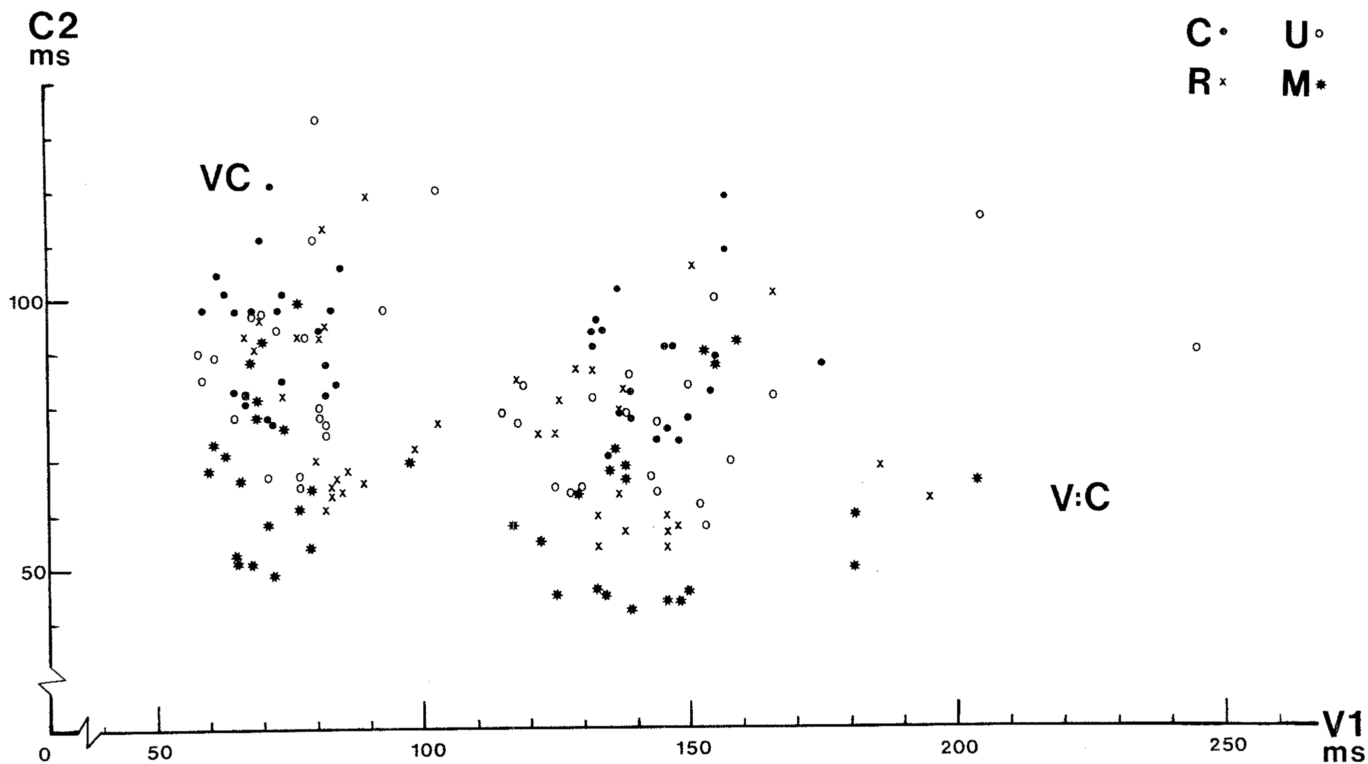

Figure 2. The temporal space. Mean durations of the accentuated vowels plotted against mean durations of the following consonants. All six versions, both positions, and all four speakers.

segment durations of vowels and consonants which are caused by varying segmental and prosodic conditions are brought about in such a way that, according to the principle of complementary length, the long and short vowel and the following consonant tend to make up a certain part of the whole sequence. This temporal relationship between the parts and the whole will remain more or less unchanged.

The VC-ratios, which show the portion of the vowel in relation to the duration of the whole VC-sequence, expressed in percent, are given for each speaker and consonant type in Figure 3. Certain patterns of VC-sequences found earlier in other material are also seen here very easily: the long vowel makes up a larger portion of the VC-sequence than does the short vowel. The VC-ratios are smaller when the consonant is a voiceless obstruent than when it is a voiced sonorant. The ratio varies only a little and, above all, not in a systematic way throughout the six different versions and the two positions. It can also be seen that the ratios keep within a relatively limited area for each length category of the vowels. Even if the ratio does not remain constant, the variation due to large durational differences appear to be minimal. Inherent features, like consonant type, do affect the VC-ratio (cf. Bannert 1976).

