ARTICULATORY FEATURES INFLUENCING REGRESSIVE PLACE ASSIMILATION IN GERMAN

Marion Jaeger and Phil Hoole

Institute of Phonetics and Speech Processing, Munich, Germany
E-mail: jaeger@phonetic.uni-muenchen.de, hoole@phonetic.uni-muenchen.de

ABSTRACT

Within the framework of current phonological theories the typological patterns of regressive place assimilation are treated as the consequence of interactions among constraints that have acoustical and perceptual teleologies. Little is known, however, about the articulatory patterns that underlie the typology of regressive place assimilation. Our current EMA study aims to investigate these patterns. Specifically, the timing and magnitude of tongue tip, lower lip, and tongue back movements of C_1C_2 productions across word boundaries in German were studied. Data of one subject are reported here. The following articulatory factors were manipulated: manner of articulation of C_1, with C_1 being either /n/ or /t/, and place of articulation of C_2, with C_2 being either /p/ or /k/. Furthermore, lexical factors such as usage of the first word in the word pair and co-occurrence frequency were tested. The results provide evidence for a greater reduction of tongue tip movements in function words as compared to content words. Reduction of tongue tip movements was particularly likely in function words with /n#k/ clusters. In these items no tongue tip excursion was visible. In addition, this word pair had a high co-occurrence frequency. With regard to C_1C_2 overlap in alveolar-labial clusters, only manner of articulation of C_1 but not word frequency played a role.

1. INTRODUCTION

Several cross-linguistic surveys [1, 2] revealed typological patterns that govern regressive place assimilation across word boundaries (i.e., sonorant and place of articulation asymmetry). Various proposals have been put forward to account for these asymmetries. For example, within the framework of Optimality Theory some researchers [2, 3] hypothesize that the greater inclination of C_1 nasals vs. C_1 plosives to undergo place assimilation can be accounted for by weaker acoustic cues to their place of articulation. As to the greater tendency of C_2 velars vs. C_2 labials to trigger place assimilation, articulatory reasons are proposed. It is argued that the coproduction of two consonants across a word boundary produces formant movements in the preceding vowel that are weaker for a labial C_2 than for a velar C_2 because the tongue back and tongue tip are parts of the same articulator [4]. Moreover, Kühnert and Hoole [5] suggest that in sequences such as [t#k] the likelihood of reduction of the tongue tip gesture and hence the likelihood of perceived assimilation increases if a high front vowel [i:] or [e:] precedes the consonant cluster.

Apart from the perceptual, articulatory and contextual factors, lexical characteristics might further affect gestural coordination. For instance, word frequency [6, 7] and co-occurrence frequency [8, 9] have been shown to influence durational and articulatory aspects of speech. Finally. the speech task [10] and other social aspects such as the level of familiarity [11] are assumed to influence the way we speak.

Up to now, articulatory studies investigating assimilations across word boundaries looked either at place of articulation of plosive-plosive [e.g., 12] or nasal-plosive sequences [e.g., 13]. To our knowledge, no study has specifically investigated how both manner of articulation of C_1 and place of articulation of C_2 influence articulatory patterns in regressive place assimilation. In particular, it is uncertain whether the acoustic properties of nasals are indeed the main cause for perceived assimilations or whether the acoustic properties of nasals allow the tongue tip to move more freely and as a result permit speakers to ease articulation by means of greater tongue tip reductions in alveolar nasals as compared to alveolar plosives, thereby making perceived assimilations more likely. The ongoing EMA study was therefore designed to test and compare the effects of manner of articulation of C_1, place of articulation of C_2, vowel context, word frequency, and speech task upon the intra- and intergestural timing and movement magnitude of various articulators in

C_1C_2 sequences across word-boundaries in ten German subjects. Today we present results of a sentence reading task for one of our speakers that was designed to investigate the influence of manner of articulation of C_1 and frequency of the first word upon the magnitude of the tongue tip gesture and the intergestural timing of C_1 and C_2.

2. METHOD

2.1. Subjects and speech material

Although more data were collected, we will only report the results for 10 repetitions of C_1C_2 sequences of a reading task for one speaker (henceforth IK). The stimuli presented were selected for a balanced factorial design. They contained either a nasal or a plosive alveolar C_1, a labial or velar plosive C_2, and a non-palatal V_1 and V_2. Word pairs were further divided into groups with high and low frequencies of the first word (we will refer to this as word type). Items in the group of high frequency words also differed by their co-occurrence frequency (frequency measure similar to joint bigram probability, [9]).

We used the IDS corpus [14] to estimate both the frequency of each test word relative to one billion occurrences and the co-occurrence frequency of word pairs (see Table 1; figures in parentheses).

