WEAK CLICKS IN GERMAN?

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ABSTRACT

We investigated alveolar-velar stop sequences in connected speech processes in order to understand the potential articulatory and aerodynamic causes for the alveolar weakening, often discussed with respect to assimilation. We will also shed light on the potential click-nature of these sequences as suggested in the literature. By means of a new experimental set-up which allowed us to monitor tongue-palatal contact patterns simultaneously with intraoral pressure variations 8 German native speakers were recorded. Temporal results and relative burst intensities were obtained from acoustic data, the potential overlap of alveolar and velar movements was obtained by tongue palatal contact patterns in the anterior and posterior regions, and a brief period of pressure rarefaction at alveolar release (negative pressure) was taken as evidence for clicks. On the basis of these data speaker specific evidence is provided for weak clicks in German.

Keywords: non-pulmonic sounds, double occlusion, assimilation, intraoral pressure, EPG

1. INTRODUCTION

The assimilation of alveolar to velar stop sequences in connected speech has been a challenging topic for phonological theory. Articulatory data (EPG, EMA) have shown that such assimilations are often not complete, i.e. assimilation is a continuous rather than categorical process and therefore a serious problem for phonological theories based on binary features [1, 2, 3, 4]. Data suggest [4, 5, 6] that C_1, the alveolar stop, is weakened, but it is unclear whether this process is of articulatory or auditory origin. Ohala [5] proposed that the source of assimilation lies in the acoustic-auditory domain of the listener (C_2V has more salient place cues than VC_1), not in the articulatory domain of the speaker (less articulatory effort, reduction for the first consonant).

Based on acoustic data from the Kiel Corpus, Simpson [8] claimed that the occurrence of alveolar-velar assimilation in German is first, frequently absent, and second, it has a complex distribution in spontaneous speech. According to Simpson, the most interesting evidence for the absence of assimilation were weak bursts (clicks) representing a double occlusion (alveolar and velar closures). Simpson [9] described these as non-pulmonic sounds resulting from the release of alveolar closure once the velar occlusion is made. A similar observation has been made [5] for /mn/-clusters where a temporal overlap of the labial and alveolar closures creates a small intraoral cavity. At the labial release a momentary rarefaction of the air pressure occurs and weak bursts (clicks) can be perceived. First experimental evidence has been provided by Silverman and Jun [7] who found a short period of oral pressure rarefaction in Korean labial-velar consonant clusters.

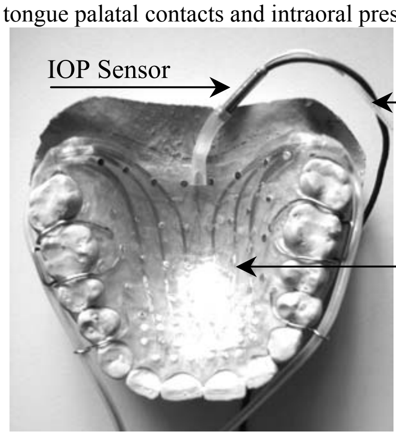
The aims of this study are to investigate simultaneously the acoustic, articulatory and aerodynamic properties of alveolar-velar sequences in German in order to study first, the potential causes for the weakening of C_1 and second, to provide further insights in the potential click-nature of these sounds.

2. METHODS

Thanks to Jörg Dreyer a new experimental set-up was designed which allows one to monitor tongue-palate contacts simultaneously with intraoral pressure variations. Tongue-palate contact patterns were recorded by means of EPG (Reading system, EPG 3) with a sampling rate of 100 Hz.

Intraoral pressure changes were recorded synchronously by means of a piezoresistive pressure transducer (Endevco 8507C-2) which was fitted to the posterior end of the artificial palate via a flexible plastic tube (see Fig. 1). The pressure sensor is about 2.4 mm in diameter and has a length of 12 mm.

Figure 1: Experimental set-up for combined recordings of tongue palatal contacts and intraoral pressure.



The sensor measures a pressure difference between intraoral and atmospheric pressure. This technique is easier to apply in comparison to set-ups like tube insertion through the nose since it is not affected by saliva blocking the tube, and participants' speech is quite natural. The pressure data were acquired using PCQuirer version 5.0 at a sampling rate of 1859 Hz and subsequently imported into Matlab for processing. All together 8 speakers were recorded, 5 males (dp, jd, rw, sg, tw) and 3 females (jb, sf, sk) with a corpus of 42 target words embedded in compounds and carrier sentences. All targets are real words of German, but most of the compounds do not occur in the German vocabulary. All sentences were repeated 10 times in a randomized order. We will here focus on two of the target items (in bold):

Er nasch**t K**itschende. [t#k^h]

Er nasch**t T**ischende. [t#t^h]

The second sentence was used as a control with no assimilation. Speaker sk had a particularly careful pronunciation whereas all the others produced the sentences more casually.

