MICROPROSODIC FUNDAMENTAL FREQUENCY VARIATIONS IN GERMAN

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ABSTRACT

As a preliminary study in the analysis of German sentence intonation, this contribution deals with two types of segmentally conditioned fundamental frequency (F₀) variations: the influence of stop consonants on F₀ of following stressed vowels (coarticulatory F₀ variation; CF₀), and the differences in F₀ between high and low vowels (intrinsic fundamental frequency; IF₀). These microprosodic phenomena are recorded, evaluated and discussed in detail for one speaker. Apart from speaker-specific variations, the results are qualitatively quite consistent with data reported in the literature /1, 3, 8/. In intonation research, the CF₀ effect may be neglected, provided that the exact point of F₀ measurement is chosen appropriately, whereas IF₀ differences have to be evaluated for each speaker separately.

INTRODUCTION

The temporal course of voice fundamental frequency (F₀), as the pre-eminent representative of sentence intonation in German, may be considered as the result of several interacting factors. A thorough description and interpretation of fundamental frequency tracings must account for at least the following factors that affect the course of F₀ in different ways: microprosody, i.e., intrinsic fundamental frequency of vowels and coarticulatory F₀ variations; the distribution of word and sentence accents; sentence position; and modality /15/.

This contribution deals with the microprosodic factors, namely the influence of initial stop consonants on F₀ of stressed vowels (coarticulatory F₀ variation; CF₀), and the differences in F₀ between high and low vowels (intrinsic fundamental frequency; IF₀). These phenomena may be defined as variations of the speech signal which depend on the acoustical and physiological constraints of the human speech production system.

The aim of this study is to record and evaluate these microprosodic effects for one speaker and to eliminate them as factors disturbing the interpretation of intonation contours at the sentence level. The relevant procedures described in the literature /e.g. 2, 7, 11, 15/ generally imply an undesirable restriction in the choice of the test material. Considering the large inter-subject variation of the microprosodic effects /1, 6, 10/ the procedure described here seems to be fairly successful.

EXPERIMENTAL DATA ON GERMAN

Intrinsic Fundamental Frequency (IF₀) of Vowels: Test Material

In the first part of our investigation we evaluated the intrinsic fundamental frequency (IF₀) of the German vowels for one speaker. Within the key words vowel quality was varied as well as vowel quantity. According to the results of earlier studies of German microprosody /1, 9/ we expected systematic higher IF₀ values for high vowels compared to low vowels. The findings for the influence of vowel quantity on IF₀ are less clear-cut. It is true that the IF₀ differences between open and closed vowels tends to be more distinct in short vowels than in long ones; but a significant difference is solely stated by Antoniadis and Strube /1/. For our speaker the difference was insignificant.

The key words were embedded in a short carrier sentence of the form "Ich habe ... gesagt" ("I said ..."). The choice of a relatively short carrier sentence enabled us to control the intonation contour of the whole utterance /cf. 5/. The test material consisted of German words with the exception of the key words "Kir" and "Punk" which are borrowed from French and English, respectively. Nevertheless these two words may be considered as elements of present-day German; they were uttered with the usual German pronunciation, i.e., [ki:ɐ] and [paŋk]. Within the key words we examined and analysed the long and short stressed vowels of German: /a:/, /ɛ:/, /e:/, /i:/, /ø:/, /y:/, /o:/, /u:/, and /a/, /ɛ/, /I/, /œ/, /Y/, /ɔ/, /U/.

Coarticulatory F₀-Variations (CF₀): Test Material

In the second part of our investigation we evaluated the coarticulatory influences of initial stop consonants on the fundamental frequency of vowels by varying the place of articulation as well as the voicing of the plosives. The key words containing the initial German plosives /p/, /t/, /k/, /b/, /d/, /g/ were embedded in the aforementioned carrier sentence "Ich habe ... gesagt".

Procedure

Since we expected the microprosodic F₀ variations to be strongly dependent on the individual speaker, we decided to process the utterances of only one speaker in the first step of the experiment. The test sentences were spoken by a male subject (DL) three times each. The recording was carried out at three different days within two weeks. The test sentences were typed on cards and presented to the speaker in random order. The subject, a native speaker of Standard German, was instructed to pronounce the sentences successively with a few seconds' interval.

