Intrinsic pitch in German – Examining the whole fundamental frequency contour of the vowel

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Introduction

It is very well known that close vowels tend to have a higher fundamental frequency (F0) than open vowels (known as intrinsic pitch differences, hereafter IF0). This phenomenon is very robust: Whalen and Levitt (1995) found these F0 differences for 31 different languages, independent of their vowel inventory and in Whalen et al. (1995) for vowel productions of French and English babbling infants. These observations suggest a biomechanical explanation for these F0 differences, related to the tongue height: an upward movement of the tongue could causes a rotation of the thyroid cartilage with respect to the cricoid cartilage and therefore raises the fundamental frequency.

However, the results of Fischer- Jørgensen (1990) indicated that in German tense-lax vowel pairs are produced with a similar F0 at the vowel midpoint, although the tongue position is lower for lax vowels. She also found a better agreement between intrinsic pitch and jaw position. Mooshammer et al. (2001) replicated this study and found comparable F0 results for the midpoint of the tense-lax vowels. Examining intrinsic F0 differences under a bite-block condition (fixed jaw) they found that intrinsic pitch differences remain constant or even increase, therefore excluding the jaw as the main cause.

The aim of the current study is first to examine intrinsic pitch differences for the German tense and lax vowels with a more accurate measurement of the fundamental frequency (EGG) and secondly to examine the complete F0 contour. This was motivated by a pilot study of Hoole (to be published) who found higher CT activity at the beginning of lax vowels for one speaker, therefore speaking for another control mechanism of IF0 in German.

Method

We recorded synchronized EMMA, audio and EGG signals for four male German speakers (CG,JD,RW,DF). Target words were /bemVme/ where V consisted of the three tense and lax German vowels /iː ɪ uː ʊ ɑː a/. Nasal context was chosen to exclude distractions of the F0 contour by possible devoicing of stops or fricatives. The carrier phrase was "Sage ___ bitte" ("Say ___ please") and each sentence was presented 8 times in randomized order. From the EGG signal the peaks of the first derivative (corresponding to the time of the glottis closing) were regarded as the fundamental period. Thresholds were set manually for each sweep to include on the one hand very weak amplitudes of the derivative at the beginning of the vowel and to exclude on the other hand peaks caused by noise. The beginning and the end of the vowel were labelled based on the occurrence of a defined higher formant structure. We calculated ensemble averages over each vowel with the line-up point at the vowel onset (see figure 1 and figure 2) and vowel offset separately.

Results

Three speakers (CG, JD, RW) have been analyzed so far using analysis of variance. The duration of tense vowels differed significantly ($p<0.000$) from the duration of lax vowels for all speakers (except /u/ for speaker JD). The F0 values for tense and lax /a/ were significantly lower than the F0 values for tense and lax /i/ and /u/ at the onset, midpoint and offset of the vowel. Speaker CG showed the described significant differences only at the midpoint of the vowel.

Analyzing F0 differences with respect to tense-lax vowel pairs, no significant differences could be found between the vowelspairs /ɑː/ and /a/ and also not between /iː/ and /ɪ/ at the onset, midpoint and offset of the vowel. The vowel /uː/ had a significantly higher F0 than /ʊ/ at the onset and at the midpoint of the vowel for two speakers (JD: $p=0.03$ at onset and midpoint; RW: $p=0.03$ at the onset and $p=0.05$ at the midpoint).

The F0-contours: Figure 1 and figure 2 show the F0 contours for the four speakers. The vowel /a/ starts for all speakers higher than in the corresponding tense vowel. Also the maximum of the F0 contour is as high or even higher for /a/. The F0 contours for /iː/ and /ɪ/ are generally similar (exception speaker DF whose /iː/ and /ɪ/ pattern shows the same characteristics as the described /ɑː/ - /a/ pattern for all speakers). Like for the vowels /ɑː/ and /a/ the F0 peaks exhibit similar F0 values for the tense-lax vowel pair /iː/ and /ɪ/. The F0 contours for the vowel /u/ show inconsistent results. For three speakers (JD, RW, DF) the F0 contour the of /ʊ/ starts lower and does not reach the height of /uː/. For one speaker (CG) the contour of the lax vowel starts higher than the tense one but reaches the same F0 height (a possible explanation for the inconsistency could be that the acoustic segmentation for tense /u/ is quite variable because of the lack of high-frequency information in the spectrogram for both tense /u/ and /m/).

