THE INFLUENCE OF THE TENSE-LAX CONTRAST IN VOWELS ON THE PRODUCTION OF POST-VOCALIC CONSONANTS IN STANDARD GERMAN

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ABSTRACT

The contrast between tense vowels and their lax counterparts in Standard German can be characterized as a difference in the intra-syllabic temporal organization, namely the degree of overlap of articulatorily defined opening and closing gestures.

This study, motivated by the inconsistency of acoustic data on consonant duration, looks for articulatory reflexes of a difference in the degree of coupling between consonantal closing and opening gestures, which would mirror the coupling contrast found in the vocalic area.

Articulatory data of four native speakers were recorded by means of EMMA. Only two subjects showed evidence for a loose coupling of closing and opening gestures after lax vowels in accordance with the hypothesis of a negative correlation. The underlying control of consonantal coupling seems to lie in a shortening/lengthening of the holding phase and not, as for vocalic gestures, in a difference of gestural organization.

1. INTRODUCTION

In one of the current phonological views on the vocalic opposition in German (cf. *Miete* [miːtʰə] vs. *Mitte* [mɪtʰə]), syllables come with two prosodies, smooth cut and abrupt cut, whose segmental concomitants are vocalic length and tenseness distinctions (cf. [2],[8]). In a series of previous articles (cf. [5],[6]) it has been shown that the articulatory correlate of syllable cut can be characterized as a contrast in the degree of coupling between opening and closing gestures on the articulatory side. As a result, the opening gesture of abruptly cut syllables is truncated by the following closing gesture. Vocalic length and tenseness, therefore, can be seen as an outcome of this truncation.

However, the segmental repercussions of the syllable cut opposition are not limited to the vocalic area because the quality of postvocalic consonants is affected as well (cf. [2]). The contentious issue, whether an additional negative correlation between the duration of vowels and postvocalic consonants exists, was fueled by the inconsistency of the acoustic data (cf. [8]). The aim of this investigation is, therefore, to provide articulatory characteristics of postvocalic consonant production dependent on the vocalic tense-lax-distinction.

2. METHOD

2.1. Target words

Two kinds of logatoms in carrier phrases were used: The logatom for testing word-final consonants was /gəC$_1$VC$_2$/ with C$_1$= C$_2$ = /t, s/z, l/, V = /uː, ʊ, iː, ɪ, aː, a/ and was embedded in the carrier phrase “Ich habe *target word* erwähnt” (I mentioned *target word*), while /gəCVCə/ with the carrier phrase “ich habe *target word* gesagt” (I said *target word*) was used to test the word-medial condition.

2.2. Speakers

Each of the four native speakers of Standard German (JD, male, from Rostock; PJ, male, from Munich; SF, female, from Saxony and TM, female, from Munich) repeated the test sentences five to seven times.

2.3. Data

Electromagnetic articulography (EMMA, AG100, Carstens Medizinelektronik) was used to monitor movement of tongue (cf. [7], for details on preprocessing see [4]). The articulatory analysis was based on the tangential velocity signal of the tongue tip sensor. The following durational parameters were collected (see Figure 1 for illustration):

DHOLD Duration of hold phase of closure
HOLDRATIO Ratio of the hold phase duration to the overall movement duration in %.

