

The production and perception of intrinsic vowel duration

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This talk

- High vowels are shorter than low vowels.
- Is this due to some physiological effect or is it built into our grammar?

Overview

- Height-duration correlation in vowels
- A series of studies: correlation robust between categories, not within categories
- How do we account for the observation that the correlation holds cross-linguistically?
- Adam Stone's thesis: low vowels are perceived as being longer even when they are not

High vowels are shorter than low vowels

- Generalization: High vowels are shorter than low vowels.
- There is a positive correlation between F1 and duration.
- English: Heffner 1937, House and Fairbanks 1953, Peterson and Lehiste 1960, Scharf 1962
- Other languages: German (Maack 1949), Inari Saami (Äimä 1918, Stone 2014), Swedish (Elert 1964), Thai (Abramson 1962), Spanish (Navarro Tomás 1916)
- Lehiste (1970:18): “It may be noted that these differences are probably above the threshold for auditory discrimination and thus should be audible.”

Explanation

- Why should high vowels be shorter than low vowels? Why is it cross-linguistically true?

Physiological explanation

- “It is quite probable that the differences in vowel length according to degree of opening [of the jaw – my note] are physiologically conditioned and thus constitute a phonetic universal”
(Lehiste 1970: 18–19)
- Also: Fischer-Jørgensen (1964), Sharf (1962), Solé and Ohala (2010)
- Lindblom (1967): the nature of the tongue’s placement with respect to the palate
- Catford (1977:197): distance between the vowel and surrounding consonants’ places of articulation

Phonology

- “each vowel has a duration target specified in the grammar” (Tauberer and Evanini 2009)
- Tauberer & Evanini’s dialect comparison: F1 and duration of “same” vowel does not always vary as predicted
- Lisker (1974): on- and off-glides not longer on low vowels; steady state is longer (from Lehiste & Peterson 1961)
- Solé & Ohala (2010): is duration difference between high and low vowels constant as duration changes according to speech rate? Yes: Japanese; No: Catalan and English

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Puzzles

- (1) If a pure physiological explanation is correct, how do we explain the findings of Tauberer & Evanini, Lisker, and Solé & Ohala?
- (2) If a pure phonological explanation is correct, how do we explain the cross-linguistic tendency?

Testing the physiology hypothesis

- If the height-duration correlation is mechanical (due to jaw movement), we should see the effect *within* as well as *between* categories.
- Every time a word is uttered, it is slightly different – among other things, the F1 is slightly different.
- If we see the duration effect when we compare different tokens of the [i] vowel (for example), that would be consistent with the jaw opening view.

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English, Swedish, and Inari Saami

- This paper investigates whether there is a correlation between vowel height and duration between and within categories in English, Swedish and Inari Saami.