Based on the acoustic data the following time landmarks were labeled using Praat 4.4.20: on- and offset of S preceding the alveolar, $burst_1$ for C_1, $burst_2$ for C_2, aspiration offset, and middle of following vowel. Relative burst intensities were calculated as the difference of the relevant burst with respect to the intensity of the following vowel mid point. The smaller the difference, the more prominent the burst. The larger the difference, the weaker (softer) the burst. Based on the EPG data we calculated the percentage of contact in the first 4 rows (ANT) to classify the /t/ and the percentage of contact in the last four rows (POST) to classify the velars. Additionally, we labeled the time point where full alveolar or velar closures were visible.

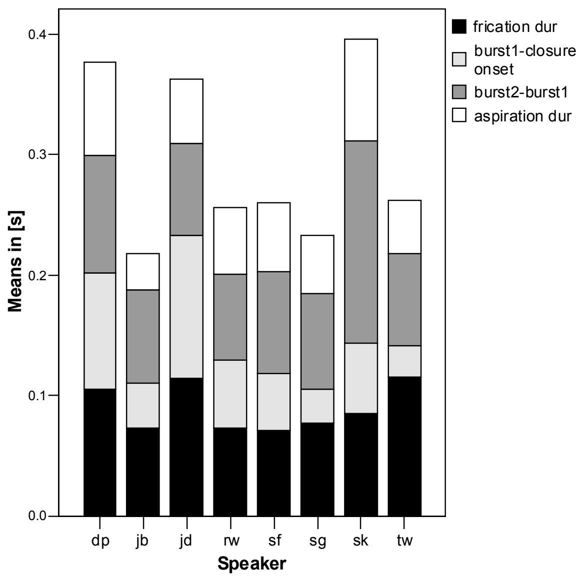
3. RESULTS

3.1. Acoustics

3.1.1. Temporal results

Figure 2 unifies the temporal results based on the acoustic data. Only those data were taken into account where two bursts were realized.

Figure 2: Stacked bar plots showing averaged temporal results in t#k for frication duration of /ʃ/ in black, closure duration for /t/ in bright gray, burst to burst duration in dark gray, aspiration duration for /k/ in white; split by speaker



Overall dp, jd, and sk show a longer duration of the whole cluster interval, i.e. they speak more slowly than all the other speakers. The most relevant measure in terms of the potential overlap of the alveolar and the velar movements is probably the duration between the two bursts (in dark gray). Sk, the one who pronounced most carefully, clearly depicts a considerably longer duration (i.e., less overlap) than all the other subjects.

3.1.2. Burst intensity

In Tab. I the averaged relative burst intensities are displayed. The larger the value, the larger the difference between vowel and burst, and hence the weaker the burst.

The frequency of missing bursts, especially for /t/, can be inferred from the number of n's in Tab. I (n = 4 or 6, i.e. from 10 repetitions 6 or 4 bursts are missing). For sg spirantization of the final /t/ was often found. For speakers jb, rw, sf, sk, and tw bursts occurred in most repetitions.

Table I: Speaker (col. 1), frequency of occurrence for burst 1 and 2 (col. 2), means of relative burst intensity for /t#k/ (col. 3) and /t#t/ (col. 4) in dB

Sub.	Burst1(n)-Burst2 (n) /t#k/	$Burst1_{rel}$ - $Burst2_{rel}$ /t#k/ in dB	$Burst1_{rel}$ - $Burst2_{rel}$ /t#t/ in dB
Dp	4-10	24.9 > 22.4	-
Jb	10-10	30.6 < 31.9	-
Jd	6-10	31.4 > 23.8	-
Rw	9-10	34.0 > 23.5	-
Sf	9-10	25.0 > 17.3	-
Sg	4-10	27.1 > 23.1	-
Sk	10-10	16.8 < 18.8	15.6 > 14.8
Tw	9-10	28.5 > 20.8	-

The averaged relative burst intensities of the first and second burst are compared: Tab. I shows that final alveolar stop has in most cases a weaker burst than the initial velar stop with the exception of sk and jb who produced a stronger alveolar burst than the velar. The strength of this effect varies subject-dependently between approximately 3 and 10 dB. In the control condition t#t all speakers realized only one burst, except for sk (all tokens) and dp (one token). For sk the final burst in /t/ is slightly weaker in relative intensity than the initial.