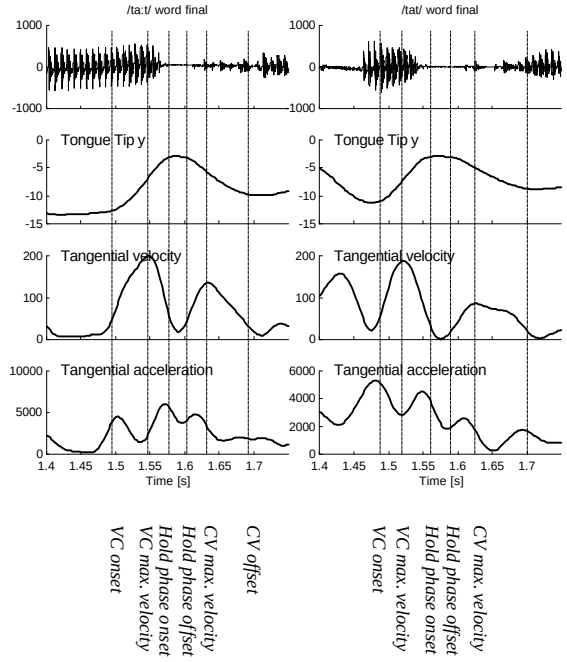

Figure 1. Examples of tongue-tip velocity signals for /t/ after tense (left) and lax vowel (right).

P2PRATIO Ratio of the interval between velocity peaks to overall movement duration in %.

ACCCL Ratio of the interval between VC-onset and peak velocity to closing phase duration in %.

ACCOP Ratio of the interval between CV-onset and peak velocity to opening gesture duration in %.

Onset and offset of opening and closing movement are defined by a 20%-threshold relative to the maximum total velocity (cf. [6]). The overall movement duration is defined as CV offset – VC onset.

2.4. Hypotheses

For vowels, a tight coupling between CV and VC movements corresponds to a truncation of the opening gesture (cf. [3], [5], [6]). A hypothetical tight coupling in the consonantal area should be produced by truncation of the closing gesture. Such truncation would result in the course of signals illustrated in Figure 2 (top: position, middle: velocity, bottom: acceleration), where the simulated degree of truncation is increased from 0 to 80 (for the simulations the first derivative of the movement signal was computed instead of the tangential velocity/acceleration).

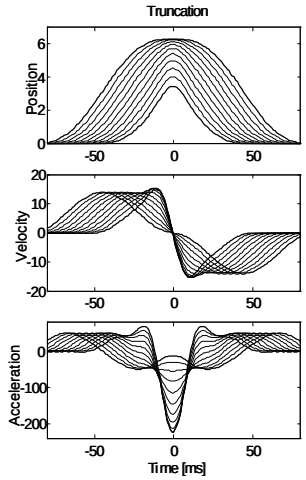

Figure 2. Simulation of VC-truncation.

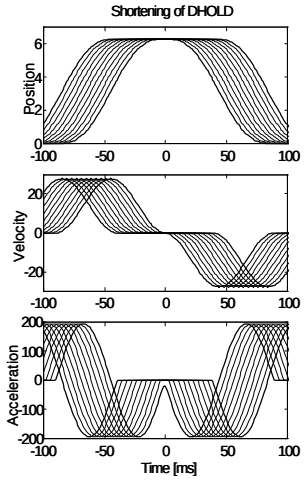

Figure 3. Simulation of shortening of hold phase

VC-truncation results in the following changes:

a) shorter duration of overall movement and
b) reduced movement amplitudes (cf. top of Fig. 2).
c) The distance between the velocity peaks of closing and opening movements decreases,
d) the maximum velocity increases,
e) the acceleration phase of the VC-gesture is enlarged and
f) the acceleration phase of the CV-gesture is reduced.
g) The maxima of acceleration merge into a single peak.

Figure 3 shows what happens when the hold phase is shortened:

a') the duration of overall movement is shortened.
b') The ratio of the hold phase duration to overall movement duration is reduced.
c') The distance between the velocity peaks of closing and opening movements decreases.

Contrary to the case of truncation, nevertheless, some parameters are unaffected by a pure shortening of the hold phase:

d') the amplitude of movement,
e') the maximum velocities,
f') the symmetry of acceleration phases and
g') the number of acceleration peaks.

Therefore, a tight coupling at the articulatory level between the closing phase and the following opening phase, which would mirror the contrast found in the vocalic area, could only be recognized by changes in the four parameters d'-g', in addition to a shortening of the hold phase.

