# Lithuanian contrastive vowel length and the voicing effect: The role of minimal contrast*

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## 1. Introduction

### ➢ Goals:

- Explore the interaction between phonological contrast and phonetic processes:
  - Test interaction between phonemic vowel length and phonetic process affecting vowel duration, i.e., voicing effect, in Lithuanian.
- Show the role of minimal contrast in this interaction.

### ➢ Voicing effect:

- Tendency for vowels to be shorter before voiced obstruents than before voiceless ones (Chen 1970, Hussein 1994 for review)
  - Example from English:

| longer V | | shorter V |
|---|---|---|
| *bed* | vs. | *bet* |
| *hide* | vs. | *height* |

## 2. Previous work

- Some previous work has looked at the impact of the phonological system of contrasts on different phonetic processes.

### ➢ Contrast and coarticulation:

- Previous studies show that contrast can limit the effects of coarticulation (Manuel 1999).
- Examples:
  - Contextual nasalization is smaller in languages with contrastive nasal vowels (Cohn 1993).
  - Undershoot of vowel F2 in C-V coarticulation is lesser in languages with /u/-/y/ contrast (Flemming 1997).

### ➢ Length contrast and cues to stress

- Languages with contrastive vowel length tend to avoid using duration as a cue to stress.

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- Hayes (1995) notes that using duration as a cue stress would obscure the contrastive vowel length.
- Berinstein (1979) conducted an experiment to test this hypothesis:
    - Phonetic cues to stress: changes in fundamental frequency, duration and amplitude.
    - In K'ekchi, language with contrastive vowel length, duration is not a strong correlate of stress and it does not affect stress perception.
    - In Cakchiquel, language related to K'ekchi but without phonemic vowel length, duration is the primary cue to stress.
- Ondráčkova (1962) finds similar results for Czech (language with phonemic vowel length).

## 3. Voicing effect

- **Phonetic process**: the voicing effect does not interact with phonological phenomena such as stress or weight → voicing effect is irrelevant in stress assignment and other weight-sensitive processes (see Hyman 1977, Gordon 2002).

- Factors affecting voicing effect:
  Word size, inherent vowel duration, place of articulation & syllabic affiliation of consonant, stress, speech rate, and position of word within the utterance (Klatt 1973, de Jong & Zawaydeh 2002, Laeufer 1992, Port 1981).

- Language-specific factors affecting voicing effect:
  Language rhythm (Port et al 1980), precise realization of voicing contrast (Kohler 1981) and **presence of phonemic vowel length** (Keating 1985).

- There are claims in the literature that presence of contrastive vowel length attenuates voicing effect (Keating 1985 for Czech and Saudi Arabic, Buder and Stoel-Gammon (2002) for Swedish).

- Need to **test hypothesis about influence of vowel length** isolating vowel length from other factors conditioning voicing effect. How?

    - Test voicing effect in a language with phonemic vowel length for a subset of its vowel qualities
        - Lithuanian has *unpaired* vowels for the long/short contrast.
    - **General hypothesis:**
        - Vowel without a long (or short) counterpart will exhibit a stronger voicing effect than vowels with short/long counterparts.

## 4. Lithuanian background

### ➢ Vowel inventory

Table I. Lithuanian vowel inventory (Mathiassen 1996).

| | Front | Back |
|---|---|---|
| High | ɪ iː | ʊ uː |
| Mid | **eː** | (ɔ) oː |
| Low | ɛ æː | a ɑː |

- **[eː]** lacks short counterpart – expected to behave different w.r.t voicing effect.
- (ɔ) marginal vowel, only in recent loanwords & some times excluded from phonemic inventory – [oː] might behave like unpaired [eː].

- Length contrast among low vowels:
    - Significant difference in duration (Balšaitytė 2004).
    - Morphological alternations where /æː/ &/ ɑː/ result from /ɛ/ & /a/ lengthening under stress (Ambrazas 1997):

(1) Alternations [ɑː/a] and [æː/ɛ] under stress shift in Lithuanian:

| | | | | |
|---|---|---|---|---|
| [ˈn**ɑː**mas] | "house.Nom.sg" | *vs.* | [n**a**ˈmʊs] | "house.Acc.pl" |
| [ˈgʲ**æː**ras] | "good.Nom.sg.masc" | *vs.* | [gʲ**ɛ**ˈrʊs] | "good.Acc.pl" |

- Evidence that /eː/ is a long vowel:
    - /eː/ behaves like other long vowels in Lithuanian w.r.t stress assignment (Tekorienė 1990) and word minimality requirements (Steriade 1991).

## ➢ Consonant inventory

Table II. Lithuanian consonant inventory (see Klimas 1970 for discussion)

| | labial | alveolar | postalveolar | palatal | velar | glottal |
|---|---|---|---|---|---|---|
| stop | p b | t d | | | k ɡ | |
| fricative | f | s z | ʃ ʒ | | x | h |
| affricate | | ts dz | tʃ dʒ | | | |
| nasal | m | n | | | | |
| trill | | r | | | | |
| approximant | v | l | | j | | |

- Processes affecting obstruent voicing (relevant for experiment set-up):
  - Final obstruent devoicing
  - Regressive voicing assimilation in obstruent cluster

> ***Hypothesis to be tested:***
> The voicing effect will be greater for /e:/ than for other vowels

*Note*: keep in mind /o:/, which might behave as an unpaired vowel.