However, there is also in this material a relatively constant temporal feature. As shown earlier for Central Bavarian, Central Swedish, and Icelandic (Bannert 1976), this feature is not the VC-ratio itself, but rather the temporal distance (TD) between the ratios of the /V:C/-sequences and the /VC/-sequences. The temporal distance seems to be rather independent of inherent features. It is defined as follows:

$$TD = Q_{V:} - Q_{V}$$

where TD = temporal distance, V(:) = long or short vowel, Q = VC-ratio

Mean values and standard deviation for the temporal distance for each speaker and each consonant type are given in Table 3. The

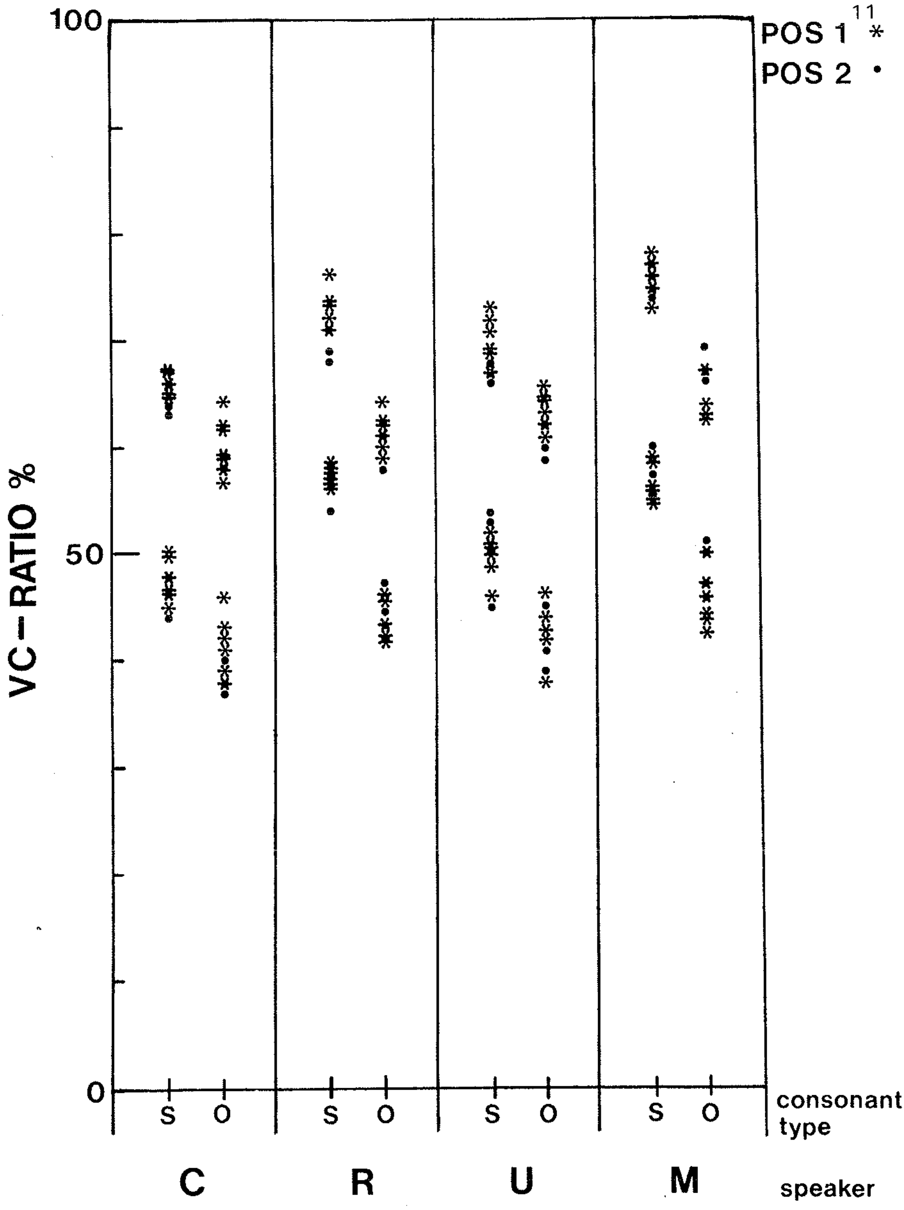

Figure 3. The vowel-to-sequence ratios for each speaker, consonant type, and position.

total mean is 18.25%.

