Vowel Duration before Ejective Stops

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Outline

It has been well established that vowels are phonetically longer before voiced than voiceless stops, all else being equal. To my knowledge, however, no studies have measured vowel durations before ejective stops. This paper aims to fill this gap: I present results from a phonetic experiment with twelve speakers of Georgian, establishing for the first time the "ejection effect". The study also tested the effects of stop closure duration. Results shed light on causes of durational differences in vowels.

Introduction

- The effect that voiced consonants have on preceding vowel duration has been observed in various languages across language families: among others in English, French, Russian, Korean, and Bengali (House and Fairbanks 1953; Lehiste and Chen 1970; Lehiste 1970; Raphael 1975; Abdelli-Beruh 2004; Durvasula and Luo 2014)
- Difference in vowel duration well established
- Causes of this difference poorly understood
- At least five proposals, more or less probable (from Lisker 1974):
  a) **fortis-lenis distinction**: voiceless stops are "fortis" which means that articulatory closure has to onset earlier
  b) **closure gesture**: "strong closure gesture" of voiceless stops is achieved more rapidly which results in shorter vowel duration
  c) **laryngeal features**: vowels are longer before voiced stops because it takes longer to activate laryngeal features necessary for voicing
  d) **timing**: if expenditure of energy is constant, then vowel before voiced stops (which are shorter) should be longer and vice-versa
  e) **perception**: vowel duration is exploited by speaker to maximize the contrast between closure duration difference of voiced vs. voiceless stops: short closure is perceived as even shorter after a longer vowel.
- No studies measure vowel durations before ejective stops (closest Yu 2008, but no direct measurements)
- Ejective stops voiceless; if differences in duration exist, feature voice alone cannot be the reason for durational differences
- Closure duration: voiced stops have shorter intrinsic closure duration. If only two series of stops are tested, closure duration cannot be distinguished from effects of voicing
- Other studies tested aspiration (Maddieson and Gandour 1976, Durvasula and Luo 2014), but smaller scale studies
- If differences in duration are comparatively small, perceptual factors likely not the primary cause

Georgian

- Vowels (Butskhrikidze 2002, Wysocki 2003)

	front	mid	back
high	i		u
mid	ɛ		ɔ
low		ɑ	

- Consonants (Butskhrikidze 2002, Wysocki 2003)

	bilab.	lab.-dent.	dent.	alveo.	p-al.	vel.	uv.	gl.
stop	p^h, b, p'		t^h, d, t'			k^h, g, k'	q'	
aff.				ts, dz, ts'	ʧ, ʤ, ʧ'			
nas.	m			n				
tap/tr.				ɾ/r				
fric.		v		s, z	ʃ, ʒ	x, ɣ		h
lat. appr.				l				