3.2. Articulatory results

Figure 3 provides qualitative evidence for a double occlusion and its time course from speaker jd. The speaker realizes successively the alveolar closure, velar closure, alveolar release, and finally the velar release. Based on these data one can clearly see that during the time of alveolar release, a velar occlusion is present. Consequently, the alveolar stop (burst) is a non-pulmonic sound. In some speakers a complete velar closure is very likely to occur, but cannot be seen on the basis of the EPG data. In these data the velar closure is probably realized behind the end of the EPG palate, at the soft palate. Depending on the placement of the velar closure, the intraoral pressure sensor is located either in the cavity between the two closures or in the cavity between the larynx and the velar closure.

Incomplete alveolar closures were found in 6 cases for sg (spirantization), 1 case for dp and tw. All other speakers showed full alveolar closures. Full double occlusion was visible for dp (n=3) and jd (n=9).

Note that in jb's data (n=9) the two closure could be seen but velar closure was in most cases not full until the alveolar closure was released (high precision despite relatively high speaking rate).

Figure 3: Evidence for double occlusion jd, temporal changes in rows from top to bottom, black dots correspond to tongue-palate contacts - y-axis: from posterior (0) to anterior (8).

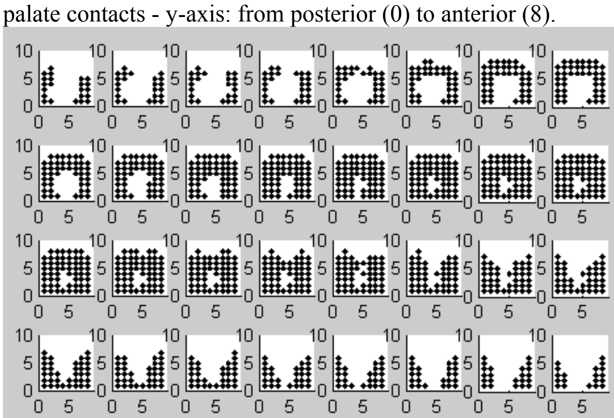


Figure 4: Changes in the % of anterior (black) and posterior (gray) contacts in /t#k/; bold lines=means, normal lines = std. dev.; 8 speakers = 8 subplots; x = norm. time; '+' = averaged and time norm. values for the burst of /t/ (black), /k/ (gray)

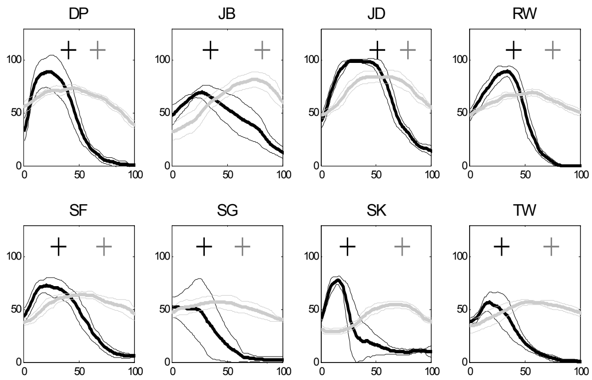
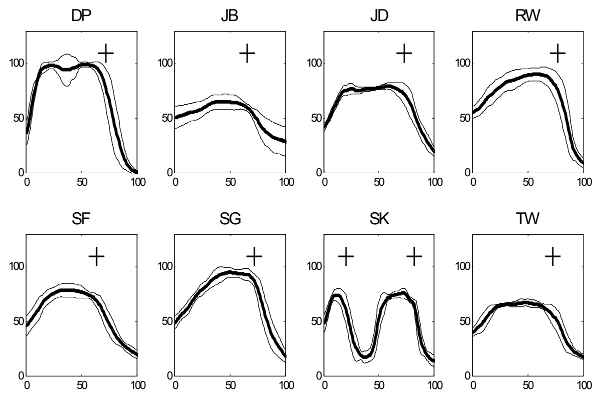


Figure 5: Changes in the % of anterior (black) for the control condition



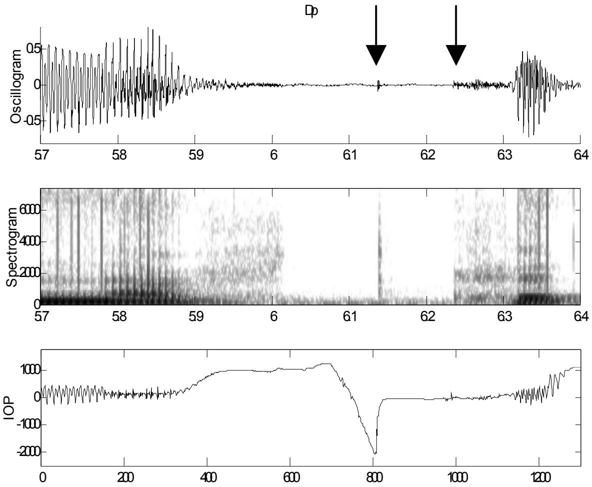
This result may explain why the burst intensity data for jb show similar relations as for sk.