## 5. Methodology

### ➢ Stimuli:

- Nonsense words of the shape ˈ$CV_1C_1C_2V$, where:
  - $V_1$ = any of the 11 monophthongs from Lithuanian inventory
  - $C_1C_2$ = /gʒ/ (voiced condition) or /kʃ/ (voiceless condition)
  - Initial C and final V = /t/ and /a/

- Examples: /t**i:**kʃa/, /t**i:**gʒa/

- Stimuli in carrier sentence:

(2) Sakyti _____ negalima ‘To say _____ is not allowed’

### ➢ Subjects, recordings and analysis:

- Five native speakers of Lithuanian from the eastern region of Lithuania.
- Speakers were shown sentences on computer screen and were cued for each sentence.

- Recordings were conducted using a laptop computer and a USB head-mount microphone.
- Relevant vowel ($V_1$) duration was measured following standard procedures, using Wavesurfer program.

## 6. Results

➢ **Questions about data to be answered by statistical analysis:**

1. Are long Vs different from short Vs in duration?
2. Is there a stop voicing effect?
3. Is the stop voicing effect greater for /e:/ than for other vowels (& potentially /o:/)?

➢ **Results for length contrast:**

- One-factor ANOVA for significance of vowel length on vowel duration, split by subject:
  - Length differences are statistically significant for all speakers ($p<.0001$), except for LV.

- Fisher's PLSD test for significance of vowel quality effect on vowel duration:
  - Vowel-to-vowel comparison for duration differences:

| | All speakers | AV | JG | LV | RK | VP |
|---|---|---|---|---|---|---|
| ɑ:-a | * | * | * | n.s. | * | * |
| æ:-ɛ | * | * | * | n.s. | * | * |
| o:-ɔ | * | * | * | n.s. | n.s. | * |
| i:-ɪ | * | * | * | n.s. | * | * |
| u:-ʊ | * | * | * | * | * | * |

*=statistically significant **n.s.**=statistically non-significant

➢ **Results for voicing effect:**

- Two-factor ANOVA (stop voicing & speaker) on vowel duration:
  - Stop voicing has a significant effect on vowel duration.
  - All speakers behave similarly.

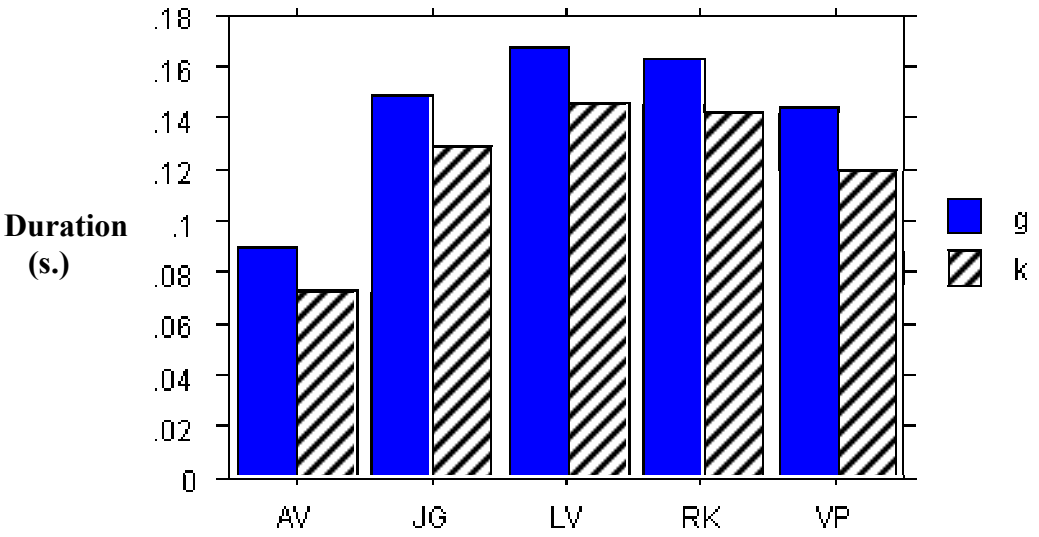


Figure 1. Vowel duration before /g/ and before /k/ stops for all speakers.

➢ **Results for voicing effect and vowel length:**

- 3-factor ANOVA (V-quality, stop voicing & speaker[1]) on V-duration:
  - All factors have significant effects.
  - All speakers behave similarly.
- Need to establish magnitude of voicing effect for each vowel:
  - Planned comparison of vowel duration means w.r.t. vowel quality and stop voicing:
    - Compare duration means for each vowel before /g/ with mean before /k/:
      - /ɪ, i:, **e**:, æ:, ɑ:, ɔ, o:/ → significant voicing effect.
      - /ɛ, a, ʊ, u:,/ → non-significant voicing effect.
- For which vowel is voicing effect strongest?
  - Ranking of F-values from means comparison – the higher the F-values, the stronger the effect.