Table 1. Mean values and standard deviation for the temporal distance (TD) between the VC-ratios for each speaker and consonant type in percent.

	speaker							
	C		R		U		M	
	SONORANT	OBSTR.	SONOR.	OBSTR.	SONOR.	OBSTR.	SONOR.	OBSTR.
$\bar{x}$	18.0	19.4	15.0	16.8	18.5	20.0	19.1	19.2
s	1.98	1.08	1.63	1.27	3.81	2.65	2.48	1.33

5. DURATION AND INTONATION

In an Fo-dependent model for segment duration the definitive duration of a given segment is the result of the Fo-change over this segment (Lyberg 1981). Lyberg showed that, in Central Swedish, there exists a strong, positive and linear relationship between the segment duration and the Fo-difference of the long vowel in sentence initial and final position with and without focus. In this North German material, however, no such relationship is to be found. And what is more, the tonal movement is determined by the feature of quantity as it is in Swedish (Bannert 1982).

5.1 Independent quantity

The phonological feature of quantity is manifested by a distinct difference in duration between the long and the short vowel. This is true of all the different tonal contours in all six versions. What is, then, the effect of quantity on the Fo-contour of the vowel, and also on larger units, e.g. the word?

Two alternatives can be proposed (cf. Erikson and Alstermark 1972, Bannert and Bredvad-Jensen 1975, 1977):

(1) TRUNCATION. The Fo-contour of a word containing a long vowel is identical with that of one containing a short vowel, i.e. in a word with a short vowel, the Fo-contour just ends earlier, due to the shorter duration of the short vowel, compared to the corresponding word with a long vowel. Line-up point is the beginning of the accentuated vowel.

(2) COMPRESSION. The Fo-contour of a word containing a long vowel is not identical with that of one containing a short vowel, i.e. the Fo-contours of both words are identical in their course (appearance), the contour in the word with the short vowel, however, is compressed in time. It shows the same tonal movements, but makes them faster.

In all cases with tonal movement, all four speakers clearly show compression. As a representative example, Figure 4 shows simplified Fo-contours of speaker M. They correspond to the mean values of Fo and duration. The Fo-contours in the words with long and short vowels are identical, by and large, at the beginning (in the initial consonant C1) in all versions. The consonant C2, following the stressed vowel, and starting earlier after the short vowel, counted from the beginning of the stressed vowel, affects the Fo-contour radically. The rise of Fo in statements is interrupted and the fall is initiated. The rise in questions is brought about earlier. In other words, certain points or levels of the tonal contour are tied to certain segments or parts of segments. Hence, quantity determines the course of the Fo-contour. As quantity in German appears not only in accentuated syllables, but also in non-accentuated ones, it has to be concluded that quantity is an independent feature, while the tonal contour, at least in certain respects, is dependent on quantity.