Timing of the F0 peak: To analyze the timing of the F0 maximum in relation to the vowel offset ensemble averages with vowel end as the line-up point were carried out. For the speakers JD and RW the following strategy could be observed for /i/ and /u/: The F0 peaks for the lax vowels are

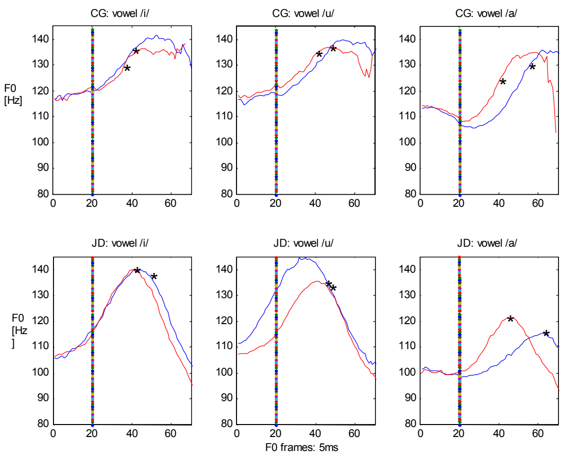

Figure 1: Averaged F0 contours for CG (top row), and JD (bottom row): tense (blue) and lax (red) vowels. The vertical line represents the vowel beginning. Stars indicate the end of the vowel.

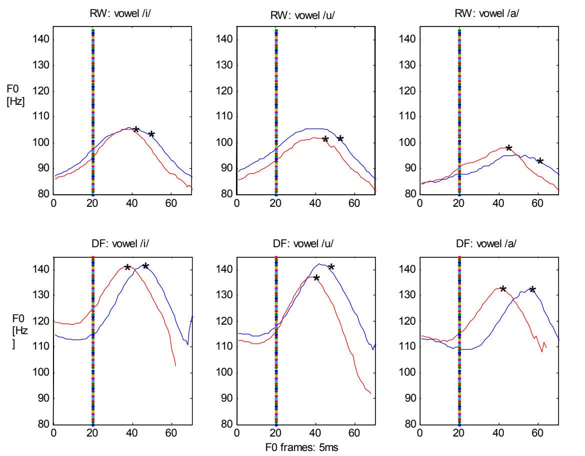

Figure 2: see Figure 1, but for speakers RW (top row) and DF (bottom row)

reached at the offset of the vowel, whereas for the tense vowels the F0 maxima precede the vowel offset (for speaker JD the differences were weakly significant with $p< 0.05$). Speaker RW shows a similar strategy for the vowel /a/, whereas speaker JD reaches the F0 maximum at the end of the /ɑː/, but later for the lax counterpart (weakly significant with $p< 0.05$).

The timing of the F0 maxima for speaker CG and DF differ from the other two speakers: The F0 maxima for both tense and lax vowels are not yet reached at the end of the vowel. The reason for CG (origin Southern Gemany), could be attributed to the latest findings of Atterer and Ladd (2004) who found, comparing lax vowels, later timing of the F0 maxima for speakers of Southern Germany, although not significantly.

Discussion and Outlook

Ladd et al. (2000) found for Dutch that the F0 peaks of tense vowels in a nuclear stressed syllable are situated at the end of the vowel whereas lax vowels tend to have the F0 peak considerably later, often at the end of the following consonant. However, the height of the F0 maximum is the same for both tense and lax vowels. For two of our German speakers results show a similar trend as the results of Ladd for Dutch. However the timing is different: In our data the F0 maximum for stressed tense vowels occurs within the vowel, whereas the F0 maximum for lax vowels is situated at the offset of the vowel. For the other two speakers different strategies for the timing of F0 maxima alignment are found.

In the current study the effect of tenseness on IF0 is not as consistent as in previous studies (Fischer-Jørgensen 1990, Mooshammer et al. 2001). On the one hand IF0 differences for the back vowels /uː/ and /ʊ/ do not contradict the notion of a biomechanical cause. On the other hand results for /iː/ versus /ɪ/ and /ɑː/ versus /a/ indicate that the tense-lax pairs show different F0 contours even preceding the vowel onset: The contours of the lax vowels start higher than the contours of the corresponding tense vowels which is in opposition to the tongue height found for the tense-lax pairs.

Both speaker-dependent and vowel-dependent strategies have been found: Therefore we assume that different mechanisms are used to produced these tense-lax F0 differences. EMMA analyses of the affected articulators at different landmarks of the contours will clarify the causes. Additionally, analyses of CT activity are in preparation to investigate its possible active control of the fundamental frequency. From a typological point of view it would be interesting to compare the presented contours of tense and lax German vowels in nasal context with a language where long and short vowels without quality differences exist, such as Finnish.

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