Covariation of voice onset time: a universal aspect of phonetic realization

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Introduction

Extensive cross-linguistic variation in the realization of speech sounds

- Vowel formants

  e.g., Disner 1978, Lindau 1978, Manuel 1990

- Fricative COG

  e.g., Gordon 2002

- Vowel f0

  e.g., Whalen and Levitt, 1995

- Stop VOT

  e.g., Maddieson 1997, Cho & Ladefoged 1999

Cross-linguistic phonetic variation

[kʰ]

DORSAL

+ spread glottis

- continuant

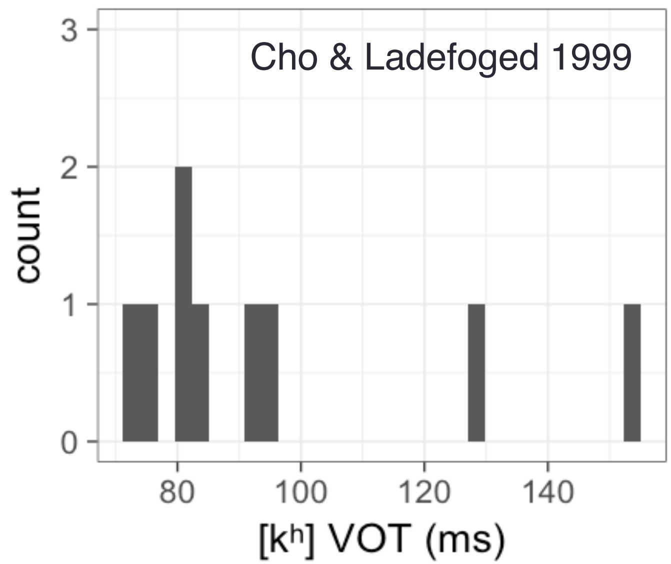
…

Phonetic implementation

TONGUE BODY: closed, velar

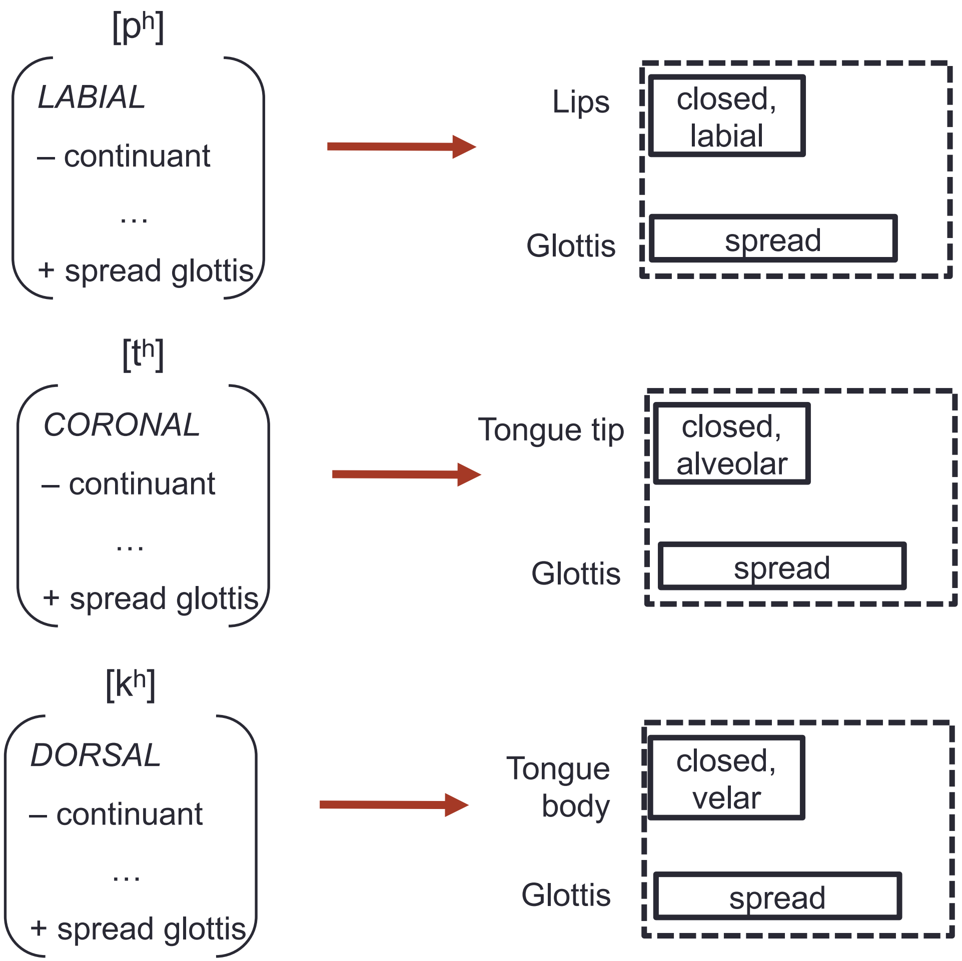
GLOTTIS: spread

articulation → acoustics



Keating 1985, 1990, Cohn 1993, Cho & Ladefoged 1999

Cross-linguistic phonetic variation



[pʰ] mean VOT range:
63 to 83 ms

[tʰ] mean VOT range:
50 to 150 ms

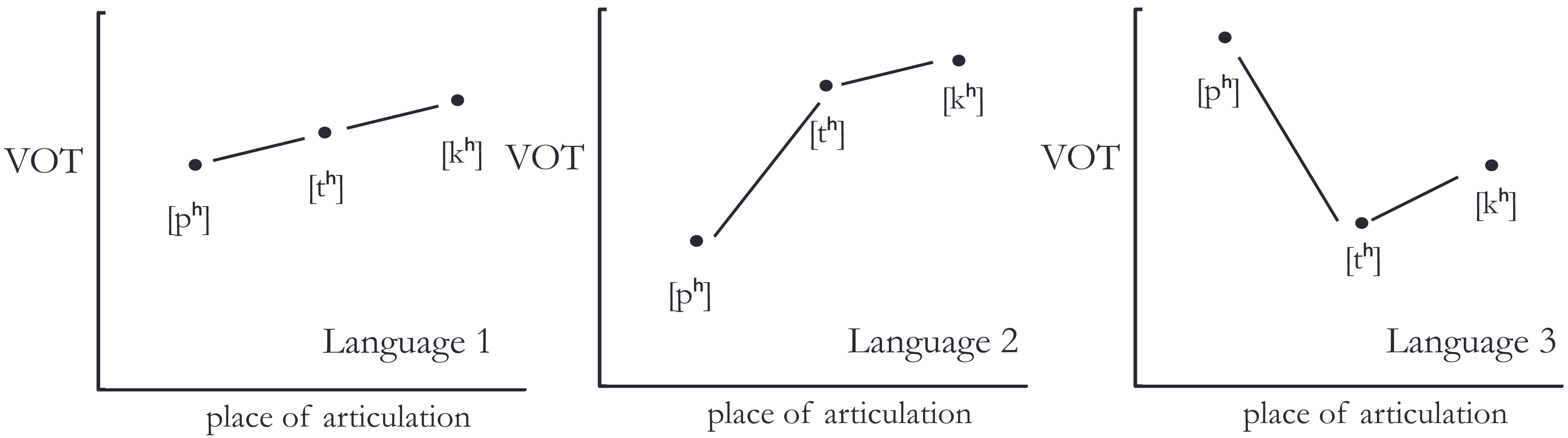
[kʰ] mean VOT range:
73 to 154 ms

What is the relational structure of cross-linguistic phonetic variation?

