TEMPORAL COMPENSATION IN CZECH?

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ABSTRACT

Temporal compensation on the segmental level refers to the tendency towards temporal equalization of CV (and possibly VC) sequences: a shorter duration of one segment leads to a longer duration of the neighbouring segment, and vice versa. Any comprehensive description of sound properties of a language must take the possible existence of this tendency into account.

The objective of this research, which constitutes a pilot study into this area for the Czech language, is the question of a possible temporal effect of a consonant on a vowel ('vocalic compensation'), and of a vowel on a consonant ('consonantal compensation'). The result suggest that there indeed is a tendency towards bilateral temporal effects between a consonant and vowel (C⇆V).

Keywords: temporal compensation, vocalic compensation, consonantal compensation.

1. INTRODUCTION

In many languages (e.g., English, French, Russian, Korean, German, Danish, Norwegian, Swedish, Italian, Hungarian, Hindi, Persian), vowels before voiced consonants are longer than before voiceless consonants [6]. The duration of vowels in relation to the phonological voicing of the subsequent consonant has been investigated especially for English (for instance, [2], [3], [5], [7], [8], [10]). Kluender [6] hypothesized that the different duration of vowels might perceptually emphasize the duration of the hold phase of the following plosive, and thus play an important part in the perception of its voicing. In some languages, then, one might talk about the phonologization of vocalic compensation in the sequence vowel-consonant (VC). This is not the case in Czech, though, where the phonological category of voicing and its phonetic representation are in harmony (*cf.* Section 2.1).

However, the latest research indicates the existence of not only vocalic, but also consonantal temporal compensation in Czech. Our objective is, therefore, to investigate these tendencies.

2. METHOD

The possible mutual temporal influences of consonants and vowels were analyzed on 638 VCV sequences (i.e., 638 consonants and 1276 neighbouring vowels). The sequences were isolated from recordings of 53 university students (31 female and 22 male) who were asked to read a short text and tell a tale according to a picture story. VCV sequences from the beginnings and ends of intonation phrases were not analyzed, so as to avoid the effects of temporal changes in these positions. The sequences were manually labelled by the first author of the study in the Praat software [1].

2.1. Consonants

Temporal properties of consonants were examined based on the contrast of voicing and on the place of articulation. For the purpose of this study, we analyzed plosives, as they represent the largest group of obstruents in Czech, with four places of articulation: bilabial [p b], alveolar [t d], palatal [c ɟ], and velar [k g].

Czech voiced plosives are characterized by the presence of f0 throughout, while f0 is absent in voiceless plosives. The phonetic representation of Czech obstruents thus indicates 'perfect harmony' of voicing with phonological features. The voicing contrast as a distinctive feature in Czech is sufficiently anchored in phonetic reality.

While the articulation of voiceless and voiced plosives in Czech is accompanied by differences in the tenseness of articulatory muscles [4], [9], this feature is not perceptually relevant; the release phase of plosives is not accompanied by aspiration. Unlike, for instance, in German or English, voicing of Czech plosives is not a phenomenon of a prevalently phonological character.

2.2. Vowels

We measured the duration of Czech phonologically short vowels, [ɪ ɛ a ɔ u]. Only vowel height was considered in our analyses, as it is known to correlate with durational characteristics.

3. RESULTS

3.1. Duration of intervocalic plosives

Voiceless plosives are longer than their voiced counterparts, which is probably caused by different requirements concerning the activity of the vocal folds, and the related differences in pressure relationships and the tenseness of articulatory musculature. The durations, their coefficients of variation and ratios are shown in Table 1.

a) [p] and [k] are by ca. 1/3 longer than [b g];

b) [c] is ca. by 1/2 longer than [ɟ];

c) [t] is ca. by 2/3 longer than [d]

Plos vl	duration [ms]	coef. var. [%]	Plos vd	duration [ms]	coef. var. [%]	Vl/Vd
[p]	107.9	16.4	[b]	80.5	16.6	**1.34**
[t]	96.9	19.7	[d]	57.4	25.5	**1.69**
[c]	104.6	15.7	[ɟ]	71.6	16.9	**1.46**
[k]	108.5	14.1	[g]	79.3	15.2	**1.37**

Table 1: Mean duration of intervocalic plosives.

3.2. Duration of vowels adjacent to plosives

The duration of vowels is mostly determined by the vertical position of the tongue. High vowels are shortest, low vowels longest, and the duration of mid vowels oscillates around the average (see Table 2).

vowel	duration [ms]	coef. var. [%]	proportion of the mean
[ɪ]	56.2	27.3	**0.91**
[ɛ]	63.6	29.1	**1.03**
[a]	69.5	22.6	**1.13**
[ɔ]	59.2	28.1	**0.96**
[u]	54.1	29.6	**0.88**
mean	61.7	27.1	**1.00**

Table 2: Duration of short vowels adjacent to plosives.

3.3. Hypotheses and raw results

The observed duration and ratio values led us to asking two questions:

1. Does a voiceless (longer) consonant mean a shorter adjacent vowel, and does a voiced (shorter) consonant mean a longer vowel?

