Articulatory investigations of assimilatory processes in German spontaneous speech

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ABSTRACT

Articulatory investigations employing electropalatography (EPG) can be used to study processes of assimilation in spontaneous speech. EPG was applied in this investigation in order to analyze the execution of apical closing gestures. Reduction phenomena and incomplete execution of the articulatory gestures observed fall in line with descriptions known from acoustic databases of spontaneous speech and can be explained with the rules of German phrase phonetics. It will be shown that articulatory investigations may complement acoustic analysis in that information about articulatory gestures not detectable in the acoustic signal alone should become discernible.

1. INTRODUCTION

Compared to canonical forms in pronunciation dictionaries spontaneous utterances of German are strongly affected by reduction and assimilation processes. These processes are well documented by the work of Klaus Kohler dating back to the 1970s [1]. In the 1990s Kohler's work on this topic was based mainly on the Kiel corpora of spontaneous and read speech. Except for some preliminary articulatory investigations (e.g. [2, 3]), these comprehensive analyses were performed mainly auditorily and acoustically.

In Kohler's latest work [4, 5] these reduction and assimilation processes are interpreted as deletion of certain articulatory gestures. These gesture deletions primarily affect the apical opening and closing gestures. Assimilation might therefore be explained as a simple gesture reduction.

One of the main theoretical questions in the framework of the present study concerns the articulatory manifestations of these processes. Here must be decided whether such processes are complete so that nothing remains of the reduced or assimilated gestures or whether there are traces left behind. The latter view would be expected on the theoretical framework set by Articulatory Phonology. This theory predicts that every (canonical) speech gesture is preserved in speech production in the cases of an assimilation or reduction process: the gesture is merely hidden but not deleted.

To resolve this question (gestural hiding or deletion) by means of acoustic analysis alone does not appear practicable; even if no traces of the reduced or assimilated sounds are detectable in the acoustic signal, there may be residual articulatory effects.

Many of the processes of reduction and assimilation affect consonants with dental or alveolar place of articulation. These areas of articulation are best suited for an articulatory investigation using electropalatography (EPG). This method has been used to study spontaneous speech in different languages, e.g. English [6] and Greek [7] where reduced articulations were found quite regularly.

2. METHOD

Three speakers of Standard High German well acquainted with the artificial palate of EPG were recorded. The Reading EPG system was used to capture fragments of a monologue of each speaker. For every speaker ca. 3 minutes of spontaneous speech were recorded and analyzed. The Reading EPG system allows the synchronized recording of EPG-data and the acoustic signal. The sampling rate is 100 Hz for the EPG-signal and 10 kHz for the acoustic signal.

3. REDUCTION PHENOMENA IN GERMAN

Kohler lists several reduction phenomena characteristic of the German language: schwa elision, place assimilation, lenition of plosives and fricatives, nasalization of plosives and vowels, lateral reduction and geminate reduction [5]. All of these phenomena are found in most speaking styles. Spontaneous speech is however best suited for the investigation of such processes as they occur more regularly here than in read speech for example. All of the processes observed take place not only inside words but also across word boundaries.

On account of the method chosen, we restricted our analysis to plosive, nasal and lateral articulation in the dental and alveolar areas. Here EPG data show very clearly whether and where there is contact between tongue and palate.

The phenomena in question are documented by numbered plots of the palatal contact zone on the EPG. In the plot a

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zero means “contact” and a dot “no contact”. In the first row which shows the alveolar area there are only 6 contacts on the artificial palates due to physical proportions of the roof of the mouth and the upper teeth. Due to the sampling rate of 100 Hz successive plots display the contact patterns every 10 ms.

3.1 Assimilation of place

3.1.1 Place assimilation of an apical nasal after a velar or labial plosive, nasal or fricative

In unstressed syllables of German words (e.g. /geːbən/, /ʃpɪnən/) [ə]-deletion is quite frequent. This deletion results in the sequence ‘plosive/nasal/fricative + apical nasal’. As a result of this process, the apical nasal comes in immediate contact with the plosive/nasal/fricative. If this sound is produced velar or labial, this should result in place assimilation of the apical nasal to velar or labial. With regard to the production mechanism, this would imply a reduction of the apical closing gesture.

Another approach maintains that there is still an apical gesture, however one which does not lead to an acoustic signal or which is executed incompletely.

