Segmental context effects on temporal realization of Estonian quantity

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Abstract. *The Estonian three-way quantity system is a robust foot-level compensatory mechanism of the stressed and the unstressed syllable durations. Beneath the three-way foot-level contrast, the quantity oppositions can be realized by seven different segmental combinations of the initial vowel and the following intervocalic consonant length. In this work we investigated the effects of context dependency on durational patterns marking this 7-way contrast. We observed a strong influence of the word initial consonant and vocalic quality context on the durations of individual segment in different quantity combinations. The results show a complex relation between the intrinsic phonemic properties and suprasegmental features. The effects of segmental context and natural variation of phonetic realization might in some cases combine to be greater than average differences between quantity degrees.*

Introduction

Estonian three-way quantity:

- Opposition between short, long and overlong (Q1, Q2, Q3) is realized by the stressed-to-unstressed syllable rhyme duration ratio.
- Stressed syllable rhyme duration is achieved by combining the length of the vowel and the coda consonant, enabling minimal septets of CVCV-sequences based on seven segmental combinations.

Intrinsic properties of segments interact with quantity:

- The difference between Q1, Q2 and Q3 segments is not symmetrical (greater between Q1 – Q2 than between Q2 – Q3).
- The intrinsic properties of sound segments have non-linear effect on the quantity-related duration variability.
- Vowel quality can shift the perceived short-long category boundary.

Data

Q1	[pɑpi]	[pipɑ]	[tɑpi]	[tipɑ]*
Q2	[pɑːpi] [pɑpːi]* [pɑːpːi]	[piːpɑ] [pipːɑ] [piːpːɑ]	[tɑːpi] [tɑpːi]* [tɑːpːi]	[tiːpɑ] [tipːɑ]* [tiːpːɑ]
Q3	[pɑːːpi] [pɑpːːi]* [pɑːpːːi]	[piːːpɑ] [pipːːɑ] [piːpːːɑ]	[tɑːːpi] [tɑpːːi]* [tɑːpːːi]	[tiːːpɑ]* [tipːːɑ] [tiːpːːɑ]

**meaningful words in Estonian*

- All possible quantity combinations of CVCV sequence.
- Two initial consonant contexts.
- Two vocalic contexts.
- Six native Estonian speakers.
- Acoustic data recorded along with EMA data in a word repetition task.

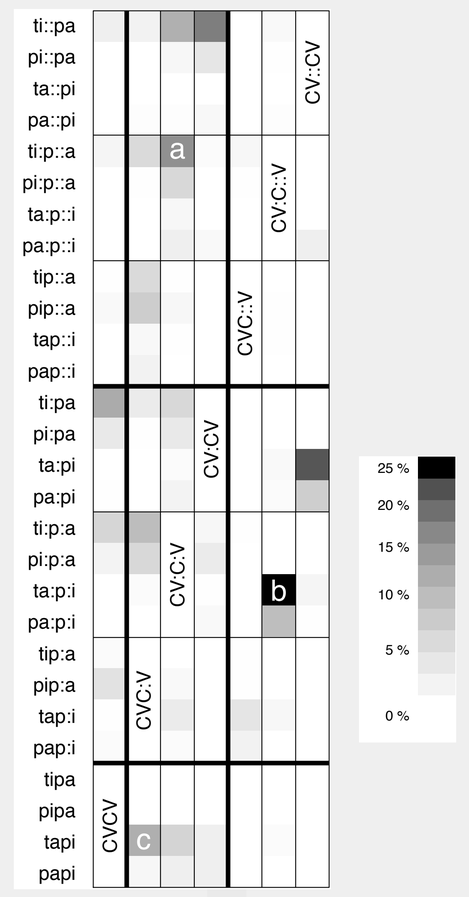

Figure 2. *The likelihood of overlaps between durational patterns of word tokens differing in both segmental content and quantity.*

Results

Context effects on segmental durations (Fig. 1)

Consonant context (*papi* vs. *tapi*):

- [p] always longer than [t].
- In [t]-context the final [i] is shortened (in some Q2 and Q3 quantity combinations).
- Only occasional effects on V1 and intervocalic C.

Vocalic context (*papi* vs. *pipa*):

- [ɑ] is longer than [i], but this has a complex non-linear pattern.
- V1 [i] is shortened more if it is long, and less, if followed by a long C2.
- V2 [ɑ] is the most lengthened in Q1, but the intrinsic lengthening effect is the smallest or not significant in Q3.