2. Does a low (longer) vowel mean a shorter adjacent consonant than in the neighbourhood of a high (shorter) vowel?

Based on these questions we are proposing the following hypotheses:

1. the duration of a plosive affects the duration of a vowel; that is, the existence of vocalic compensation ($C \rightarrow V$);

2. the duration of a vowel affects the duration of a plosive; that is, the existence of consonantal compensation ($V \rightarrow C$).

First of all, we examined possible compensation tendencies and their intensity in the sequences plosive-vowel (PV) and vowel-plosive (VP), without distinguishing the quality of vowels. The differences between the mean duration of a short vowel following a voiceless and voiced homorganic plosive (PV) were statistically significant as ascertained by t-tests ($p < 0.001$) in sequences with alveolars (a difference of 15.7 ms), palatals (14.8 ms), and velars (11.0 ms); this effect was not observed for bilabials. In VP sequences, this tendency was significant only for the differences in vowel duration before palatals (6.5 ms; $p < 0.01$) and velars (8.5 ms; $p < 0.001$). A significant reverse tendency was not observed.

These rough results suggest that compensation tendencies in Czech might exist. In the next section, we analyzed the PV and VP sequences according to the voicing contrast of the plosive, as well as the phonological quality of the vowel.

3.4. Degree of compensation

The expression “degree of compensation” will refer to the intensity of compensation (given in percentage) between two sequences differing in one segment. An extreme case of complete, 100% compensation would occur if the sequences had exactly the same duration. For instance, the duration of [tɛ] would be equal to that of [dɛ] (the shorter the duration of [ɛ] after the longer [t], the longer its duration after the shorter [d]), and the duration of [tɪ] would be equal to that of [ta] (the longer the duration of [t] before the shorter [ɪ], the shorter its duration before the longer [a]).

In the raw results reported above, the degree of vowel compensation (without distinguishing vowel quality) was in the PV sequences 40 % after alveolars, 45 % after palatals, and 38 % after velars. In the VP sequences, the degree of vowel compensation was 20 % before palatals and 28 % before velars. Compensation thus seems to be stronger in PV than in VP sequences.

3.5. Vocalic compensation in PV sequences

This concerns the degree of compensation between sequences differing in the voicing of the plosive, e.g., [tɛ] as opposed to [dɛ]. We examined the mean duration of vowels of different quality after homorganic plosives, voiceless (longer) and voiced (shorter). There were 32 types of PV sequences ([pɪ pɛ pa... bɪ bɛ ba...]), which gave rise to 16 relationships ([pɪ bɪ], [pɛ bɛ], ...). As some sound combinations are rare in Czech, sequences *palatal plosive* + *non-front vowel* and *velar plosive* + [a] were not analyzed.

Table 3 shows the difference in the duration of voiceless and voiced plosives before the same vowel (Pvl-Pvd), the difference in the duration of the sequences based on the voicing contrast of the plosive (PvlV-PvdV), compensation in ms, degree of compensation in percentage, and significance as expressed by *p*.

PV sequence		Pvl-Pvd [ms]	PvlV-PvdV [ms]	comp. [ms]	degree of comp. [%]	p
p b	ɪ	44.8	55.6	-10.8	-24	**<0.05**
	ɛ	24.6	22.3	2.3	**10**	>0.1
	a	24.1	17.0	7.1	**29**	>0.1
	ɔ	19.2	9.6	9.6	**50**	>0.1
	u	38.2	34.5	3.6	**9**	>0.1
t d	ɪ	65.4	56.9	8.4	**13**	>0.1
	ɛ	39.3	23.2	16.1	**41**	**<0.001**
	a	35.2	13.3	21.9	**62**	**<0.001**
	ɔ	24.0	9.0	15.0	**62**	**<0.01**
	u	39.6	21.8	17.8	**45**	<0.1
c ɟ	ɪ	36.6	24.2	12.4	**34**	**<0.01**
	ɛ	30.7	15.6	15.1	**49**	**<0.001**
k g	ɪ	36.6	22.5	14.1	**39**	**<0.05**
	ɛ	32.6	12.8	19.8	**61**	**<0.05**
	ɔ	24.1	18.3	5.9	**24**	>0.1
	u	22.1	4.4	17.7	**80**	**<0.01**

Table 3: Temporal compensation in PV sequences (see text).

Of the listed 16 relationships, the vowel is shorter after a voiceless (longer) plosive than after a voiced (shorter) plosive in 15 cases; 8 of them are statistically significant ($p < 0.05$), one marginally significant ($p < 0.1$) and six insignificant.

The results suggest that there indeed is a tendency toward vocalic compensation in PV sequences.

3.6. Vocalic compensation in VP sequences

There are 19 relationships in VP sequences, as depicted in Table 4. In 15 of these, the vowel is shorter before a voiceless (longer) plosive than before a voiced (shorter) plosive; this is significant only in three cases ($p < 0.05$). In four cases is the tendency opposite (negative).