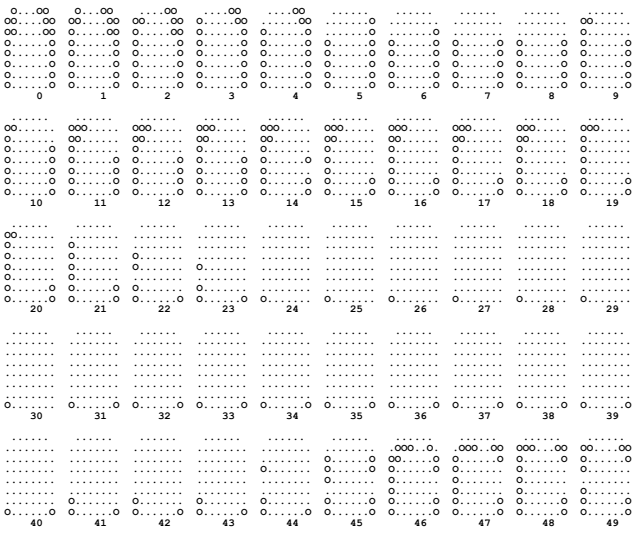

Fig.1: EPG-pattern for <Silben od(er)> (lit.: “syllables or”): friction [z] (0-2), vowel [ɪ] (3-10), lateral [l] (11-22), plosive occlusion [b] (24-25), nasal [m] (25-36), vowel [oː] (36-45), incomplete plosive occlusion [d] (46-49)

Figure 1 shows a typical pattern of this assimilation process. Between the opening gesture of /l/ and the closing gesture of /d/ there is no apical contact in the frontal area detectable. While a nasal sound is audible (frame 25 - 36) there is only one change in the contact patterns on the palate. So it must be assumed that the apical gesture for /n/ is deleted completely and an [m] is produced instead.

In Table 1 the articulations of the three speakers (DM, UK, LZ) are listed in an ‘x/y/z’ manner, where ‘x’ denotes complete deletion (no detectable change in one of the 3 front rows while articulating the /n/), ‘y’ partial deletion (detectable change in the 3 front rows) and ‘z’ no deletion (complete closure contact in the 3 front rows). Due to the sparse data, we chose not to differentiate between preceding manner; nor do we differentiate whether the contact of velar, labial and apical nasal respectively result on account of a [ə]-elision or merely a concatenation of two words.

	DM	UK	LZ
Velar [k,g,ŋ]	8 / 3 / -	3 / - / -	6 / - / -
Labial [p,b,m,f,v]	10 / 1 / 1	4 / - / 1	4 / 2 / 1

Table 1: Deletion, reduction and presence of apical nasal following a velar or labial sound (e.g. <gegenüber> [gŋ], <haben wir> [bm])

In most cases, the reduced form dominates. Residual apical gestures are found only in some instances.

3.1.2 Place assimilation of an apical nasal before a velar or labial plosive, nasal or fricative

The same assimilation process operating conversely round from right to left was also analysed. In most cases it is found in word boundaries without previous Schwa-deletion (e.g. <dann war> [mv], <mussten ganz> [ŋg]).

Again is assumed that the apical gesture is replaced by the following labial or velar, whereas nasalization remains.

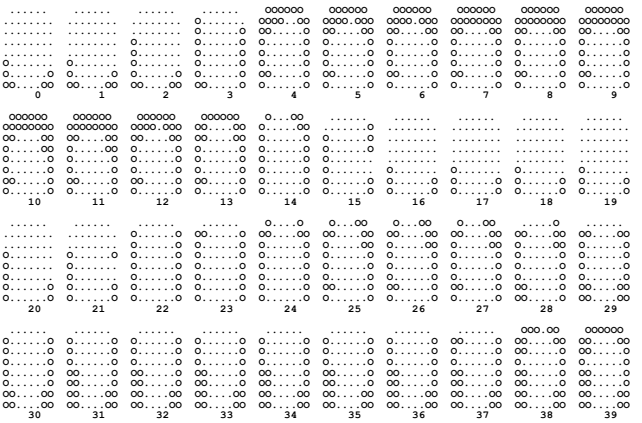

Fig. 2: EPG-pattern for <und dann bin> (lit.: “and then (I) am”): vowel (0-3), nasal [n] (4-9), plosive occlusion [d] (10-13), burst [d] (14-15), vowel [a] (16-23), incomplete occlusion nasal [m] (24-28), plosive occlusion [b] (29-31), burst [b] (32), vowel [ɪ] (33-37), nasal [n] (38-39)