5.2 Statistical examination

Before the question about any causal relationship between the

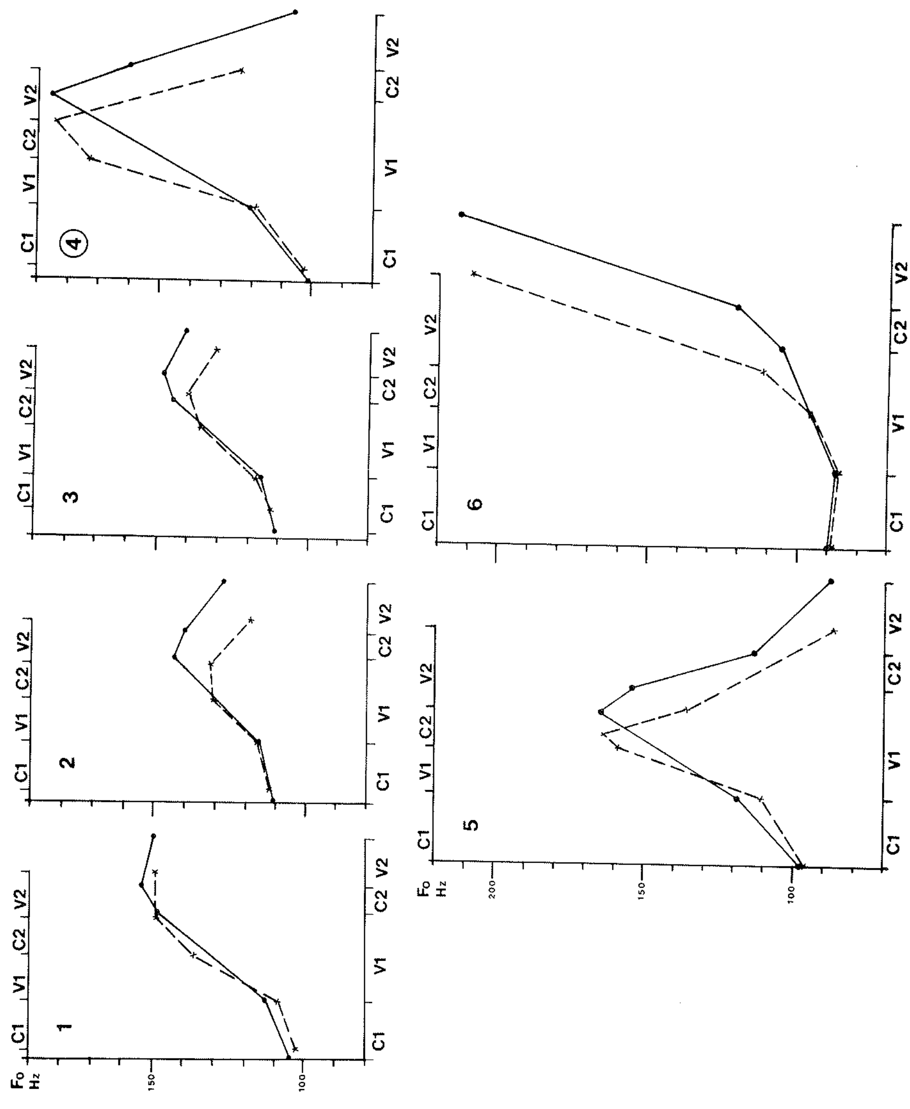

Figure 4. The effect of quantity on the tonal contours. Superimposed Fo-contours of words with long and short vowels. Line-up point is the beginning of the stressed vowel. Mean durations and Fo-values. Sentence versions 1-4 (above), position 1; isolated versions 5,6 (below). Speaker M.

segment duration and the Fo-change can be answered, it has to be settled whether or not there is any relationship at all between these two features. In order to determine step by step if any relationship exists, two methods[5] will be employed. First, it will be determined if the durations of the segments, the VC-sequence, and the word in all the four sentence versions and both positions, are significantly different from each other. If they are different, it could be assumed then that this difference is related to the tonal difference. Second, in any case, it will be tested if there exists any relationship between durations and Fo-changes, i.e. if both variables are correlated. Only if it can be established that they really are correlated, will it be warranted to ask which variable is determined or caused by the other.

5.2.1 Differences in segment duration

Using the statistical method of the Mann-Whitney-Test, the question of whether the segment durations in the four sentence versions were significantly different from each other was tested. In most cases, the versions differed from each other in their tonal aspects (cf. Figure 1). In the test, every version was compared with all the others, i.e. version 1 with 2, 1 with 3, 1 with 4, 2 with 3 etc. Thus for each of the segments six comparisons were made for each position and each speaker.

If one can find significant differences in duration between the different versions, and if all other factors, e.g. speech tempo, can be considered constant, it has to be assumed that these durational differences have to be traced back to the tonal differences. Thus, looking at the high tonal peak of focus in position 1 (version 4) and comparing it to the other three rather similar and low contours, one could expect that the segment durations of version 4 in position 1 would be different from those of versions 1, 2, and 3. And, if there exists any relationship between the Fo change and the segment duration, it should show up in a systematic way, in some kind of pattern.

The result of the statistical testing is shown in Table 2. As can be seen, there is no regular picture to be found. No pattern