The material was recorded in an anechoic chamber using a professional microphone and tape recorder. Before digital processing we checked whether the test sentences were uttered with the same underlying intonation contour in all cases. A group of four listeners had to identify the sentence modality unanimously as declarative. The syllable containing the test vowel had to be realized with nuclear stress, i.e., rising F₀, controlled by means of a Frøkjaer-Jensen Transpitch Meter output. Utterances that did not meet these requirements were eliminated for the moment and recorded again; this proved to be necessary in a total of 14 cases.

The fundamental frequency extraction was carried out by an algorithm /13/ that represents the speech oscillogram in high temporal resolution. The program enables determining the duration of fundamental periods and calculating the actual F₀ values for each period. The results are presented and discussed in the following section.

RESULTS

The values of intrinsic fundamental frequency for the German long and short vowels presented in figure 1 were determined as follows. Presuming that our studies into microprosody are subordinate to intonation analysis on the sentence level, we looked for a way to condense the F₀ microstructure of a vowel in one single representative value. Two procedures with two measuring points seem to be particularly suitable:

a) Arithmetic mean $\bar{x}$: To begin with, we cut off the first and last third of the temporal course of the vowel. Then the arithmetic mean is calculated for the F₀ values of the remaining (second) third. This procedure is motivated by the fact that the influences of neighbouring segments may be considered relatively small in this quasi-stationary part of the vowel /1/.

b) 2/3 value: This is the momentary value of fundamental frequency at two thirds of the duration of a vowel /12/. This well-established method has been applied repeatedly in the literature /cf. 2/. Rossi defines a regularity which says that a pitch movement is not perceived by listeners as a whole; on the contrary, the perceived pitch of a vowel corresponds to a value of fundamental frequency that is measured at the boundary between the second and the last third of the temporal course of F₀. The 2/3 value may be regarded as representative for linearly rising or falling F₀ glissandos.

The results show - as we had expected - essentially higher IF₀ values for high vowels compared to those of low vowels, with the exception of the short /U/ which has even lower IF₀ values than /ɛ/. With the tongue height being equal, back vowels show higher IF₀ than front vowels, which is in accordance with data reported in the literature /1, 10/; /U/ is the exception here, too. The values for /i:/ and /I/ turned out somewhat lower than expected, a finding that may be caused by the structure of the test material containing several key words with final vocalized /r/, such as "Pier" or "Tier". This ought to be controlled by using other test words containing the vowels /i:/ or /I/, respectively, and final obstruents.

Two essential results of our investigation concerning the coarticulatory fundamental frequency variations are illustrated by figures 2 and 3. Figure 2 gives a detailed representation of the averaged F₀ tracings for the CV combinations "voiceless plosive + long vowel" and "voiceless plosive + short vowel". The figure shows that vowel quantity influences the actual F₀ values rather than the whole contour. Furthermore the influence of the initial plosive has decayed after at most 50 ms. This is important for further measurements. The influence of coarticulatory F₀ variations may be neglected when the point of measurement is chosen appropriately, that is, at least 50 ms after the vowel onset.

Figure 3 supports the hypothesis /1, 2/ that the place of articulation of the stop consonant has no significant influence on the course of fundamental frequency in the following vowel.