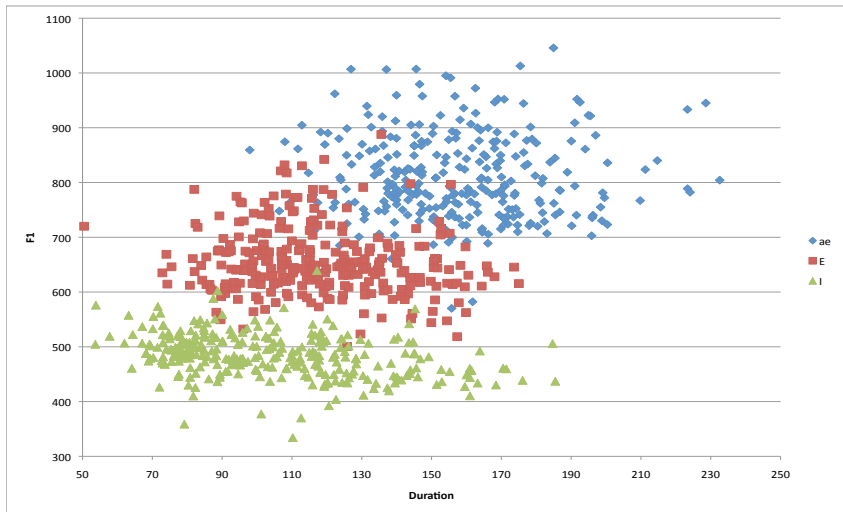
English: Three studies

- Study 1: nonce words collected for Andrea Gormleys thesis (Gormley 2010), 4 speakers
- Study 2: a mixed set of real English words, data collected by Nalini Ramlakhan, 2013, three participants
- Study 3: a more limited set of real English words, more repetitions, data collected by Nalini Ramlakhan, 2013, three participants

English Study 1

- data from Andrea Gormley
- we looked at four speakers
- 4730 data points
- nonce words: tiff tivv keff kevv taff tavv

English study 1, Speaker A



Speaker A: between categories

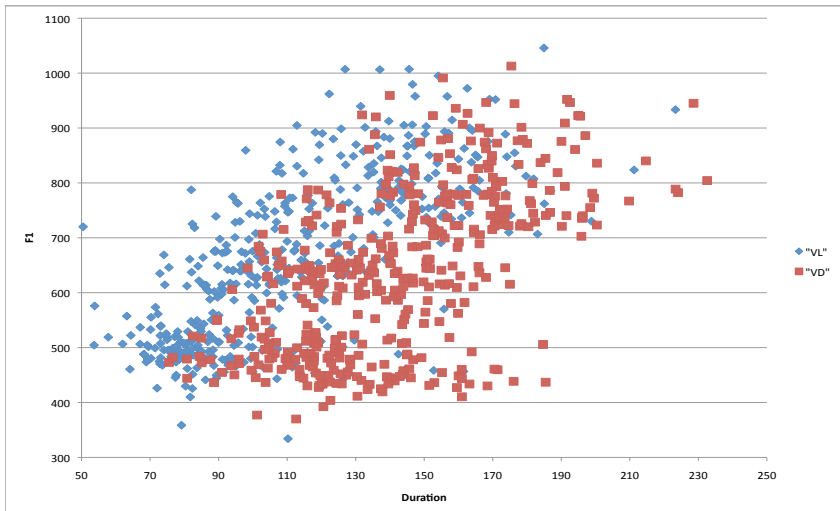
	Duration	F1
[i]	87/123 msec	496/473 Hz
[ɛ]	103/132 msec	669/643 Hz
[æ]	147/169 msec	821/800 Hz

- before voiceless C/ before voiced C
- all distinctions highly significant
- strong positive correlation between f1 and duration

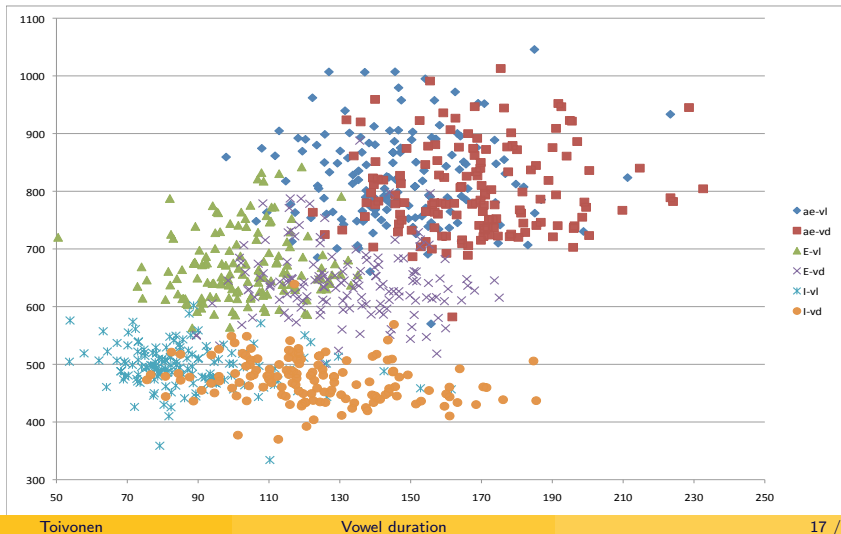
Speaker A: within categories

- There is no positive correlation between f1 and duration
- Within the [ɪ] category, there is a weak negative correlation
- F1 of V and voicing of C: vowels are lower before voiceless consonants (Moreton 2004)