As both the amplitude of movement and the maximum velocity are dependent on the tenseness of the preceding vowel (lax vowels being centralized), only the opening gesture is a clear indicator for verifying the hypothesis of an independent coupling contrast in the consonantal area.

3. RESULTS

3.1. Hold phase duration

In Figure 4 and Table 1 the measured durations of the hold phases are given for each of the four speakers.

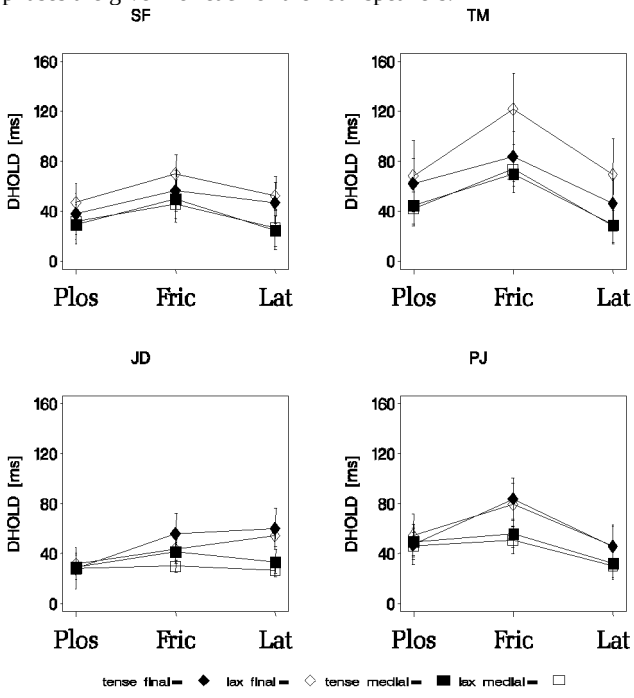

Figure 4. Hold phase duration

Speaker		N	DHOLD [ms]	s.d.	HOLD-RATIO [%]	s.d.
SF		216	43.13	20.02	20.59	7.29
	tense final	54	46.93	17.83	19.48	6.42
	lax final	54	56.26	18.20	24.61	7.05
	tense medial	54	34.61	18.99	17.58	6.57
	lax medial	54	34.74	16.73	20.70	7.37
JD		177	38.42	15.89	19.27	5.86
	tense final	45	48.00	21.62	20.90	7.90
	lax final	43	43.21	12.84	20.91	5.89
	tense medial	44	34.64	10.98	18.28	4.73
	lax medial	45	27.98	5.00	17.05	2.93
TM		178	61.35	31.82	28.27	10.27
	tense final	43	63.14	24.84	25.40	7.48
	lax final	45	86.47	37.65	35.76	11.15
	tense medial	45	47.96	22.53	23.89	8.08
	lax medial	45	47.91	23.26	27.90	9.82
PJ		216	51.78	20.60	25.06	6.75
	tense final	54	59.02	24.00	26.22	7.04
	lax final	54	59.98	21.93	27.43	7.32
	tense medial	54	45.83	14.85	23.07	5.55
	lax medial	54	42.28	13.93	23.53	6.11

Table 1. Means and standard deviations of hold phase duration and ratio of hold phase duration to overall movement duration.

Speaker		N	Peak-to-peak ratio	s.d.	
SF		216	60.79	8.96	
	tense final	54	58.20	6.73	lf>tf
	lax final	54	65.92	6.13	
	tense medial	54	56.53	10.36	lm>tm
	lax medial	54	62.51	8.94	
JD		177	56.87	6.32	
	Tense final	45	54.61	6.24	
	lax final	43	57.57	5.99	
	tense medial	44	57.92	6.76	
	lax medial	45	57.42	5.88	
TM		178	64.22	10.98	
	tense final	43	59.02	11.24	lf>tm
	lax final	45	70.85	9.41	
	tense medial	45	58.99	9.35	lm>tm
	lax medial	45	67.77	8.73	
PJ		216	63.91	7.76	
	tense final	54	64.65	6.20	lf>tf
	lax final	54	69.05	5.48	
	tense medial	54	59.11	8.49	lm>tm
	lax medial	54	62.83	7.17	

Table 2. Means and standard deviations of Peak-to-peak ratio relative to overall movement duration.