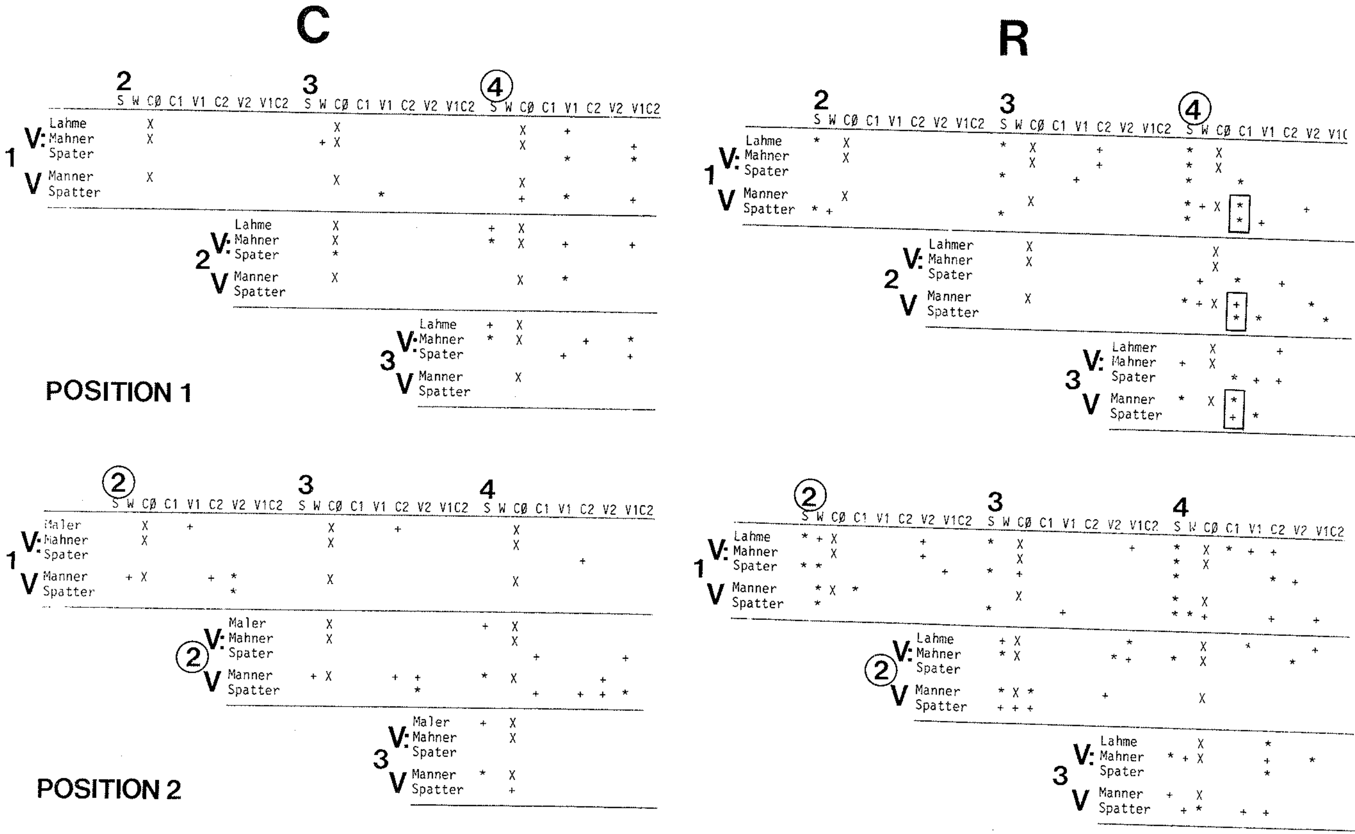

Table 2a. Significant differences of durations of sentence, word, segments, and VC-sequence for each test word between the four versions. Speaker C (left) and R (right). Position 1 above, position 2 below. + $0.01 < p < 0.05$, * $p < 0.01$