Fig. 4 displays articulatory overlap on the basis of the percentage of ANT (alveolar) and POST (velar) gestures; Fig. 5 shows the pattern for the control condition. The most relevant information for the production of weak bursts is the % of POST at the time of alveolar release ('+' $burst_1$). If it is already close its maximum in /k/ one can assume that velar closure is complete or nearly complete. Except jb and sk, most speakers show such a pattern.

3.3. Intraoral pressure results

So far we have analyzed intraoral pressure data for 5 of 8 speakers and provide qualitative evidence.

Figure 6: Acoustic (top + middle) and IOP (bottom) data in St#k for Dp, arrays correspond to the 2 bursts



Negative intraoral pressure of varying strength occurred 6x in dp's data, 8x in jd's data, and 1x in rw's data. It never occurred (1) in sk's data who showed the least overlap between the alveolar and velar gesture, (2) in sf's data, and (3) in the control condition t#t.

Fig. 6 provides an example of dp's data. Just before the alveolar release ($burst_1$ is marked by the first black line, 2nd track) the pressure drops quickly, becomes shortly negative, and rises again.

4. DISCUSSION & CONCLUSION

Acoustic, aerodynamic and articulatory results of our study support Simpson's [8] findings that alveolar assimilation in alveolar-velar stop sequences is frequently absent in connected speech in German. In more details, the alveolar stops have a weaker relative burst intensity and no aspiration in comparison to the following velars and may therefore be perceptually 'missing'. The acoustic weakening does not necessarily coincide with an articulatory weakening. Full alveolar closure, a requirement to realize an air tight seal, was present in most cases. However, temporally alveolar gestures are shorter (or faster) than velars. An intraoral pressure rarefaction (negative pressure), as evidence for clicks was found subject dependently. So far it is uncertain whether speakers realized a velar closure further back than the EPG palate can capture, velar closure was not complete or whether a pronounced negative pressure at the alveolar release needs an additional increase of the cavity between the 2 closures.

We propose that non-pulmonic sounds, i.e. weak clicks can be realized in connected speech in German, but they are less prominent than the phonologically specified clicks found in many African languages. After all, in one sense, clicks, being allophonic in German, are clearly 'different'.

5. ACKNOWLEDGEMENTS

This work was supported by a grant from the German Research Council (DFG) GWZ 4/8-1, P1. We like to thank Jörg Dreyer for the development of the experimental set-up, Anke Busler for acoustic labeling, Barbara Kühnert and Amanda Miller for helpful comments. This work is dedicated to Dieter Fuchs.

6. REFERENCES

[1] Ellis, L. & Hardcastle, W. 2002. Categorical and gradient properties in alveolar and velar sequences: evidence from EPG and EMA data. *J. Phon*. 30, 373-396.

[2] Kühnert, B. 1993. Die alveolar-velare Assimilation bei Sprechern des Deutschen und des Englischen – kinematische und perzeptive Grundlagen. *FIPKM* 34, 175-335.

[3] Kühnert, B. & Hoole, P. 2004. Speaker-specific kinematic properties of alveolar reductions in German and English. *Clin. Ling. & Phon*. 18, 1-17.

[4] Nolan, F. 1992. The descriptive role of segments : evidence from assimilation. In: Ladd, D. & Docherty, G. (eds), *Papers in Laboratory Phonology II*. Cambridge: Cambridge University Press, 261-280.

[5] Ohala, J.J. 1990. The phonetics and phonology of aspects of assimilation. In J. Kingston & Beckman, M.E. (eds.) *Papers in Laboratory Phonology I. Between the Grammar and Physics of Speech*. Cambridge University Press.

[6] Ohala, J.J. 1995. A probable case of clicks influencing the sound patterns of some European languages. *Phonetica* 52, 160-170.

[7] Silverman, D. & J. Jun (1994). Aerodynamic evidence for articulatory overlap in Korean. *Phonetica* 51, 210–220.

[8] Simpson, A. 2001. Does articulatory reduction miss more patterns than it accounts for? *JIPA* 31, 29-40.

[9] Simpson, A. 2006. Acoustic and auditory correlates of non-pulmonic sound production in German. Talk at P&P3 meeting Stuttgart.