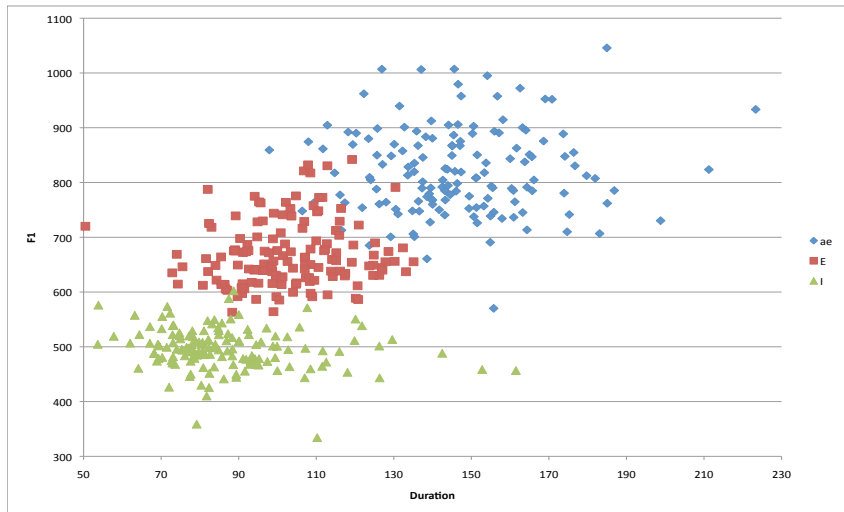
English study 1, Speaker A



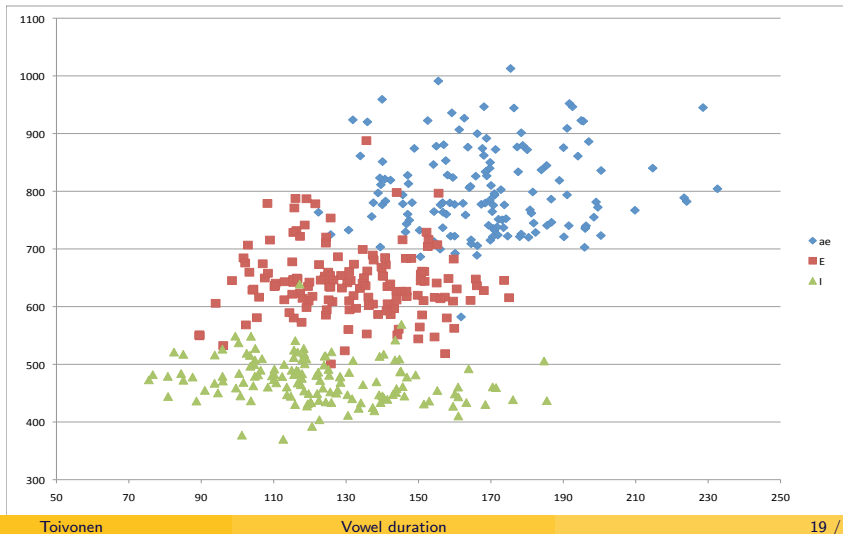
English study 1, Speaker A



Speaker A, before voiceless C



Speaker A, before voiced C



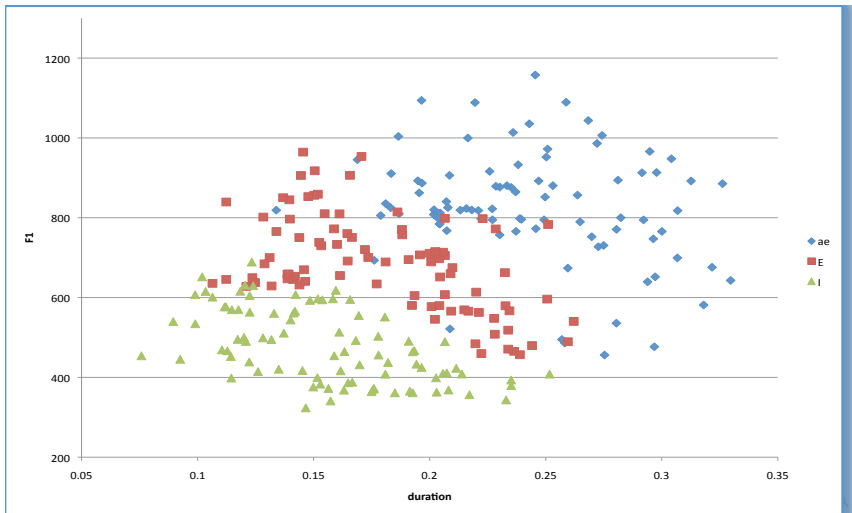
English Study I, general results

- Higher vowels are shorter
- This effect is not seen within categories
- Potential problems:
 - (1) designed to be a tongue twister (plus controls!)
 - (2) nonce words

English study 2: Methodology

- Stimuli: five set of minimal or near-minimal triplets with the vowels [ɪ ɛ æ]
- {sit set sat}; {bit bet bat}; {big beg bag}; {give bev jazz }; {miss mess mass}
- repeated six times, randomized
- three subjects
- subjects were shown one word at a time (written, on a computer screen)
- even timing (power point)
- the subjects read each word in a carrier phrase ('say X to me')
- the target words were segmented in PRAAT
- a PRAAT script extracted the duration and f1 of each segment (thanks Mietta Lennes!)

English study 2



English Study 2, between categories

	Duration	F1