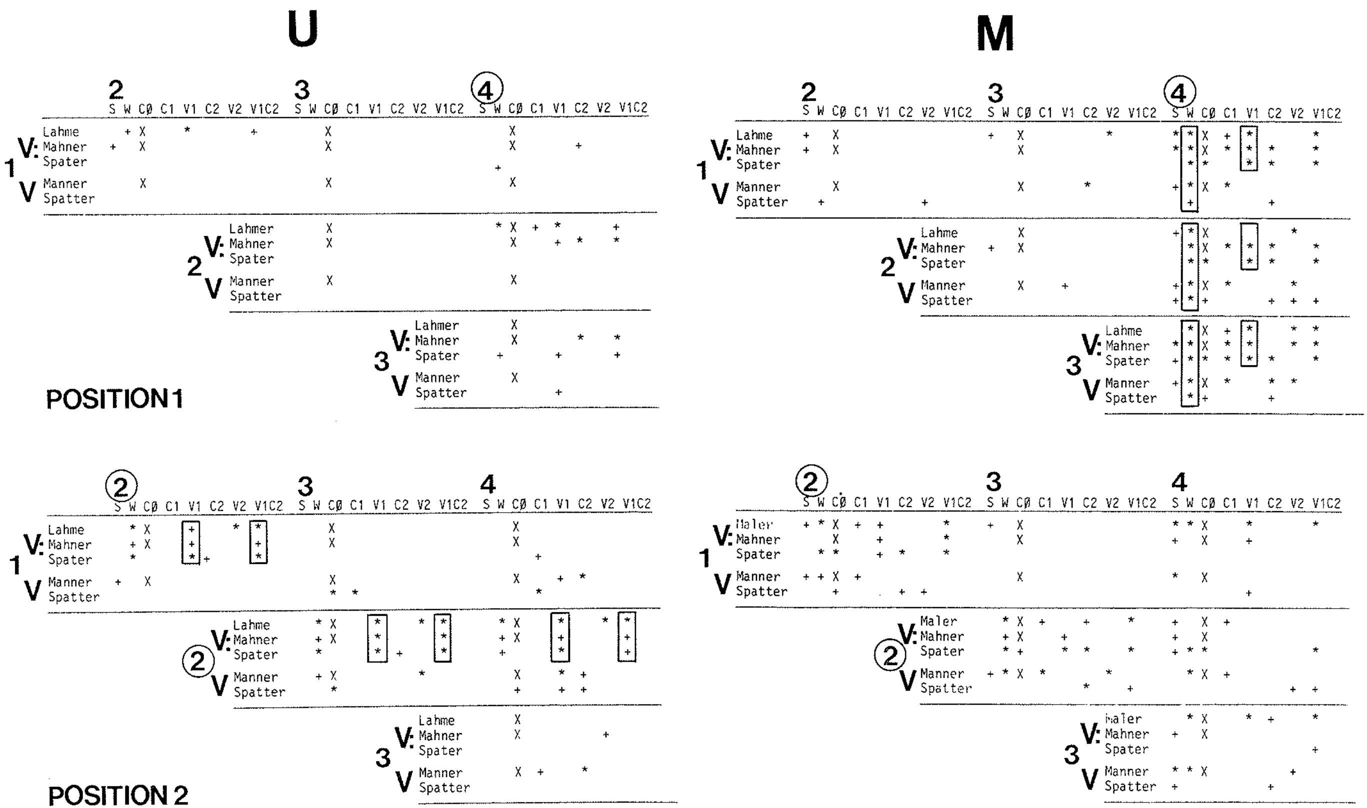

Table 2b. Significant differences of durations of sentence, word, segments, and VC-sequence for each test word between the four versions. Speaker U (left) and M (right). Position 1 above, position 2 below. + 0.01 < p < 0.05, * < 0.01

of systematic variations of durational differences can be detected, not even for one speaker alone.

In some cases, however, fragments of a systematic behaviour can be discerned. They are, though, limited to a certain position (indicated in Table 2). The initial consonant C1 of speaker R has a different duration, but only in the words containing short stressed vowels in position 1. The word duration and almost all durations of the long vowels of speaker M in position 1 are significantly different. The third speaker U, however, shows some instances of significantly different durations in position 2 (version 2 against versions 1, 3 and 4). And last, the fourth speaker C does not show any kind of regularity.

Therefore it has to be concluded that there is no general relationship between the segment duration and the corresponding Fo change.

5.2.2 Segment durations and Fo-change

In contrast to Lyberg (1981, 44), here the Fo-change was defined more completely. In a complex tonal contour, consisting of two different movements and a maximum or a minimum in between, e.g. a rise-fall, the total tonal change is to be considered the tonal difference in both directions. In my opinion it is wrong to calculate the tonal fall only and disregard the rise or vice versa.

By way of simplification, though, the difference in direction of the tonal movements will not be treated. It is known that it takes somewhat more time to increase Fo than to decrease it (Sundberg 1979, Ohala & Evan 1973). However, it seems unlikely that a division of the Fo-changes according to whether they rise or fall would lead to different results.

The Fo-change of a simple, uninterrupted Fo-movement is defined as: $Fo = \left| Fo_{initial} - Fo_{final} \right|$.

The Fo-change of a complex Fo-movement is defined as:

$$Fo = \left| Fo_{initial} - Fo_{max/min} \right| + \left| Fo_{max/min} - Fo_{final} \right|.$$

Due to restrictions of space, neither the Fo-measurements nor the Fo-changes can be presented here. But examining Figures 1 and 5, one can get a fair impression of the size and range of the Fo-change.

