When does lip protrusion start in Standard Austrian German? An acoustic investigation.

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ABSTRACT

CV, V_1CV_2- and $V_1\#CV_2$-sequences of reading material of six speakers of Standard Austrian German have been analysed. V_1 was a pre-palatal, constricted vowel /i/ in unstressed position. C was an alveolar consonant. V_2 was either a pre-palatal, constricted vowel /i/, or a back, rounded vowel /u, o/ in a stressed position. F1, F2, F3, and VOT measurements were performed. Lip protrusion starts at consonant release and may affect the transconsonantal vowel, as long as V_1 and C are not separated by a word boundary.

Keywords: coarticulation, interindividual differences, lip protrusion, acoustic analysis of vowels.

1. INTRODUCTION

Although Menzerath & de Lacerda [11, 12] were not the first to observe anticipatory lip protrusion[i], they coined the term "coarticulation" for this and resembling phenomena. Many, mainly articulatory studies on anticipatory lip protrusion followed [2, 5, 6, 7, 8, 16, 17, 18, 19, to name just a few]. It can be concluded from their results that the realisation of anticipatory lip protrusion displays considerable language and speaker specific differences, both as regards the amount of time or the number of phonemes preceding the rounded vowel, or even as regards the quality of the transconsonantal vowel [18]. Farnetani [4] put forward that languages with front rounded vowels might suppress anticipatory lip protrusion, in order to avoid confusion. However, results on Swedish [8] and French [17, 19] do not support this hypothesis.

Acoustically, lip protrusion manifests itself in a lowering of all formant frequencies; a lengthening of the cavity by 0.5 cm causes the formant frequencies to drop approximately 3% to 4%, depending on the length of the cavity.

A CV sequence, where C is an alveolar consonant and V a back, rounded, constricted vowel /u, o/, demands a steep F2 transition starting at approximately 1800 Hz at consonant release and falling to approximately 800 Hz to 600 Hz for the vowel when lip protrusion has been accomplished. The steep F2 transition is the result of

- tongue body retraction (the further back, the lower F2, provided F2 is a natural frequency of the front cavity),
- constriction degree (the higher, the lower F2), and
- degree of lip protrusion (the more protruded, the lower F2).

The release of the consonantal constriction causes a slight rise in F2 directly at the point of release. Consonantal release does not, however, affect F2 any further [10]. Where a language has less protruded or unrounded back vowels at the same constriction location, the contribution of tongue body retraction to F2 can be teased apart from the contribution of lip protrusion. F3 gives information about the degree of constriction; the higher F3 of back vowels, the tighter the constriction [3].

As concerns transconsonantal anticipatory lip protrusion, articulatory studies prefer labial contexts, because labial consonants hardly interfere with the vocalic lingual articulation [1]. Acoustically, however, a closure of the lips inevitably leads to a fall of the formant frequencies of the preceding vowel. This is not the case in the alveolar context. An alveolar consonantal context is therefore to be preferred in an acoustic study on anticipatory lip protrusion.

In the case of anticipatory lip protrusion in a V_1CV_2-sequence, where V_2 is a back rounded vowel and V_1 a front unrounded vowel, formant frequencies of V_1 are supposed to show lower F2 values as compared to the same vowel without lip protrusion. However, not every drop of formant frequencies needs to be the result of anticipatory lip protrusion. In a comparison where V_2 is either a back rounded vowel or a front unrounded vowel (/itu/ vs. /iti/), higher F2 values at vowel offset of V_1 in /iti/ as compared to vowel offset of V_1 in /itu/ might as well be attributed to palatalisation of the consonant and, concomitantly, a higher degree of constriction in V_1 (henceforth palatalisation). In the case where a language discerns front rounded and front unrounded vowels, anticipatory lip protrusion can be assumed, if formant frequency values approach those of the respective front rounded vowel.

Standard Austrian German, as defined in [13], discerns 13 vowels on five constriction locations: pre-palatal /i, ɪ/ and /y, ʏ/, mid-palatal /e, ɛ/ and /ø, œ/, velar /u, ʊ/, upper pharyngeal /o, ɔ/, and lower pharyngeal /ɑ/. The pairs are further distinguished by degree of constriction and degree of lip aperture [14]. Therefore, all conditions necessary for analysing anticipatory lip protrusion from an acoustic point of view are met.

2. METHOD

Three female (AF, BF, CF) and three male (AM, BM, CM) speakers of Standard Austrian German were asked to act as speakers. In a sound proofed room, open interviews were carried out with the speakers. The speakers were then asked to read a list of 72 sentences twice. For the current investigation, the reading sentences material has been analysed.