[i]	156 msec	477 Hz
[ɛ]	183 msec	683 Hz
[æ]	241 msec	825 Hz

- the distinctions are highly significant
- duration of [i] and [ɛ] not significantly different for one speaker (cf. Solé & Ohala 2010, who also reach inconclusive results for [i] and [ɛ] in English)
- strong positive correlation between f1 and duration

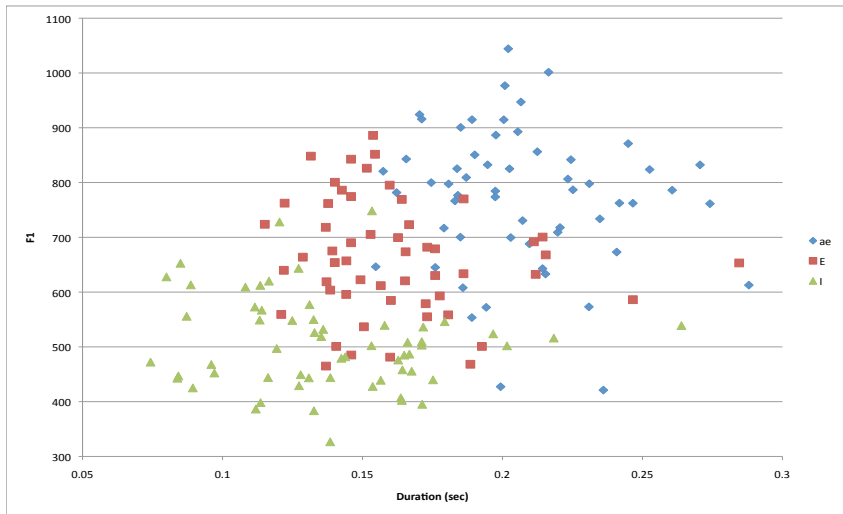
English Study 2, within categories

- No f_1 /duration correlation within categories
- except a weak negative correlation in [æ] for one speaker

English study 3

- miss mess mass; bit bet bat
- method: same as study 2, except each word read ten times
- Three participants

English study3



English Study 3, between categories

	Duration	F1
[i]	138 msec	505 Hz
[ɛ]	162 msec	662 Hz
[æ]	207 msec	772 Hz

- the distinctions are significant
- strong positive correlation between F1 and duration
- no F1-duration correlation in the within-category analysis

English studies, summary

- High vowels are shorter than low vowels.
- This generalization holds between categories, not within categories.