The results for DHOLD and HOLDRATIO turned out to be highly speaker dependent. The two female subjects SF and TM lengthened the hold phase of final consonants after lax vowels. Especially fricatives were affected by this lengthening in final position. In medial position, however, the slightly higher HOLDRATIO after lax vowels was not significant. The male speakers showed no effect, or, in the case of JD, a general lengthening of the hold phase in final position independent of the tense/lax distinction of the preceding vowel.

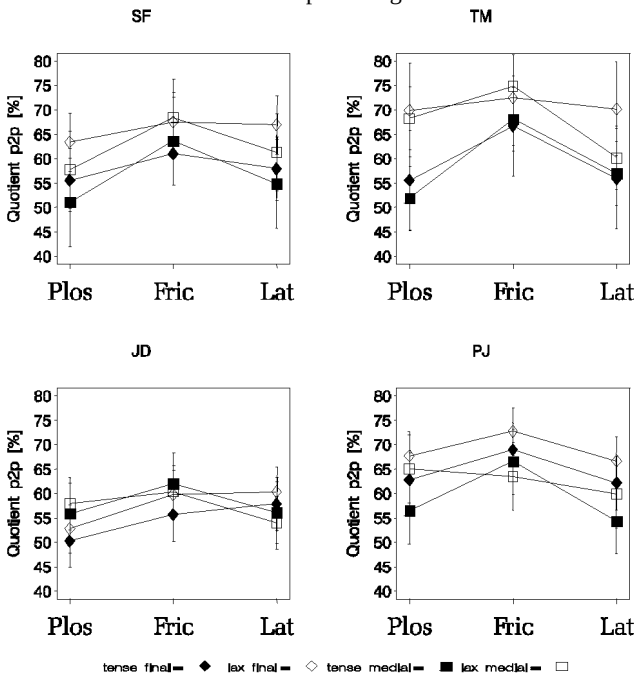

Figure 5. Ratio of the duration of the interval between velocity peaks to total movement duration.

3.2. Ratio of the duration of the interval between velocity peaks to total movement duration

According to the hypothesis of both truncation or pure shortening of the hold phase, the distance between the velocity peaks of VC- and CV-gestures should be reduced after tense vowels. Figure 5 and Table 2 show the obtained results. Three (SF, TM, PJ) out of four subjects showed a significantly reduced peak-to-peak ratio after tense vowels in line with the hypotheses. This effect, however, is no clear indicator of truncation, because pure shortening of the hold phase would produce the same effect. The fact, that in the case of truncation the peak-to-peak ratios after tense vowels should be below the level of 50%, indicates pure shortening of the hold phase.

3.3. Skewness of velocity profiles

As shown by [6], for tight coupling between opening and closing gestures (lax vowels) the peaks of acceleration phases of CV and VC movements are closer together than in the case of loose coupling (tense vowels). This follows from the fact that the corresponding acceleration phase ratios are a measure for the skewness of the velocity profiles, i.e. the later the velocity peak, the greater the acceleration phase ratio. According to the hypotheses, loose consonantal coupling after lax vowels is expected, resulting in a left-skewed VC-velocity profile and a right-skewed CV-velocity profile.

The results can be seen in Table 3. Subject TM revealed effects in the expected direction for all conditions (tense final, lax final, tense medial, lax medial). The results for the other subjects were inconsistent: either the expected effects showed up only in a subset of the four conditions, or, only one of the two peaks (mostly ACCCL, which is a symptom of the vocalic coupling contrast) displayed the effect. Nevertheless, all significant effects found go into the expected direction.