Keating 1985, 1990, Cho & Ladefoged 1999

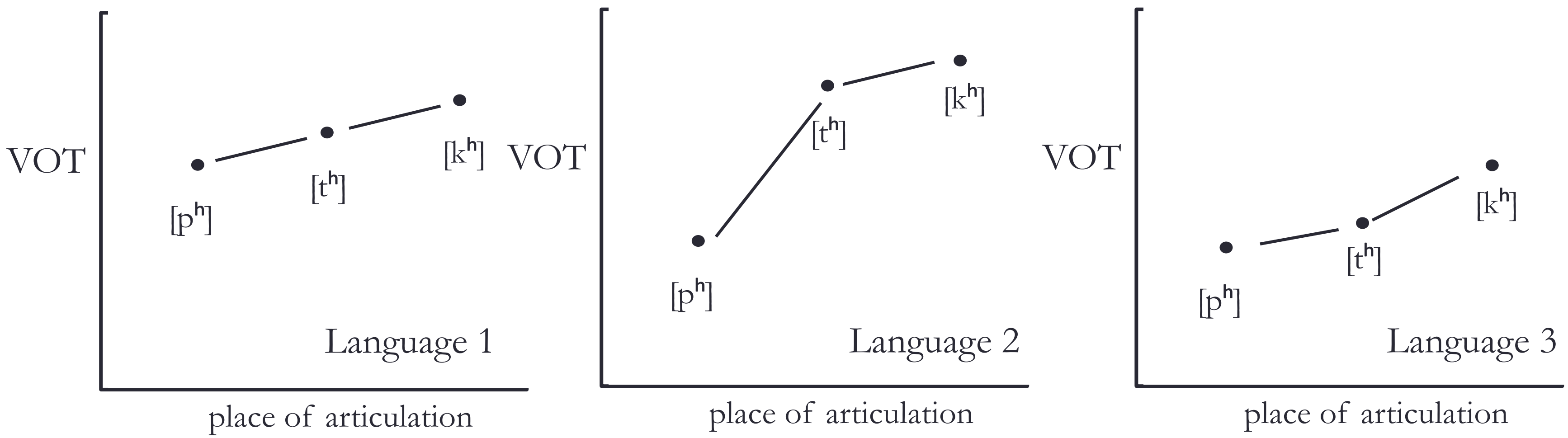
Relational structure of phonetic variation

1) Do the VOTs of [pʰ], [tʰ], and [kʰ] vary independently of one another?



Relational structure of phonetic variation

2) Is there consistency in the ordinal ranking of [pʰ], [tʰ], and [kʰ]?

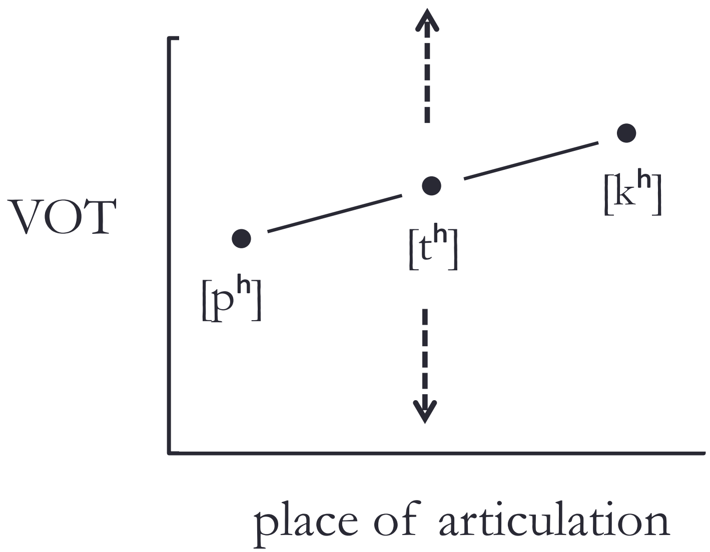


VOT[pʰ] < (VOT[tʰ]) < VOT[kʰ]

e.g., Maddieson 1997, Cho & Ladefoged, 1999
Variable ranking of [tʰ]: Suomi 1980, Docherty 1992, Whalen et al. 2007, Yao 2009, Chodroff & Wilson 2017

Relational structure of phonetic variation

3) Is there a consistent linear relationship among [pʰ], [tʰ], and [kʰ]?



- Linear relationship is a simple type of patterned covariation
- Could imply ordinal relation (e.g., VOT[kʰ] = VOT[pʰ] + x, x ≈ 17 ms)

Chodroff & Wilson 2017

Outline

1. Introduction
2. Cross-linguistic VOT survey
3. Uniformity constraint
4. Discussion
5. Future Directions

Cross-linguistic VOT survey

Large collection of previously reported stop VOT values

Examine relational structure of VOT among stops that have the same laryngeal feature specification*

* not just [+spread glottis], but also [-spread glottis], [-voice], [+voice], etc.