Swedish

Quantity in Swedish

- complementary quantity system:
 - long vowels are followed by short consonants
 - short vowels are followed by long consonants

Swedish examples

Long V words:

[ha:t]

'hatred'

[ka:l]

'bare'

[he:ta]

'be called'

Short V words

[hat:]

'hat'

[kal:]

'cold'

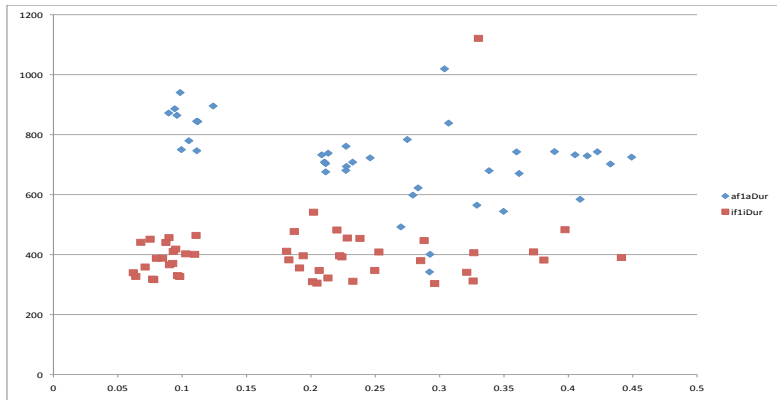
[het:a]

'heat'

Swedish Study 1

- 6 speakers
- every speaker: 60 words five times each
- mono- and disyllabic, before voiced & voiceless, before stops and fricatives, inherently long and short vowels
- similar results to English study

Speaker KS



Speaker KS, Duration & F1

	Duration	F1
[i]	190 ms	404 Hz
[a]	256 ms	720 Hz

- between categories: high vowels are shorter than low vowels
- Within [i]: no correlation between f1 and duration
- Within [a] category: a negative correlation between f1 and duration
- Other speakers and sounds: similar results

Swedish Study I, results

- Same results as English study
- Between categories: high vowels are shorter than low vowels; some exceptions where they are the same
- Within categories: no correlation between f_1 and duration, or a weak negative correlation

Swedish Study 2

- two speakers
- better controlled than Study 1
- missa messa massa
- two speakers
- stimuli eight times, ten times

Swedish study II, both speakers, duration

- [i] < [ɛ]
- [ɛ] < [ɑ]
- within categories: no correlation

Swedish Studies, results

- Same results as English study
- Between categories: high vowels are shorter than low vowels; some exceptions where they are the same
- Within categories: no correlation between f_1 and duration, or a weak negative correlation

Inari Saami

- Spoken in Northern Finland
- About 350 speakers
- Part of the Saami language group, about 20,000 speakers total

The phonetic study of Inari Saami

- 5 native speakers
- 99 words (types)
- 1003 tokens
- words uttered in carrier phrase
- words with [l] and [n] as middle consonant, low or back vowel as V_1
- words with two syllables
- PRAAT and R
- See Bye, Sagulin & Toivonen (2009) *Phonetica*