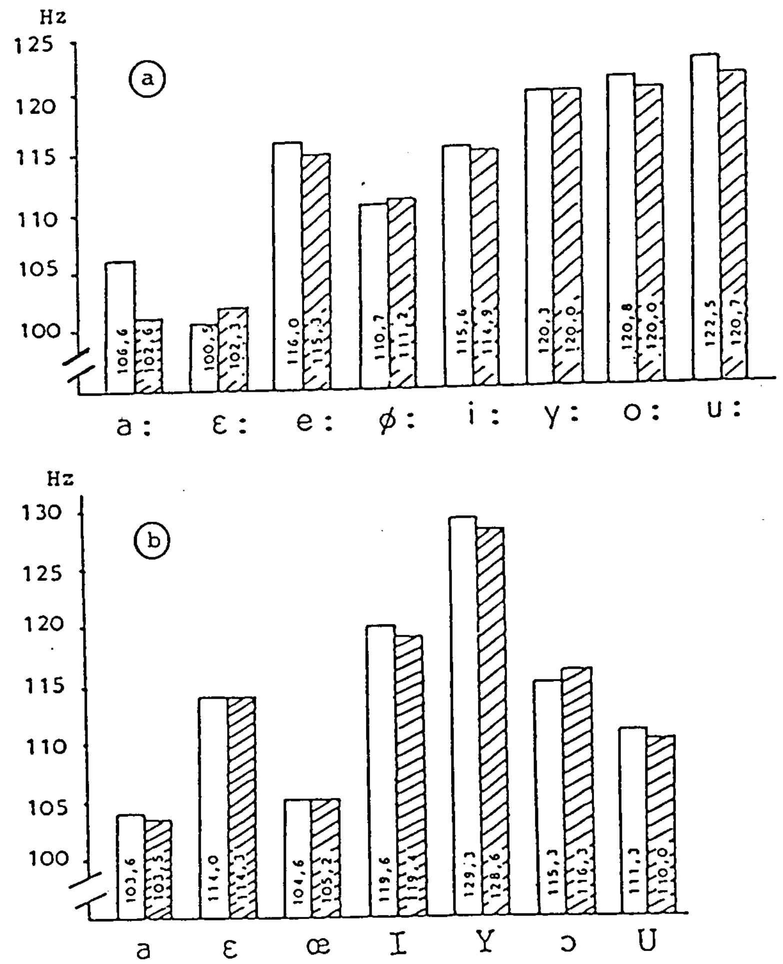

Figure 1a, b. Intrinsic fundamental frequency values of the German vowels. (a) Long vowels; (b) short vowels. F_0 calculation for the 2/3 value (/12/; white surfaces) and for the arithmetic mean $\bar{x}$ (hatched surfaces). All utterances by one speaker (DL, male)

DISCUSSION

There remain at least two problems deserving discussion here, in particular for the part of our study that deals with the influence of initial stop consonants on the course of fundamental frequency of vowels.

The vowel onset after voiced and voiceless plosives is mostly reported in the literature to be rising or falling, respectively. We also share this observation. In a recent study Silverman /14/ argues that this so-called "rise-fall dichotomy" - falling F_0 after voiceless stops and rising F_0 after voiced ones - is an artifact brought about by the structure of the test sentences. In the great majority of investigations the key words are integrated within a carrier sentence in nuclear-stress position. In many languages, however, this position is marked by a rising underlying intonation contour. This constellation, applying to our data as well, is in Silverman's opinion and in accordance with the results of his experiments the ideal condition for an apparent dichotomy of rising and falling F_0 contours.

Furthermore we proceeded from the assumption that the influence of a stop consonant on vowel F_0 is purely progressive, i.e., only following vowels are affected /3, 6, 8/. In two recent studies, however, Kohler /4, 5/ showed that the F_0 microstructure may also contribute to the discrimination of postvocalic lenis and fortis obstruents.

We hold the view that Silverman's arguments as well as Kohler's findings will have to be taken into account in the choice of test material in future studies

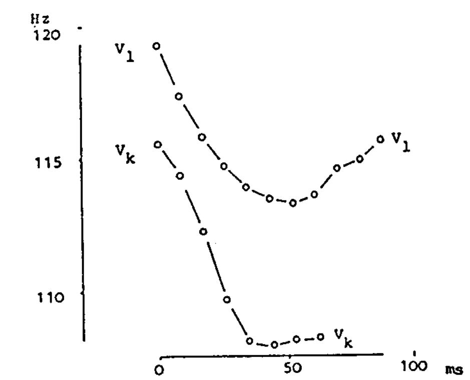

Figure 2. Coarticulatory F_0 variations. The figure shows the F_0 course of the CV combinations "voiceless plosive + short vowels" (V_k) and "voiceless plosive + long vowels" (V_l). Vowel onset at 0 ms. All utterances by one speaker (DL, male)

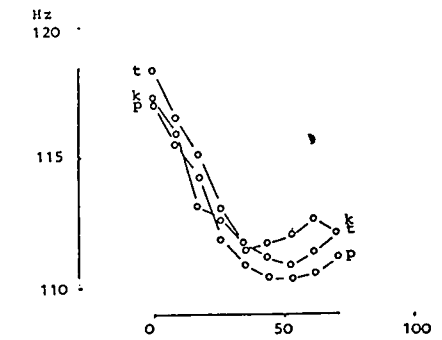

Figure 3. Coarticulatory F_0 variations. The figure shows the F_0 course of the combinations "(/p/, /t/, /k/) + vowel". Vowel onset at 0 ms

and in the interpretation of data reported in the literature.

CONCLUSION

The procedure presented here will allow us to study and analyse intonation on the sentence level without considering the interfering influences of the microprosody. The proposed points of measurement-arithmetic mean $\bar{x}$ and 2/3 value - are both found representative of vowel fundamental frequency. The actual variations of the intrinsic fundamental frequency of high and low vowels, however, will have to be determined for each speaker separately.

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