The relationship between the segment durations and the Fo-changes was examined by means of linear regression. The calculation was carried out with the values of the sonorant words Lahme, Maler, Mahner, and Manner in several sub-categories according to the variables of test word, quantity, and position. As a representative summary, Table 3 shows the correlation coefficient (r) as a measure of the strength of the relationship according to segment, speaker, and quantity. The level of significance is indicated. For each speaker, the calculation is based on 1008 values of segment durations and the corresponding values of Fo-differences (6 segments x 7 renderings x 4 versions x 3 test words x 2 positions).

Table 3. The relationship between the duration of the segments C1, V1, C2, V2, the sequence /V1C2/, and the word /C1V1C2V2/ and the Fo-change over these segments in the four sentence versions, expressed as the correlation coefficient (r). The levels of significance are indicated. n for each segment and speaker: /V:/ = 118, /V/ = 56.

		SEGMENTS					
Speaker	Quantity	C1	V1	C2	V2	V1C2	Word
C	V:	0.053	0.132	0.083	0.138	0.046	-0.162*
	V	0.184	-0.015	0.019	0.338**	-0.036	0.037
R	V:	-0.075	0.181*	0.200*	0.253**	0.256**	0.210*
	V	0.137	0.037	0.019	0.362**	-0.115	0.421**
U	V:	0.090	0.473**	0.335**	-0.009	0.582**	0.361**
	V	-0.225*	0.121	0.239	0.436**	0.258*	0.353**
M	V:	0.392**	0.557**	0.307**	0.419**	0.582**	0.706**
	V	0.614**	0.323**	0.460**	0.504**	0.451**	0.789**

It can be seen that the values of (r) are quite small, perhaps except for the word (W) of speaker M. Therefore it has to be concluded once more that there is no statistically provable and systematic relationship between the segment duration and the Fo-change in this North German material.

6. CONSEQUENCES FOR A MODEL OF PROSODY

On the basis of the present findings, showing that there is no general and systematic relationship between Fo-change and segment duration, the question of the temporal and tonal control in German can be highlighted in a few essential respects. A comparison with the situation in the related languages Danish and Swedish will render a deeper dimension of understanding to these findings.

It could be shown that there is no relationship between the temporal and tonal dimension in this North German material. It does seem, however, that speakers are also free to use the temporal dimension, apart from the tonal, when focusing. The double signalling of sentence prominence appears to be more effective than the use of one dimension only. Similar variations between speakers in using the temporal and tonal dimension for focus is also to be found in my Central Bavarian material (Bannert 1976). Furthermore, the four North German speakers of this investigation behave partly like the Danish speakers in Thorsen (1980) and one of the Swedish speakers in Bruce (1981), partly like the Swedish speakers in Bannert (1979, forthcoming 1), and the other speaker in Bruce (1981). While segment durations of the Danish speakers and one of Bruce's speakers remain unchanged in focus, the duration of all segments in focus is increased with the other Swedish speakers. And this in spite of the large tonal difference between the Central and Southern variety of Swedish. Therefore, it has to be assumed that an increase of duration in focus need not necessarily be a result of the changed Fo-contour. On the contrary, as languages may differ in this respect, time and tone have to be treated basically as independent features.

Thus some consequences for a model of prosody in German emerge. Starting from an input[6], defined and specified by necessary linguistic information, segmental and prosodic, the model firstly will generate the basic temporal and tonal structure of the utterance separately and independently of each other. This can be done either in parallel or successively. Then both basic structures will be joined or added. Due to various conditions, certain adjustments will appear to be necessary, e.g. the adjustment of the basic tonal contours as a consequence of temporal limitations (varying number of unstressed syllables between the stressed ones). It seems clear that these adjustments will be less in German than in Swedish. There the tonal structure is much more complex due to the word accents. An important factor of the mutual temporal and tonal adjustments is speech tempo. The output contains the final prosodic form of the utterance.

A simple sketch of the model for generating the prosody of a German utterance is shown in Figure 5. Although the model contains the important components, it is just a beginning; developing the model further will require extensive work. However, the point of departure is rather favourable. Quite obviously, it is not necessary to start from scratch. As mentioned in the introduction, models for time and intonation for related languages do exist. Therefore it seems to me most advantageous to start out from suitable models developed for other languages and to examine their usefulness for German. What is the new approach here, is the treatment of the two main dimensions of prosody, time and intonation, at the same time and basically independent of each other. In order to generate the temporal basic structure, a model like Klatt's (1979) presents itself. In order to generate the tonal basic structure, the Danish model (Thorsen 1979) and the Swedish model (Bruce 1977, Bruce 1982, Gårding 1982, Gårding & Bruce 1981) seem convincing.