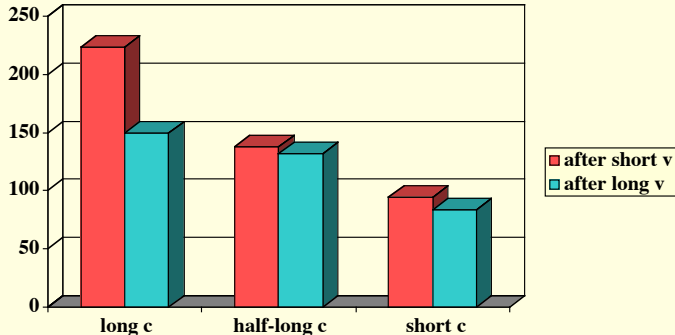
Inari Saami

WORD TYPE	NAIVE PHONEMIC
VCV	/tʃælæm/
VC·V	/manʰan/
VCCV	/kannun/
VVCV	/moonəm/
VVC·V	/laanʰan/
VVCCV	/pæænnin/

All combinations of short/long V and short/half-long/long C allowed

Consonants: long, half-long, short

Consonants after short vs. long vowels (Speaker K)



Inari Saami quantity

- There is a binary vowel duration distinction and a ternary consonant duration distinction
- The expected inverse correlations are found between categories: the shorter the V1, the longer the C
- However, Inari Saami is not a complementary quantity language

Inari Saami, results

- Between categories: high vowels are shorter than low vowels
- Within categories: inconclusive results, however, the within-category correlation does not seem to mirror the between-category one

Summary

- Three English studies, two Swedish studies, one Inari Saami study
- Stone (2014): six Chilean Spanish speakers, same results
- Generalization: High vowels are shorter than low vowels.
- The generalization does not hold for all sounds and all speakers, but we never found a higher vowel to be longer
- The generalization holds between categories only, not within categories.
- Toivonen, Lev Blumenfeld, Andrea Gormley, Leah Hoiting, John Logan, Nalini Ramlakhan, Adam Stone 2014 (WCCFL paper)

Interim conclusions

- High vowels are shorter than low vowels, even in quantity languages.
- This is consistent with Meister & Werner's (2009) findings for Estonian and Finnish.
- The results of these studies are consistent with the hypothesis that vowels have a duration target in the grammar
- Vowel duration is a secondary cue that helps distinguish between vowels
- The duration-height correlation is a phonological (controlled) feature.
- Our studies do not support the claim that lower vowels simply take longer to produce (physiological, mechanical explanation).
- Remaining puzzle: how do we explain the cross-linguistic tendency? Why don't we find languages where low vowels are shorter than high vowels?

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Why are high vowels cross-linguistically shorter than low vowels?

- If it is not jaw movement or something else production-related, then what is it?
- Perhaps it *is* production-related, just not directly?
- Solé & Ohala (2010:647):
 - Duration is one of several distinctive manifestations of vowel identity, but the specific durational targets of vowels may have originated in biomechanical differences.
 - The cross-linguistic tendency then has a physiological explanation, but this tendency has been phonologized in some languages and not others.
- Perception?
- Perhaps high vowels *sound* shorter than low vowels?
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Perceived vowel duration

- Gussenhoven (2007): “Higher vowels sound longer than lower vowels, by way of compensation for the articulation-driven lengthening of open vowels.” Limburgian dialects of Dutch.
- Gussenhoven and Zhou (2013): High vowels sound shorter than low vowels. Dutch and Chinese listeners.
- Note: not exactly relevant here, but see Heike Lehnert-LeHouillier (2007) *The Perception of Vowel Quantity*

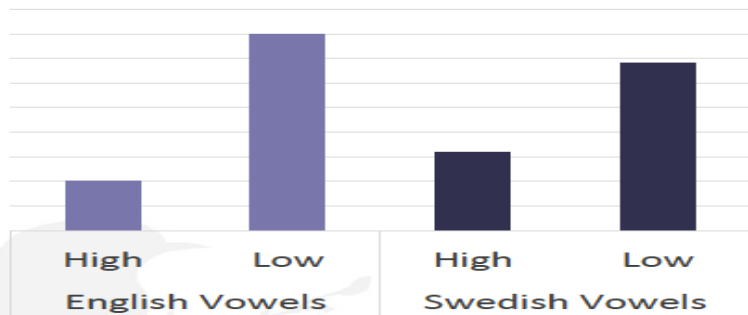
Adam Stone's thesis

- Forced choice perception task.
- Participants heard word pairs and were instructed to pick the longest word.