C_1 MOA	C_2 POA	Content word / Low first word frequency		Function word / High first word frequency	
nasal	velar	Zahn kann (7000, **12**)	'tooth can'	dann kann (1064000, **9433**)	'then (it) can'
nasal	labial	Zahn passt (7000, **0**)	'tooth fits'	dann passt (1064000, **38**)	'then (it) fits'
oral	velar	Blatt kann (24000, 2**0**)	'page can'	statt kommende (370000, **2**)	'instead of next'
oral	labial	Blatt passt (24000, **2**)	'page matches'	statt Padua (370000, **0**)	'instead of Padua'

Table 1: Test items with estimated frequencies (per billion). In normal font: frequency of first word, in bold font: co-occurrence frequency (see text). C_1C_2 sequence underlined. MOA: manner of articulation, POA: place of articulation, word type label refers to first word and corresponds with word frequency.

All items including the recorded subset were block-wise randomized. The sentences were prompted on a computer screen and the subjects were instructed to read them at a self-determined, but fast rate.

2.2. Recording and data analysis

Articulatory movements were monitored by means of a 3-D electromagnetic transduction device (Carstens AG500). Data were acquired by three sensors attached to the tongue (tip, mid, back), one to the upper and lower lip, one to the lower jaw, and one to the velum. Additional sensors placed on the nasion, the upper incisors, and behind the left and right ear served as reference coils to compensate for head movements. The acoustic signal was recorded synchronously with the movement signals. A detailed description of data acquisition, normalisation and preparation procedures is outlined in Hoole et al. [15]. Our focus was on data from the lower lip (LL), the tongue tip (TT), and the tongue back (TB) transducer.

The articulatory data were extracted from the VC_1C_2V signal using Matlab routines to identify several kinematic landmarks in the displacement and velocity signals of the EMA recordings: on- and offset of C_1 and C_2 constriction, and C_1 closing gesture for the tongue and lip and C_1 opening gesture for the velum. On- and offsets were defined as points in time at which the tangential velocity exceeded or fell below a threshold value, i.e., 20% of its maximal speed above minimal velocity. Figure 1 illustrates the parameters derived from the above mentioned landmarks.

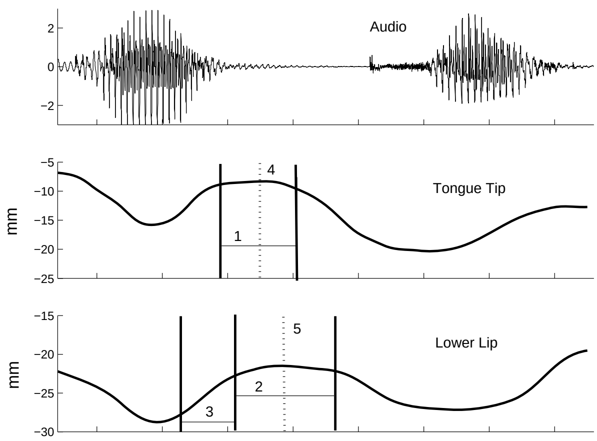

Figure 1: Kinematic parameter extraction (illustration only) in one production of Blatt passt produced by IK. Top: audio, middle: TT-movement, bottom: LL-movement. 1 = C1 constriction time; 2 = C2 constriction time; 3 = C2 closing gesture; 4, 5 constriction maxima (see text).

To describe the temporal overlap between C_1 and C_2, two measures were evaluated paralleling [16, 17]: (a) the interval between the end of the constriction plateau of C_1 and the moment in time of the gesture onset of C_2, i.e., how early does the gesture onset of C_2 occur within C_1 (equals onset overlap) and (b) the interval between the end of the constriction time of C_1 and the start of the constriction time of C_2, i.e., the temporal lag between C_1 constriction offset and C_2 constriction onset (equals constriction lag). Both indices are given as a percentage relative to the overall cluster constriction time, defined as interval between C_1 constriction onset and C_2 constriction offset. In addition, the displacement of the TT gesture was calculated as the difference between the TT vertical excursion at the time of maximum constriction and the onset of the gesture.

The statistical analyses included two-factor analyses of variance for alveolar-labial clusters. However, for reasons explained below, only t-tests could be applied to alveolar-velar clusters on each dependent variable. The dependent variables were: C_1 displacement, percentage of C_1C_2 onset overlap, C_1C_2 constriction lag. The independent variables were manner of articulation of C_1 and/or word frequency.

3. RESULTS

3.1. Tongue tip displacement

As mentioned above, the vertical TT displacements were measured from the onset of the gesture up to its maximum constriction. However, in eight out of ten *dann kann* sequences no TT excursions were visible in the recorded signal. Hence, TT displacement as a function of word type could only be tested in word pairs with a C_1 plosive *Blatt kann, statt kommende* while TT displacement as a function of manner of articulation could only be tested within the content words *Blatt kann, Zahn kann.*

3.1.1. Alveolar-labial sequences

In the word pairs *Blatt passt*, *statt Padua*, *Zahn passt* and *dann passt* TT displacements differed significantly by word type ($F(38,1)=39.30$, $p<0.01$) and manner of articulation ($F(38,1)=11.55$, $p<0.01$). Interaction of these two factors was not significant. Within the two word type categories, TT displacements were on average 4 mm smaller in function than content words and 2 mm smaller in nasal than plosive C_1.