The current investigation comprises three parts. In the first part, CV-sequences were analysed, where C is an alveolar lenis or fortis plosive and V a back, rounded, constricted vowel /u, o/. Correlations of VOT and the first frame of F2 have been performed.

In the second part, V_1CV_2 sequences were chosen. V_1 is a pre-palatal vowel /i/ in an unstressed position. V_2 is either a pre-palatal, unrounded, constricted vowel /i/ or a back, rounded, constricted vowel /u/ in a stressed position. C is an alveolar consonant. The last five frames of V_1, preceding either a Cu- or a Ci-sequence, were submitted to a one-tailed t-test. In order to test whether lip protrusion affects the transconsonantal vowel, the mean values of the respective /y/ and /i/ vowels in unstressed position have served as reference values. Differences (in %) from these reference values have been calculated. Anticipatory lip protrusion was assumed, when a) a drop of formant frequencies > 4 % with respect to /i/ was observable and b) when formant frequency values approached the values for /y/ (difference < 4 %).

The third part is the same as second, except that V_1 and C are separated by a word boundary.

F1, F2, F3, F0, and duration measurements were performed on the selected vowels. Formant frequencies were calculated with linear predictive coding (26 coefficients, and a pre-emphasis of 0.9). A window length of 46 ms was chosen, with an overlap of 95%, rendering, depending on the duration of the vowel, 20 – 150 measurements per vowel. VOT was measured for all plosives.

3. RESULTS

3.1. VOT and F2 at vowel onset

As can be seen from Figure 1, there is a strong negative correlation between the duration of VOT and the value of F2 at vowel onset: i.e. the longer the duration of VOT, the lower F2 at vowel onset.

Figure 1: Regression lines and scatter plot of VOT vs. F2 at vowel onset for CV sequences, where C is an alveolar plosive and V a back, rounded, constricted vowel /u, o/. Dashed line, triangles: female speakers. Solid line, circles: male speakers.

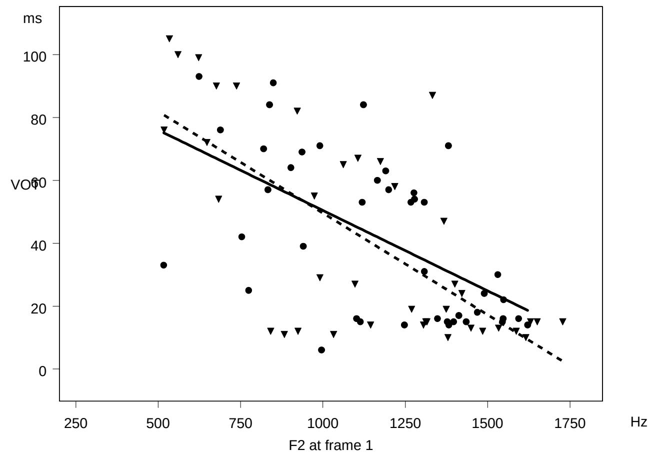

Table 1 gives the correlation coefficient r broken for speakers.

Table 1: Correlation coefficient r for VOT/F2 at vowel onset, broken for all speakers. Statistically significant results ($p < 0.05$) are in bold.

Speaker	AF	BF	CF	AM	BM	CM
r	**-0.8**	**-0.9**	**-0.7**	**-0.6**	**-0.8**	-0.5

It can be seen from Table 1 that, with the exception of speaker CM, all speakers expose a statistically significant, strong negative correlation between the duration of VOT and the value of F2 at vowel onset.

The values of F2 at vowel onset are, for each speaker, lower for the constricted, rounded vowels /u, o/ than for the unconstricted, less rounded vowels /ʊ, ɔ/. Only one speaker (CF) exposes statistically significant differences of F3 in the pair /u/ – /ʊ/. Three speakers (CF, AM, BM) expose statistically significant differences of F3 for the pair /o/ – /ɔ/. Therefore, it can be concluded that a substantial part (200 Hz to 400 Hz) of the decrease in F2 of the vowels /u, o/ can be attributed to lip protrusion.

In Standard Austrian German, lip protrusion starts at plosive release. Whether it is accomplished at vowel onset or not, depends on the amount of time that lies between plosive release and vowel onset. In cases where VOT is short, the completion of lip protrusion is dragged into the vowel. These findings are in accordance with results on perception tests which show that in CV sequences, where V is a rounded vowel, lip protrusion has to start at plosive release in order to guarantee the correct perception of the plosive [9]. Vaxelaire et al. [19] found out that, although lip protrusion traverses the preceding plosive in French, the audible part of lip protrusion is located after plosive release, in the VOT span.