Figure 2 shows an incomplete apical closure gesture for [n] (Frames 24-28). The tongue tip is moving forward as the contacts in the first row are activated. However, the complete closure in the first row necessary for the production of a canonical [n] is absent. In Frame 29 the tongue tip is retracted once again. As in the acoustic signal, there is a clear nasal formant pattern enduring from Frame 24 to 28 and followed by a bilabial closure (Frames 29-31). It can be assumed that an [m] was pronounced. This can be

regarded as an example of a incomplete apical gesture which is hidden by the simultaneous labial gesture.

In this type of assimilation process the apical gesture was generally still active - at least before a labial sound (Table 2).

	DM	UK	LZ
Velar [k,g]	2 / 1 / -	1 / - / -	1 / - / -
Labial [p,b,m,f,v]	4 / 4 / 5	5 / - / 5	4 / - / 5

Table 2: Deletion, reduction and presence of apical nasal preceding a velar or labial (e.g. <dann bin> [mb])

3.2 Reduction of apical closure gestures

EPG also allows a closer look at other processes involving deleted or incomplete gestures in spontaneous speech. We focus on three phenomena evident in the apical articulation area.

3.2.1 Lenition of voiced plosives

An incomplete reduction of the apical closure gesture can be observed very frequently in the articulation of voiced plosives (in our case [d]) in intervocalic surroundings.

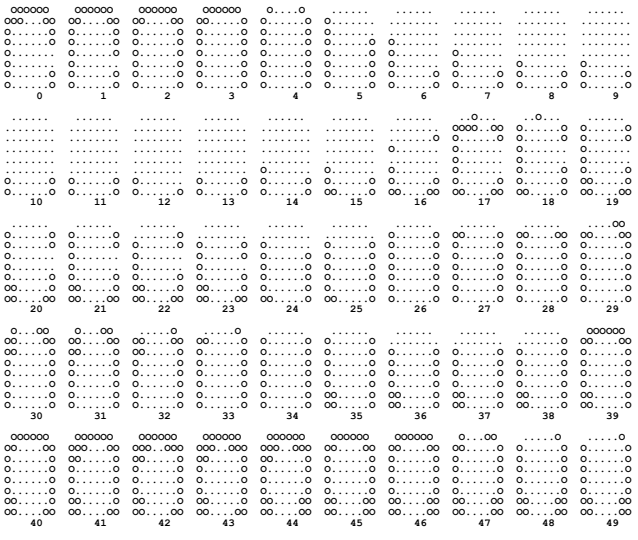

Fig. 3: EPG-pattern for <tat das dann t(otal)> (lit.: "did it then t(otaly)"): occlusion [t] (0-3), burst+aspiration [t] (4-7), vowel [aː] (8-16), incomplete occlusion [d] (17-20), vowel [a] (21-28), fricative [s] (29-33), incomplete occlusion [d] (34-35), vowel [a] (36-38), nasal [n] (39-44), occlusion [t] (45-46), burst+aspiration [t] (47-49)

For intervocalic lenis plosives, Kohler classifies realizations as approximants or deletion. In the corpus, gesture reductions of this kind may be found quite often. Figure 3 shows an example.

In the canonical articulation of <tat das dann t(otal)>, 4 successive apical closing gestures are anticipated. In this sample of spontaneous speech no further closure was detectable between the apical occlusions for the initial [t] of <tat> (Frames 0-3) and the final nasal [n] of <dann> (Frames 39-46).

Two reduced gestures are to be found, leading to a partial contact in the front row (Frames 17-20 and 34-35). These are perceived as [d] from the acoustic signal.

Acoustically, such incomplete reductions may be accompanied by a loss of the plosive burst or even a fricative noise as in the case of a broader frontal opening zone.

3.2.2 Reduction of apical closure after fricative articulation

Following an apical [s,ʃ] or predorsal [ç] fricative, the oral closure of a plosive [t,d] or nasal [n] may be dispensed. While this phenomenon is quite obvious for [t] and is even recognized by untrained listeners in words such as <nicht>, regularly pronounced as [nɪç] in informal speech, it is found in the EPG-corpus additionally for the voiced plosive and nasal.