Table III. Ranking from lower to higher of F-values from means comparison

| Vowel | ɛ | ʊ | u: | a | ɔ | æ: | ɪ | i: | ɑ: | **o:** | **e:** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F-value | 2.889 | 3.103 | 3.618 | 3.784 | 4.131 | 4.132 | 4.319 | 4.978 | 6.373 | **9.298** | **13.428** |

**Voicing effect is strongest for /e:/ & /o:/**

[1] Speaker LV (outlier in length differences) is not included in the rest of the analyses.

- But is the difference in stop voicing effect among vowels statistically significant?
    - Two new variables:
        - Difference in the mean vowel duration before /g/ minus each vowel's duration before /k/ – *voiced-voiceless difference*
        - Difference in the mean vowel duration before /k/ minus each vowel's duration before /g/–*voiceless-voiced difference*
    - These variables reflect the amount of variation in duration for each vowel depending on the following stop voicing:
        - Is this variation greatest for /e:/?
    - Both variables behave similarly – I only report results for the voiced-voiceless difference.
    - Two-factor ANOVA (vowel quality & speaker) on voiced-voiceless difference:
        - Vowel quality has a significant effect and all speakers behave similarly.
    - Fisher's PLSD test on voiced-voiceless difference for vowel quality (speakers grouped):

| ***Vowels compared*** | ***Statistical significance*** | ***Mean difference (ms.)*** |
|---|---|---|
| e:-a | * | 15 |
| e:- ɑ: | * | 10 |
| e:- ɛ | * | 18 |
| e:- æ: | * | 15 |
| e:- ɪ | * | 14 |
| e:-i: | * | 11 |
| e:- ɔ | * | 15 |
| e:-o: | n.s. | 5 |
| e:- ʊ | * | 18 |
| e:-u: | * | 14 |

*=statistically significant **n.s.**=statistically non-significant

- Summary of results for voicing effect and vowel length:
  - From F-values ranking – /e:/ shows the strongest voicing effect
  - Statistically significant difference between /e:/ and all other vowels, except /o:/.

**Voicing effect is strongest for /e:/, with statistical significance.**

➢ **Summary of results:**

1. Are long vowels different from short vowels in duration?
- Yes, there is a significant difference for short/long vowel pairs, all speakers except for LV.

2. Is there a stop voicing effect?
- Yes, for all the data grouped together, vowels are longer before /g/ than before /k/ for all the speakers.

3. Is the voicing effect greater for /e:/ than for the other vowels (& potentially for /o:/)?
- Yes, the difference in duration before /g/ and before /k/ for /e:/ is greater than for the other vowels.
- This comparison reaches statistical significance for all vowels except **/o:/**:
  - This seems related to phonemic status of /ɔ/-/o:/ contrast
  - In our data, /o:/ does not behave as part of short-long contrast – /ɔ/ seems to be non-phonemic.

➢ **Is the hypothesis borne out?**

*Hypothesis:*
The voicing effect will be greater for /e:/ than for the other vowels.

**Yes, the voicing effect is greater for /e:/ which is not part of a short/long contrast pair, than for other vowels.**

## 7. Discussion

- Results show that contrastive vowel length interacts with voicing effect, i.e., *phonological information impact the application of a phonetic process*:
  - Presence of contrastive length inhibits the voicing effect.

- But what is limiting the voicing effect?
  - Length contrast as a feature of the entire system?
    - All vowels would behave similarly – this is not the case.
  - Length contrast as specified for each vowel?
    - Different behavior depending in vowel:
      - If vowel has short/long counterpart, then voicing effect is attenuated.
      - If vowel does not have a short/long counterpart, then voicing effect is stronger.

- Relevant notion – **minimal contrast**:
  - **Minimally contrastive segments** = segments that differ just along one dimension of contrast, e.g. length. Example:
    - /i:, i/ differ only in length → minimal length contrast.
    - /e:, i/ differ in length & height → no minimal contrast.
  - /e:/ does not minimally contrast for length.

- Voicing effect and minimal contrast:
  - Vowels behave differently depending on whether they minimally contrast for length.
  - Asymmetrical vowel system influences voicing effect.

**Phonetic process is sensitive to minimal contrast**

- Phonological representation needs to include information about minimal contrast.

➢ **Can moraic theory capture minimal contrast**?

- Minimal contrast cannot be based on number of moras:
  - /e:/ behaves as bimoraic vowel (see section 4).
  - If based on moras, then /e:/ would pattern with bimoraic ones.
- Minimal contrast cannot be based on moraic underspecification of /e:/:
  - /e:/ behaves as bimoraic in phonology.

## 8. Conclusion

- Minimal length contrast influences the outcome of the phonetic effect.
- Phonology needs to encode minimal contrast information.
- Moraic representation fails to capture it.
- Need for new representation of minimal contrast.

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