Speaker		N	ACCCL %	s.d.		ACCOP %	s.d.
SF		216	50.25	12.05		51.62	14.06
	tense final	54	55.24	12.89	*	50.07	10.79
	lax final	54	44.11	9.18	⇐⇒	53.61	11.55
	tense medial	54	55.15	12.43	*	51.21	16.69
	lax medial	54	46.50	9.06	⇐⇒	51.58	16.33
JD		177	53.84	9.32		47.00	10.58
	Tense final	45	61.31	6.51	⇒⇐	45.97	8.40
	lax final	43	48.58	7.56	*	43.16	9.20
	tense medial	44	56.37	10.20	*	52.46	10.96
	lax medial	45	48.94	5.84	*	46.36	11.55
TM		178	48.13	11.01		49.22	15.89
	tense final	43	55.96	10.48	⇒⇐	46.48	19.10
	lax final	45	43.52	9.00	⇐⇒	53.36	15.62
	tense medial	45	51.29	10.07	⇒⇐	44.23	14.33
	lax medial	45	42.07	8.44	⇐⇒	52.69	12.48
PJ		216	48.04	10.67		51.74	11.55
	tense final	54	52.09	10.71	*	55.01	10.20
	lax final	54	42.41	10.44	⇐⇒	55.84	10.53
	tense medial	54	52.35	8.79	⇒⇐	47.09	12.66
	lax medial	54	45.30	9.25	*	49.03	10.42

Table 3. Means and standard deviations of ratio of acceleration phase duration of closing and opening movements relative to overall movement duration (⇐⇒ = more separated acceleration peaks, i.e. ACCCL < 50% and ACCOP > 50%; ⇒⇐ = acceleration peaks closer together, i.e. ACCCL > 50% and ACCOP < 50%; * = only one of the two peaks shows an effect).

3.4. Amplitude and maximum velocity of the opening gesture

According to the hypotheses in 2.4, truncation of the closing gesture would be accompanied by a reduced amplitude and higher peak velocities of the VC and CV movements after tense vowels. If only a shortening of the hold duration is involved, there should be no effects. Shortening of the hold phase without truncation should not affect the amplitude of the opening gesture.

All main effects and nearly all interactions were significant. Only one speaker (PJ) showed a higher amplitude after lax vowel (medial plosive after /i/). All of the other significant differences went into the wrong direction, i.e. the amplitude after tense vowels was higher than the amplitude after lax vowels (mostly for /i/ and /u/, and rarely for /a/). This may indicate a carry-over effect induced by the target position of the preceding vowel, i.e. the higher the amplitude of the CV-gesture, the higher that of the CV-gesture.

Altogether, the differences are very inconsistent for speaker, vowel and type of consonant.

Maximal velocity of opening gestures was in most cases higher after tense vowels. This can be explained by the correlation between V_{max} and amplitude, i.e. the longer the distance, the faster the tongue tip moves.

4. CONCLUSION

Only the two female speakers showed an effect of lengthening consonants after lax vowels. This effect, however, was restricted to word-final position. Due to the small number of subjects it is not permissible to call that a sex-specific effect. The relative shortening of fricatives and laterals, but not of plosives, after long tense vowels is a result of shortened hold phases and not a result of VC truncation. This can be seen from the fact that any systematics in the symmetry of the velocity peaks is lacking and the amplitudes are not in line with the hypothesis of truncation. Therefore, the type of coupling in the consonantal area is of a different kind than that found in the vocalic area.

Due to the specifics of consonant production, nevertheless, the option of real truncation of VC-gestures is less likely, because the consonantal target (in this case: apical contact or critical narrowness) must be reached. This would be impossible for truncation. For vowels, however, the gestural undershoot corresponds to the phonetic correlate of the tense-lax-distinction.

A comparison of consonant production between syllable cut languages like German or Swedish and quantity languages like Finnish should be made in order to clarify the issue of truncation vs. shortening of hold phase.

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