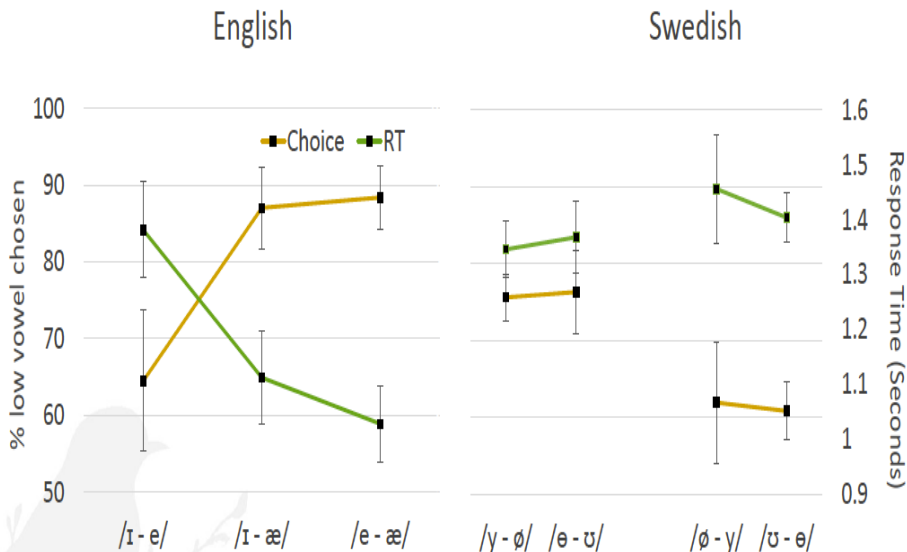
Stimuli

- Participants: 31 native speakers of English
 - (1) English words; e.g., *big–beg*
 - (2) English nonce words; e.g., *mib–mib*
 - (3) Swedish words; e.g., *gnytt–gnott*
 - (4) Swedish nonce words; e.g., *drytt–drott*
- All words appeared in the way they were recorded and in a modified form where the duration was manipulated so that the duration of both words in the pair was the same.

Adam's study

English vs. Swedish *Choices*

Adam's study



English results

Table 4: English length choices between natural and modified duration conditions

	Natural Duration			Modified Duration		
	/ɪ - ɛ/	/ɪ - æ/	/ɛ - æ/	/ɪ - ɛ/	/ɪ - æ/	/ɛ - æ/
% Chosen	64.68	88.85	89.12	65.12	84.13	87.09
#V1 Chosen	137	50	36	201	62	42
#V2 Chosen	264	380	303	378	371	299
Effect Size ϕ	.32	.77	.79	.31	.71	.75

The bold vowel in each pair refers to the measurably lower one. “% Chosen” refers to how much the lower vowel was chosen. “#V1 Chosen” refers to the amount of times the first (higher) vowel in the above pairs was selected, and “#V2 Chosen” refers to the second (lower) vowel. All effects are significant, $p < .0001$.

Swedish results

Table 5: Swedish length choices between natural and modified duration conditions

	Natural Duration		Modified Duration	
	<i>/y - ø/</i>	<i>/e - u/</i>	<i>/y - ø/</i>	<i>/e - u/</i>
% Chosen	73.36 , 68.66	75.27 , 58.46	77.86 , 55.19	77.88 , 63.63
#V1 Chosen	119 , 108	56 , 132	90 , 158	48 , 101
#V2 Chosen	315 , 233	161 , 178	313 , 214	169 , 178
Effect Size φ	.45 , .37	.48 , .15	.55 , .15	.56 , .28

Each result is composed of normally-ordered pair results on left (in bold), followed by reverse-ordered pairs on right, separated by a comma

Conclusion

- High vowels are shorter than low vowels.
- This seems to be true cross-linguistically.
- There are reasons to believe that this is not due to physiology, or at least not pure physiology
- There is some evidence that high vowels are perceived as shorter than low vowels.