Methods

Examined ~350 theses, articles, grammars, and manuscripts
Collected stop VOT values from 164 sources

113 languages (149 dialects)
36 language families

Removed:
- Breathy / voiced aspirated
- Glottalized / ejective
- Tense (Korean)
- Implosives
- Palatal stops
- Uvular stops

Removed:
- Child data
- Explicitly labeled bilingual data
- L2 data

1671 VOT values remained for analysis

Methods

Averaged VOT data points with shared place and voice within each study, resulting in 1079 data points

Language Family	Languages	Data points
Indo-European	Afrikaans, Armenian (Eastern), Assamese, Bengali, Catalan, Croatian, Danish, Dutch, English, French, Gaelic (Scots), German, Greek (Modern), Hindi, Icelandic, Italian, Kurmanji, Marathi, Nepali, Norwegian, Pahari, Panjabi, Pashto, Persian, Polish, Portuguese (Brazilian), Portuguese (European), Russian, Serbian, Sindhi, Spanish, Swedish, Welsh	557
Sino-Tibetan	Bunun, Burmese, Cantonese, Fukienese, Galo, Hakha Lai, Hakka, Hokkien, Karen (Sgaw), Khonoma Angami, Kurtop, Mandarin, Stau, Taiwanese, Wu (Shanghainese)	106
Afro-Asiatic	Amharic, Arabic, Dahalo, Hebrew (Modern), Musey	41
Austronesian	Belep, Madurese, Malay, Tsou, Yapese	31
Niger-Congo	Bowiri, Igbo, Shekgalagari, Swati, Tswana, Zulu	39
Uralic	Finnish, Hungarian	21
Na-Dene	Apache (Western), Hupa, Navajo, Tlingit	19

Methods

Language Family	Languages	Data points
Korean	Korean	18
Tai-Kadai	Tai Khamti, Thai	18
Tupian	Arara, Munduruku	17
Dravidian	Tamil, Telegu	15
Quechuan	Quechua (Bolivian), Quechua (Cuzco), Quichua	15
Japanese	Japanese	14
Mayan	Itzaj Maya, Mam (Southern), Mopan Maya, Tzutujil, Yukateko Maya	14
Altaic	Azerbaijani, Turkish	12
Kartvelian	Georgian	12
Austro-Asiatic	Pnar, Remo	11
Oto-Manguean	Mazatec (Jalapa), Zapotec (Yalalog)	10
Burushaski	Burushaski	9
Algic	Ojibwe	6
Kordofanian	Moro	6
Muskogean	Chickasaw	6

Methods

Language Family	Languages	Data points
Northwest Caucasian	Kabardian	6
Pama-Nyungan	Warlpiri, Yan-Nhangu	6
Salishan	Montana Salish	6
Ticuna	Ticuna	6
Uto-Aztecan	Paiute (Northern), Ute	6
Wakashan	Kwakw'ala	6
Tucanoan	Waimaha	5
Eskimo-Aleut	Aleut (Eastern), Aleut (Western)	4
Chapacura-Wanham	Wari’	3
Creole	Hawaiian Creole	3
Ijoid	Defaka	3
Nakh-Dagestanian	Udi	3
Tangkic	Kayardild	3
Arauan	Banawa	2