In the case of [t], the missing apical closure will result in elision of [t]. This [t]-elision is quite frequent in spontaneous speech in the word final position. For [d] and [n], a non-closure may also be observed in initial position. In the case of the (canonical) [n], whether a nasal, a nasalized approximant or, as in the case of a proceeding vowel, a nasalized vowel is audible will depend on the degree of the (non complete) constriction.

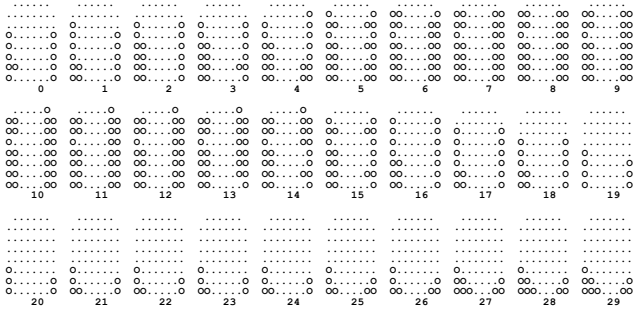

Fig. 4: EPG-pattern for <ich noch> (lit.: "I still"): vowel [ɪ] (0-5), palatal fricative [ç] (6-10), nasalized palatal approximant [n] (11-14), vowel [ɔ]: nasalized (15-19), oral (20-24), uvular fricative [χ] (25-29)

Figure 4 shows two phases of nasal articulation. In the acoustic signal, a voiceless palatal fricative [ç] is still audible as the tongue tip advances (Frame 10). It does not close the front row and during Frame 11-14 a nasal sound is perceivable. The nasalization overlaps onto the ensuing vowel (Frame 15-19).

3.2.3 Lateral reduction

Reductions of lateral production are classified by Kohler by employing a scale ranging from 'full lateral' via 'reduction',

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'deletion with residue' progressing to 'complete deletion' or 'central occlusion' based on acoustic and auditory analysis.

Cases of reductions and deletions of lateral sounds may also be found in the EPG-corpus. Figure 5 shows the pattern of a reduced lateral.

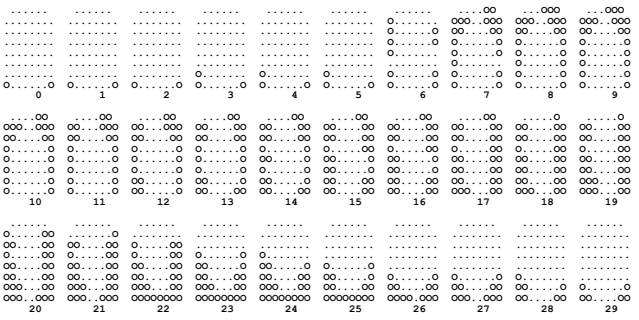

Fig. 5 EPG-pattern of <also ich ko(nnte)> (lit.: "thus I could"): vowel [a] (0-6), lateral [l] (7-9), fricative [z] (10-12), vowel [o] (deleted), vowel [ɪ] (13-17), fricative [ç] (18-21), occlusion [k] (22-27), vowel [ɔ] (28-29)

In Figure 5, the apical contact is restricted to both sides of the palate. The high vowel context and the position preceeding the voiced alveolar fricative [z] are features of the detected tongue contact. Thus the lateral may be defined as reduced. After the velar opening, the contact advances towards the sides of the palate. No frontal contact area is detectable.

The corpus contains even more different patterns for lateral reduction ranging from asymmetrical lateral contacts (see Figure 1, Frames 11-22) to complete reductions with no contact at all (e.g. <nochmal> ("once again")).

4. CONCLUSION

The EPG data of German spontaneous speech samples collected are in line with phenomena documented in auditory and acoustic analyses of large speech databases. They portray qualitative and quantitative performance of speakers in the reduction of certain articulatory movements.

The data presented illustrate that in most reduction phenomena, there is no clean cut between complete deletion of articulatory gestures and residual execution or rather gestural hiding. In spontaneous speech both "types" of reduction phenomena may occur simultaneously.

In this paper only a rather small sample of reduction phenomena could be presented but it should have been sufficient to demonstrate that articulatory investigations of spontaneous speech are beneficial for comprehension of the reduction phenomena found in large acoustic databases of spontaneous speech.

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