Thank you

- LLI Lab, Carleton University
- Patrik Bye, Jen Hay, Raj Singh
- CUNY Phonology Forum
- NAPHC8
- WCCFL
- SSHRC

Selected references

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Different types of quantity languages

- Swedish has complementary quantity
- Inari Saami does not, but an effect can still be seen: longer V1 goes with shorter C
- Inari Saami and Swedish are both quantity languages, but they are described as being quite different.
- Do Swedish and Inari Saami have fundamentally different quantity systems?
- Hypothesis: Inari Saami effects on vowels are simply phonetic side effects; the Swedish interaction between vowels and consonants is a fundamental part of the phonology
- Can we look for acoustic evidence for the hypothesis?

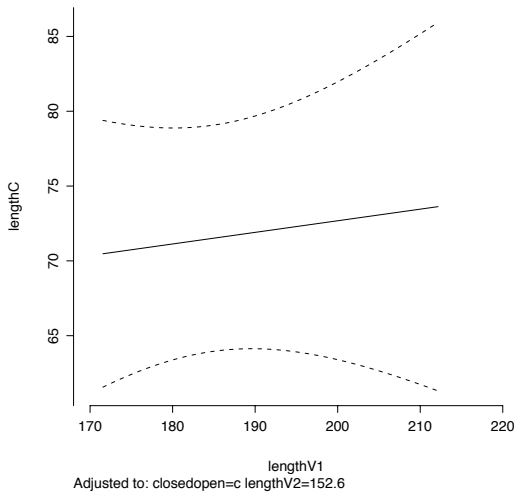
Within category

- Do we find a negative correlation in duration between vowels **within** categories?
- Example: several instances of words of the type [ha:t]
- If the duration of consonants and vowels are fundamentally co-dependent in Swedish, then perhaps we would expect a negative correlation within categories in Swedish, and not in Inari Saami

Inari Saami

- *Category*: For example, words with short V1 and short C.
- Within categories, there is no negative correlation in duration between vowel and consonant in Inari Saami.
- Within categories, there is either no significant correlation, or else a (weak) positive correlation
- Positive correlation probably due to weak speech rate effects

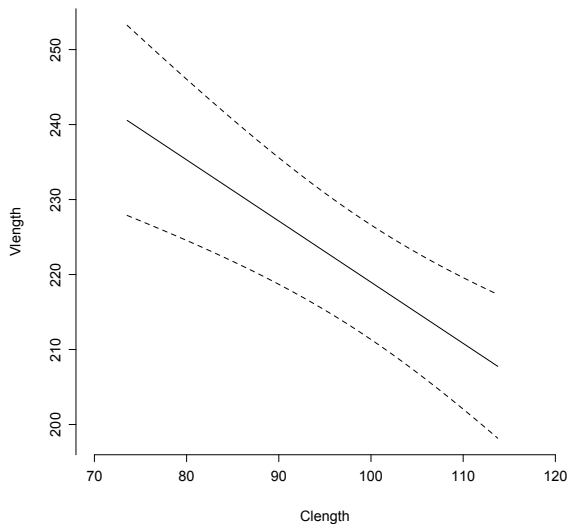
Speaker IM, short V1 short C



Swedish

- *Category*: For example, words with long V and short C.
- Within categories, there is sometimes negative correlation in duration between vowel and consonant in Swedish, for some speakers and categories.
- For some speakers and categories, there was no correlation or a weak positive correlation
- Again, positive correlation probably due to weak speech rate effects

Speaker GT, long V short C



Results of within-category study of vowel & consonant duration

- In Swedish, but not in Inari Saami, there are within-category negative correlations between vowel and consonant duration.
- Perhaps this makes sense if Swedish is a complementary quantity language and Inari Saami is not?