VP sequence		Pvl-Pvd [ms]	PvlV-PvdV [ms]	comp. [ms]	degree of comp. [%]	p
p b	ɪ	22.4	30.6	-8.2	-37	>0.1
	ɛ	31.8	32.9	-1.1	-3	>0.1
	a	29.1	28.1	1.0	**3**	>0.1
	ɔ	23.1	18.5	4.7	**20**	>0.1
	u	26.2	22.2	4.0	**15**	>0.1
t d	ɪ	36.5	29.9	6.6	**18**	>0.1
	ɛ	30.5	24.7	5.7	**19**	>0.1
	a	38.0	37.6	0.5	**1**	>0.1
	ɔ	30.9	20.9	10.0	**32**	>0.1
	u	46.1	47.8	-1.7	-4	>0.1
c ɟ	ɪ	22.7	7.8	14.9	**65**	**<0.01**
	ɛ	38.0	33.6	4.4	**12**	>0.1
	a	36.9	33.1	3.8	**10**	>0.1
	ɔ	34.9	29.1	5.8	**17**	>0.1
	u	27.3	33.3	-6.0	-22	>0.1
k g	ɪ	17.9	4.7	13.2	**74**	**<0.05**
	ɛ	29.5	20.7	8.8	**30**	**<0.05**
	a	33.3	30.4	3.0	**9**	>0.1
	ɔ	29.8	17.4	12.4	**42**	>0.1

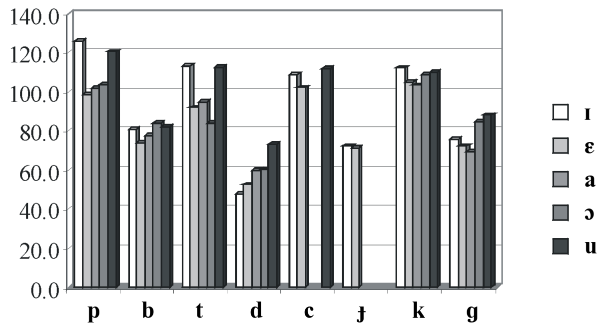
Table 4: Temporal compensation in VP sequences.

The compensation tendencies are weaker in VP sequences than in PV sequences. This is probably caused by the fact that both segments belong to one syllable in PV sequences. The relationship between them can thus be considered tighter than in the VP sequence, where the segments are divided by a syllabic boundary.

3.7. Consonantal compensation

We examined the possibility of consonantal compensation in the tautosyllabic PV sequences; our question thus was whether the same consonant will be longest before high (shortest) vowels, shortest before low (longest) vowels, and somewhere in between before mid vowels. This is indeed the case with [k], as shown in Figure 1 (the individual columns within the groups represent the duration of plosives before given vowels).

Figure 1: Duration of plosives before individual vowels.



The comparison of the duration of one plosive before a high and low vowel shows that the plosive is longer before a high (shorter) vowel than before a low (longer) vowel in 11 of the 12 PV relationships. In six of these 11 instances, these differences are statistically significant ($p < 0.05$).

The duration relationships of plosives before mid vowels are less straightforward. It can be said, however, that plosives before the high front [ɪ] (shorter) are longer than before the mid front [ɛ] (longer). The same applies for sequences with back vowels (plosives are longer before [u] than before [ɔ]). 12 of 14 such relationships seem to support the hypothesis of consonantal compensation; four of them are significant ($p < 0.05$), two marginally significant ($p < 0.1$), six insignificant. In sequences [bu dɪ] the tendency is opposite ($p > 0.1$).

The results suggest that there indeed is a tendency to consonantal compensation in PV sequences.

4. DISCUSSION AND CONCLUSION

The aim of this research was to find out whether there is some mutual temporal influence between plosives and adjacent short vowels in Czech.

Our study was based on the fact that voiceless plosives are known to be on average longer than their voiced counterparts. The results indicate that vowels after a voiceless (longer) plosive tends to be shorter than after a voiced (shorter) plosive. Compensation tendencies appear to be stronger in CV than in VC sequences. This could be explained by the tautosyllabicity of CV sequences, which is not the case in VC sequences.

The results also suggest that temporal relationships between vowels based on their height (high vowels are shortest, low vowels longest) exert some influence on the duration of plosives.

To conclude, our data indicate a tendency to temporal compensation of the duration of plosives and adjacent vowels, and thus confirm the hypotheses listed in Section 3.3:

- voicing of plosive → duration of vowel (vocalic compensation);
- vowel quality (height) → duration of plosive (consonantal compensation).

There is thus a bilateral temporal influence in vowel-plosive combinations:

- the duration of plosives (related to their voicing status) tends to affect the duration of adjacent vowels. The initiating factor of vocalic compensation is the voicing contrast in plosives.
- the duration of vowels (related to their height) tends to affect the duration of preceding plosives. The initiating factor of consonantal compensation is vowel height.

In our future work on temporal compensation tendencies in Czech, it is necessary to include other types of speechsounds, take into account syllable structure and a broader segmental context of the sequences. Other factors which will have to be considered are, for instance, the position within the stress group, articulation rate, or speech style. We hope that the results will contribute to efforts aimed at natural speech synthesis algorithms.

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