The interaction (*papi* vs. *tipa*):

- The interaction with vocalic context neutralizes the main effect of the consonant context: the difference between [t] and [p] duration becomes minute.
- In interaction with the consonant context [i] is extra shortened and [ɑ] is lengthened.

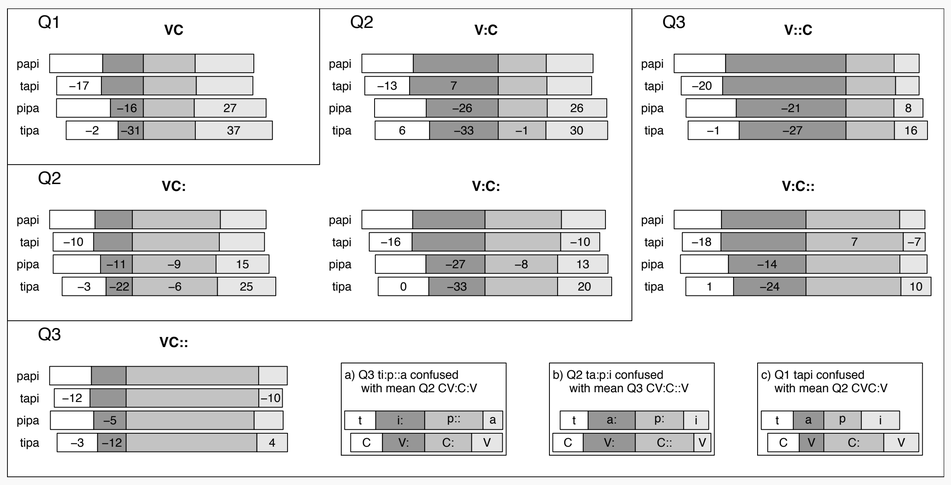

Figure 1. *Context effects on segmental durations.*

For each of the four segments in the CVCV target word, linear mixed effect models with the segment duration as a dependent variable, both vocalic context and word initial consonant as independent factors were fitted separately for each quantity combination. For each quantity combination, *papi* is taken as the reference value. The second row (*tapi*) plots the main effect of the initial consonant context, the following row, *pipa*, the main effect of vocalic context, and the last, *tipa*, the interaction of both. The numbers on the segments are the estimated differences (in milliseconds) compared to the base values and are shown only if the effect is significant.

Overlaps of overall duration patterns (Fig. 2)

- A small amount of durational overlaps is present for most combinations of segmental context and quantity.
- Overall duration patterns of ɑ–i tokens is closer to that of median patterns of the higher quantity while i–ɑ tokens are more similar to the lower quantity medians.
- Overlaps are considerably more frequent for tokens with initial [t].

To capture the duration of all segments in our words in parallel, we can conceptualize each token as a point in a 4-dimensional space with axes representing segment durations at the four subsequent positions: C1, V1, C2 and V2. In this space, points representing individual tokens from the same quantity category should form a bounded region. For each point we evaluated the percentage of how many times it ended up too close to a "wrong" category center: we counted all occasions when a token-point was actually closer to the median of a different quantity combination category than to its own one.

Different intrinsic duration of segments and their different sensitivity to lengthening effects might lead to considerable overlaps in durational patterns pertaining to distinct quantity combinations. The insets in Fig. 1 illustrate this point. Panel Fig. 1a) compares the mean durational pattern of a Q3 [tiːpːːɑ] with a mean pattern of Q2 CVːCːV quantity combination. The naturally shorter duration of [iː] compared to [ɑː] combined with the additional shortening due to [t] context reduced the expected Q2–Q3 difference in V1 duration. At the same time, the lengthening of word final [ɑ] due to interaction with initial [t] further reduces the overall difference between duration patterns. As a result, at least when it comes to segment durations, Q3 [tiːpːːɑ] is not considerably different from an average token from Q2 CVːCːV category. Similar trends and consequences can be observed in the other two cases comparing Q2 and Q1 words with mean patterns from Q3 and Q2 categories, respectively.

Conclusions

We have identified several influences of segmental quality on durational patterns of seven quantity combinations present in the system. The interactions are not linear nor are they limited to the effects of intrinsic phoneme durations; they also involve the place of articulation of the word initial consonant. The durational differences marking quantity contrast are in some cases not robust enough to make the contextual effects negligible. The listeners most likely process the primary temporal cues of quantity contrast in a context-dependent manner.