3.2. Does lip protrusion affect the transconsonantal vowel?

V_1CV_2-sequences have been compared where V_1 is a pre-palatal, constricted vowel in an unstressed position, C is an alveolar plosive, and V_2 is either a pre-palatal, constricted, unrounded vowel /i/ or a velar, constricted, rounded vowel /u/ in a stressed position (i.e. a comparision between /i'tu/ and /i'ti/). All speakers show statistically significant differences in dependence on the quality of V_2 in the last five frames of V_1. F2 is lower for all speakers, when V_2 is a velar, rounded vowel. Five speakers show a lower F3 as well (differences are not statistically significant for AF). Results for F1 are not as clear. This is not surprising, since both lip protrusion and palatalisation lead to a drop in F1. Therefore, the most relevant parameters are F2 and F3.

Table 2 gives the results of the differences (in %) of F2 and F3 of the last five frames of V_1, when V_2 is a velar, rounded vowel /u/, to the mean values of all measured /i/ and /y/ in unstressed positions.

Table 2: Differences of F2 and F3 (in %) of the mean values of the last five frames of V_1, when V_2 is a back, rounded vowel, to the mean values of /i/ and /y/ in unstressed position.

Speaker	AF	BF	CF	AM	BM	CM
F2 /i/	1.8	3.6	14.2	4.2	1.8	5.0
F2 /y/	14.1	19.6	3.4	4.1	10.1	16.1
F3. /i/	2.1	2.5	5.6	8.0	0.4	0.3
F3 /y/	15.0	3.7	7.1	10.3	10.6	15.5

The differences as concerns the last five frames of V_1 and the mean values of /i/ are < 4 % for both F2 and F3 of AF, BF, and BM. Moreover, these three speakers show considerable differences with respect to the mean values of /y/. Therefore, it can be concluded that for these three speakers, lip protrusion does not affect the transconsonantal vowel.

The differences of CM exceed 4% as regards the mean values of F2 of the vowel /i/. However, the differences with the mean values of /y/ exceed 15 %. It is therefore concluded that V_1 is not affected by lip protrusion.

Values are not conclusive for AM: whether he applies transconsonantal lip protrusion or not can not be traced from the data.

However, for one speaker, CF, especially F2 values depart substantially from the mean values of /i/ and approach those of /y/. The differences also exceed 4% for F3, so that it can be concluded that lip protrusion affects V_1.

The differences observed between V_1 in dependence of the quality of V_2 cannot, therefore, be attributed to transconsonantal lip protrusion, at least for four out of six speakers. Rather, the differences must be attributed to a palatalisation of V_1, when V_2 is a pre-palatal, constricted vowel /i/.

3.3. The role of the word boundary in V_1#-CV_2-sequences.

From the results obtained for V_1CV_2-sequences it can be assumed that the word boundary puts a further constraint on anticipatory lip protrusion. Again, all speakers show statistically significant differences in dependence of the quality of V_2. F2 is lower for five speakers (no differences for CF), when V_2 is a velar, rounded vowel. Five speakers show a lower F3 as well (differences are not statistically significant for CM).

Table 3 give the results of the differences (in %) of F2 and F3 of the last five frames of V_1, when V_2 is a velar, rounded vowel, from the mean values of all measured /i/ and /y/ in unstressed position.

Table 3: Differences of F2 and F3 (in %) of the mean values of the last five frames of V_1, when V_2 is a back, rounded vowel, to the mean values of /i/ and /y/ in unstressed position. V_1 and C are separated by a word boundary.

Speaker	AF	BF	CF	AM	BM	CM
F2 /i/	1.1	2.7	2.6	0.4	2.7	3.1
F2 /y/	15.0	20.7	17.4	8.3	9.2	18.3
F3. /i/	0.9	1.7	4.5	3.3	0.1	4.0
F3 /y/	11.6	4.5	8.3	16.0	11.1	10.5

It can be concluded from this data that none of the speakers protrudes the lips in V_1, when V_1 and C are separated by a word boundary.

4. CONCLUSION

In Standard Austrian German, lip protrusion starts with plosive release. Usually, lip protrusion does not affect the transconsonantal vowel. However, this possibility is not ruled out, as long as the consonant and V_1 are not separated by a word boundary. At least one speaker applied transconsonantal lip protrusion. Therefore, as has been shown in many previous studies, the application of transconsonantal lip protrusion is a speaker-specific trait. This means that coarticulatory phenomena, e. g. lip protrusion, are lead by (phonetic) processes and are, ultimately, planned. The (at least partly) planned nature of coarticulation has already been put forward by [5, 15, 20, 21, 22], among others.

5. REFERENCES

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