3.1.2. Alveolar-velar sequences

Since no TT excursions were visible in the majority of *dann kann* sequences, TT displacement could only be measured in pairs in alveolar-velar sequences. For the word sequences *statt kommende* vs. *Blatt kann*, TT displacements differed significantly by word type ($t=6.78$, $df=18$, $p<0.01$), i.e., TT displacements were on average 3 mm smaller in *statt kommende* than *Blatt kann*. For the word sequences *Zahn kann* vs. *Blatt kann*, TT displacement differed significantly by manner of articulation ($t=9.10$, $df=18$, $p<0.01$), i.e. TT displacements were on average 5 mm greater in *Zahn kann* than *Blatt kann*.

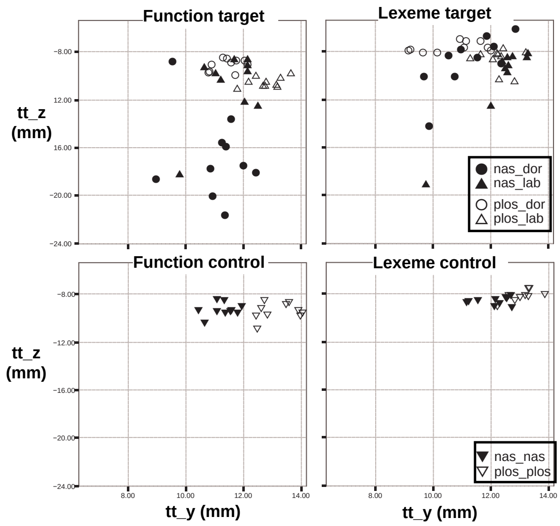

Figure 2: Tongue tip position at a point 25% into the acoustic C_1C_2 cluster. Reference point: upper incisors. Horizontal and vertical coordinates correspond to anterior-posterior and up-down location within the oral cavity. Top panels, target items; bottom panels alveolar-alveolar control items; left panels, function words; right panels, content words.

In Figure 2, we see how word type clearly effects TT position in all word pairs. This corresponds to our statistical results. Within the two word types, manner of articulation affects TT position more in items with a nasal C1 than in those with a plosive C1.

3.2. Gestural overlap

3.2.1. Alveolar-labial sequences

In alveolar-labial sequences, onset overlap and constriction lag tended to vary as a function of manner of articulation but not word type. That is, nasal-labial sequences yielded a nonsignificantly greater temporal overlap than plosive-labial sequences.

3.2.2. Alveolar-velar sequences

Testing the influence of manner of articulation in *Zahn kann* vs. *Blatt kann*, constriction lag, but not onset overlap, differed significantly by manner of articulation (T=4.48, df=18, $p<0.01$), being smaller in word pairs with a C_1 nasal than C_1 plosive. No significant effect of word type upon onset overlap and constriction lag in *Blatt kann* vs *statt kommende* was found.

4. Discussion

While investigating the greater tendency of C_1 nasals vs. C_1 plosives to undergo place assimilation, we looked at articulatory data under the assumption that differences in TT displacements due to manner of articulation and word type rather than acoustic-perceptual properties of nasality [2, 3] might be the cause of this asymmtry. The plotted TT position of all items clearly shows that TT displacement is affected both by manner of articulation as well as word frequency. The only exception was *Zahn kann* vs. *Blatt kann*. Here the influence of manner of articulation was concealed by the larger jaw movements in the longer vowel of *Zahn* vs. *Blatt*. In general, however, we found for each word type greater TT reduction in word pairs with a nasal C_1. One factor causing the greater TT reduction might be that nasals involve the coordination of two gestures, the tongue front closing and the velic opening and are therefore harder to produce than alveolar plosives (see Winter [18] for a similar account). In addition, acoustic properties of nasals might permit the tongue tip to move more freely in nasals than plosives. As a result, speakers may tend to ease articulation by reducing tongue tip movements in alveolar nasals as compared to alveolar plosives and in that way make perceived assimilations more likely. With regard to word frequency, we found more TT reductions in function than in content words. However, the influence of lexical frequency is more complex than that. There were many more 'null alveolars' in *dann kann* than *dann passt* indicating that co-occurrence frequency rather than word frequency alone might be the dominant factor. This finding is consistent with the hypothesis that frequently co-occuring word pairs might eventually become lexical entries [6, 9].

With regard to temporal overlap of C_1C_2 clusters, in alveolar-labial sequences manner of articulation showed a marginal effect. In alveolar-dorsal sequences, manner of articulation affected only constriction lag and in a fashion contrary to expectations. Temporal overlap indices were not affected by word type in either alveolar-labial or alveolar-velar sequences. The interpretation of these results warrants further analysis.

In particular, we are currently in the process of carrying out a more comprehensive analysis not only of intergestural but also intragestural features for C_1 and C_2, such as displacement, constriction time and formation time in all target and control items for all speakers. Furthermore, we will have a closer look at how place of articulation of C_2 influences regressive assimilation patterns in sequences with either a nasal or plosive C_1.

5. REFERENCES

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