Methods

Relied on primary source descriptions of the laryngeal specifications

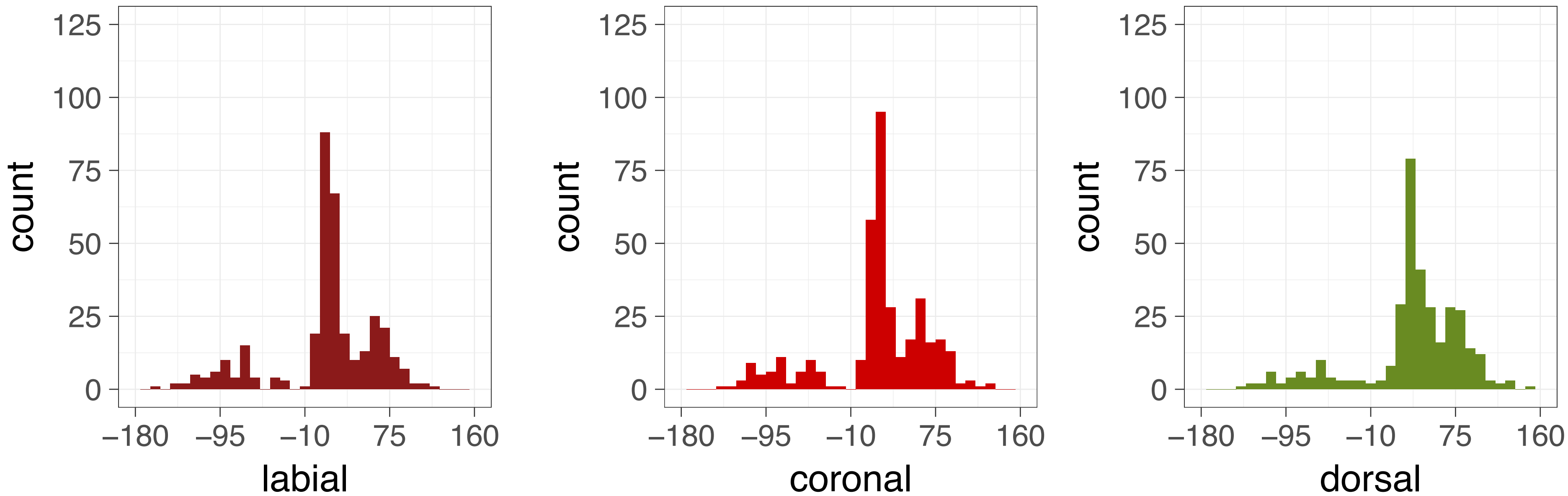
Aggregate analyses

VOT categories
Negative: < 0 ms
Short-lag: > 0 ms and < 35 ms
Long-lag: > 35 ms

Kuhl & Miller 1975

Results

Variation in language-specific VOT means (ms)



Range: -161 to 117 ms

Range: -177 to 130 ms

Range: -144 to 154 ms

Median values

category	labial	coronal	dorsal
Negative	-83 ms	-80 ms	-64 ms
Short-lag	14 ms	18 ms	30 ms
Long-lag	62 ms	65 ms	76 ms

Ordinal rankings

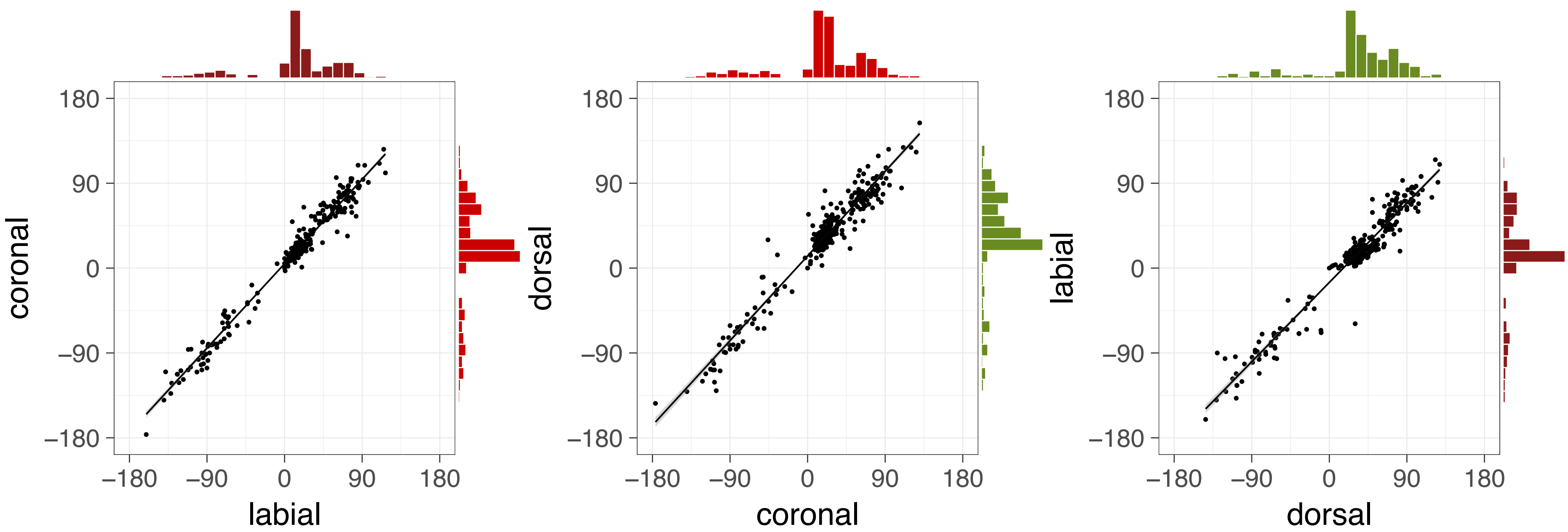
Place differences
Canonical order: VOT[labial] < VOT[coronal] < VOT[dorsal]