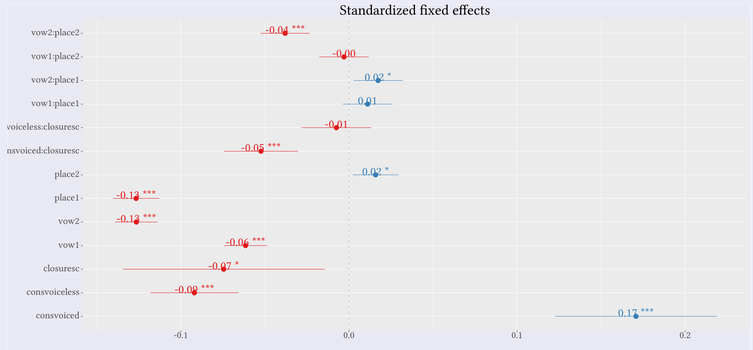
Methodology

- 12 speakers of Georgian (8F, 4M, mean age 23.5, all except one from Tbilisi, recorded in US)
- Open medial syllable — to test smaller scale effects
- 3 vowels ([a, e, o]) × 3 places (labial, alveolar, velar) × 3 laryngeal features (voiced, voiceless aspirated, ejective)
- 25 frame words, no repetitions:
  masV$_x$C$_x$i, ɾɑxV$_x$C$_x$ɑ, vɛʃV$_x$C$_x$ɔ, nisV$_x$C$_x$u, ɾɔʃV$_x$C$_x$ɛ, vɑxV$_x$C$_x$ɔ, mɛxV$_x$C$_x$ɑ, zuxV$_x$C$_x$u, ʒixV$_x$C$_x$ɛ, nɑxV$_x$C$_x$i, nɔsV$_x$C$_x$ɑ, lɑsV$_x$C$_x$u, lixV$_x$C$_x$ɛ, luʃV$_x$C$_x$ɔ, miʃV$_x$C$_x$i, lɛsV$_x$C$_x$ɑ, mɛpV$_x$C$_x$ɛ, ɾubV$_x$C$_x$i, xup'V$_x$C$_x$ɔ, vɔtV$_x$C$_x$i, lidV$_x$C$_x$u, mut'V$_x$C$_x$ɑ, sɔkV$_x$C$_x$ɑ, vɛgV$_x$C$_x$u, ʃuk'V$_x$C$_x$ɔ,
- Speakers read printed sentences with tokens in Georgian script with a carrier sentence *Maiam tkva X ara* 'Maya said X, right?' (e.g. მაიამ თქვა როშათე არა)
- 9 undergraduate research assistants and the author
- 675 tokens per speaker; tokens with mistakes or reading mistakes removed

Results

- Linear model fit using lme4 (Bates et al. 2015) package in R (R Core Team) with laryngeal feature, scaled and centered closure duration, vowel, place of articulation as fixed effects with lar.feature×closure and place×vowel interactions, speaker and frame as random effects with random slopes for closure duration (scaled) and laryngeal feature (for both random effects)

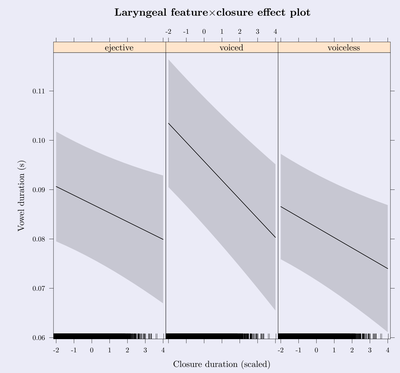
	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.0871	0.0056	13.4494	15.4472	0.0000
ejec. vs. voiced	0.0087	0.0012	10.3263	6.9515	0.0000
ejec. vs. vless	-0.0047	0.0007	12.1917	-6.8953	0.0000
closure.sc	-0.0018	0.0007	20.8574	-2.4390	0.0238
vow e vs. mean	-0.0018	0.0002	7783.0574	-9.5408	0.0000
vow o vs. mean	-0.0037	0.0002	7785.2797	-19.6225	0.0000
lab. vs. mean	-0.0037	0.0002	7792.2017	-18.1136	0.0000
vel. vs. mean	0.0005	0.0002	7816.0464	2.3072	0.0211
voiced:closure.sc	-0.0021	0.0004	177.2187	-4.6896	0.0000
vless:closure.sc	-0.0003	0.0004	124.3904	-0.7111	0.4783
vow1:place1	0.0004	0.0003	7784.4698	1.4890	0.1365
vow2:place1	0.0006	0.0003	7787.3000	2.3280	0.0199
vow1:place2	-0.0001	0.0003	7778.7834	-0.3977	0.6909
vow2:place2	-0.0014	0.0003	7779.9421	-5.1031	0.0000



Ejection effect

Vowels are (i) significantly longer before ejective stops than before voiceless aspirated stops and (ii) significantly shorter before ejective stops than before voiced stops.

Ejection Effect



- Small effects, perception likely not the primary factor
- Closure inversely correlated, but smaller effect
- Significant interaction: more effect of closure in voiced stops
- Durvasula and Luo (2014): aspiration effect
- Voicing effect, aspiration effect, ejection effect
- Laryngeal features or VOT?
- "Laryngeal effect hypothesis:" laryngeal features affect preceding vowel durations
- VOT inversely correlated with stops. But: Hindi data (Durvasula and Luo 2014)
- Future work:
  - What is the articulatory basis for the laryngeal effect?
  - Test effects of VOT

Conclusions

Based on the results from the experiment on Georgian speakers, I propose "ejection effect": vowels are shorter before ejectives than before voiced, and longer before ejectives than before voiceless stops. Several proposed explanations for vowel duration differences are rendered considerably less likely by the results: voice feature or closure duration by itself are not solely responsible for durational differences. Perception is likely not the primary factor. I conclude that laryngeal features are best predictors of vowel length, but closure duration also affects vowel duration in the expected direction. Future research on this topic should be oriented towards testing the "laryngeal effect" hypothesis and its articulatory basis as well as influences of VOT on vowel duration.

Selected References

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