It can be expected that future work with this model will promote

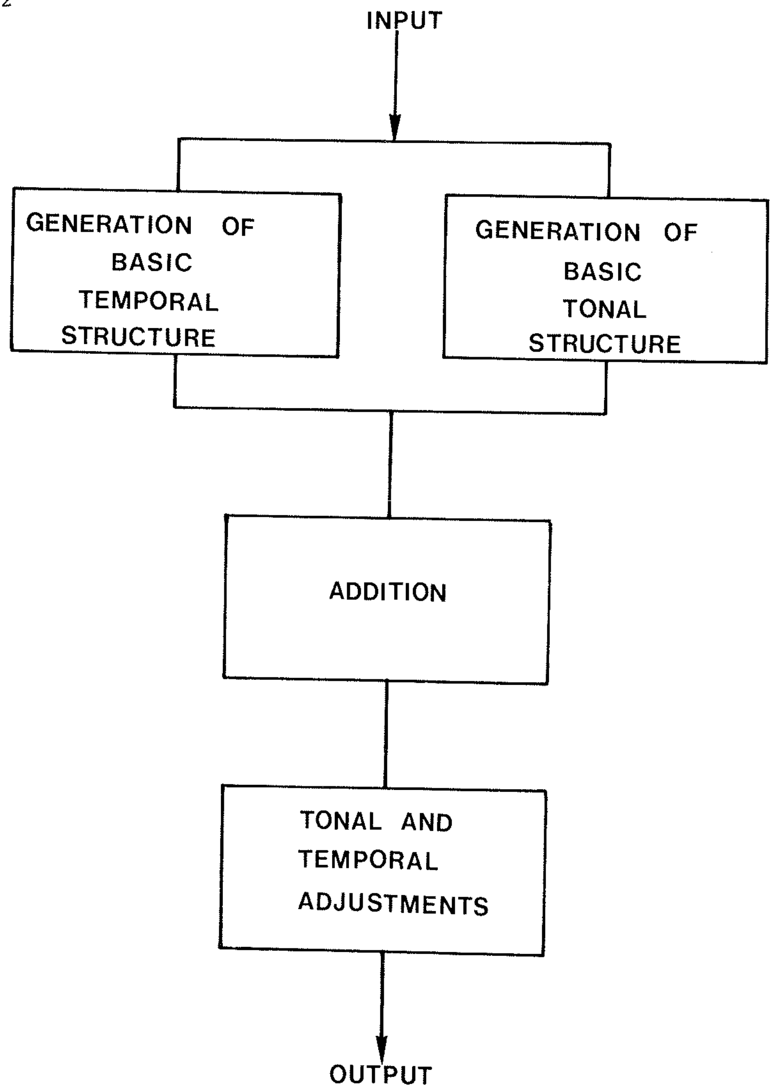

Figure 5. The basic components of a model for prosody in German.

phonetic knowledge and understanding of prosody in German. It will not only bring new insights into the nature of prosody, and thus lead German intonation studies from the level of merely describing auditory impressions to the level of acoustic measurements. Later on, when the level of perception has been reached, the development of speech synthesis will be pushed forward. Of course, applied phonetics, too, will profit by this, and the teaching of rhythm and intonation, important for intelligibility and acceptability of spoken German, will be improved.

FOOTNOTES

1. This investigation was begun at the same time as Bruce (1981) as a reaction against Lyberg's proposal of an Fo-dependent model for segment duration (Lyberg 1979). While Bruce studied Central Swedish, the same variety of Swedish as Lyberg, my work aimed at extending the issue to another language.

2. Prosody is used here in a restricted sense. It means the rhythm and melody of language, i.e. the temporal and tonal structure of utterances. Concentrating on the basic linguistic components of prosody, other features, e.g. vocal quality, are excluded for the sake of simplification.

3. For a detailed description of the method of moving focus within a sentence, see Bruce (1977).

4. Data concerning the speakers:

Abbreviation	Sex	Place of birth	Year of birth
C	female	Lübeck	1957
R	female	Fintel (Rothenburg/ Wimme)	1952
U	female	Bleckede (Lüneburg)	1952
M	male	Marne (Dithmarschen)	1952

5. The two statistical tests were run by using the SPSS-programme at the Computer Center of the Christian-Albrechts-University in Kiel.

6. In this paper, I do not intend to explore any details of the basic components of the model. Thus no further specification of the input will be presented here. A more detailed exposition of the model will be given in Bannert (forthcoming 1, 2).

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