	Canonical order	Non-canonical order	
Comparison	**Place1 < Place2**	**Place2 < Place1**	**N**
labial - coronal	76%	24%	339
coronal - dorsal	89%	11%	337
labial - dorsal	96%	4%	317

Maddieson 1997, Cho & Ladefoged 1999, Whalen et al. 2007, Chodroff & Wilson 2017

Linear relation

Aggregate analysis of language-specific VOT means (ms)



r = 0.98*

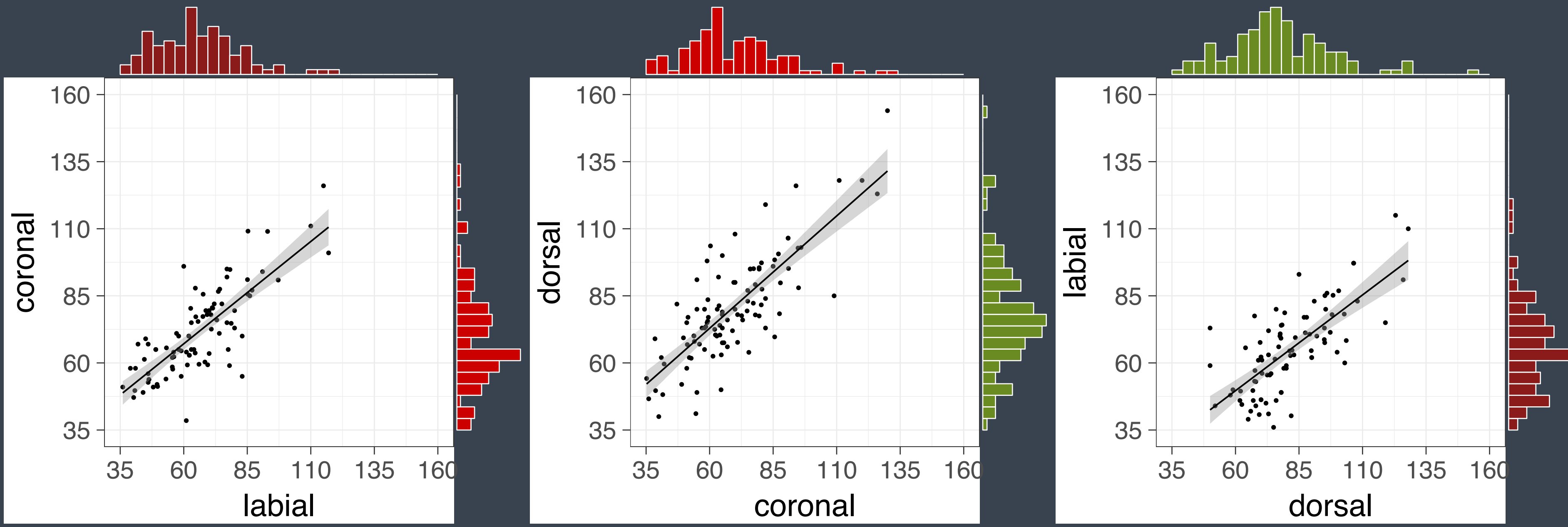
r = 0.97*

r = 0.97*

http://dev.eleanorchodroff.com/apps/crosslgVOT

Linear relation

Long-lag VOT



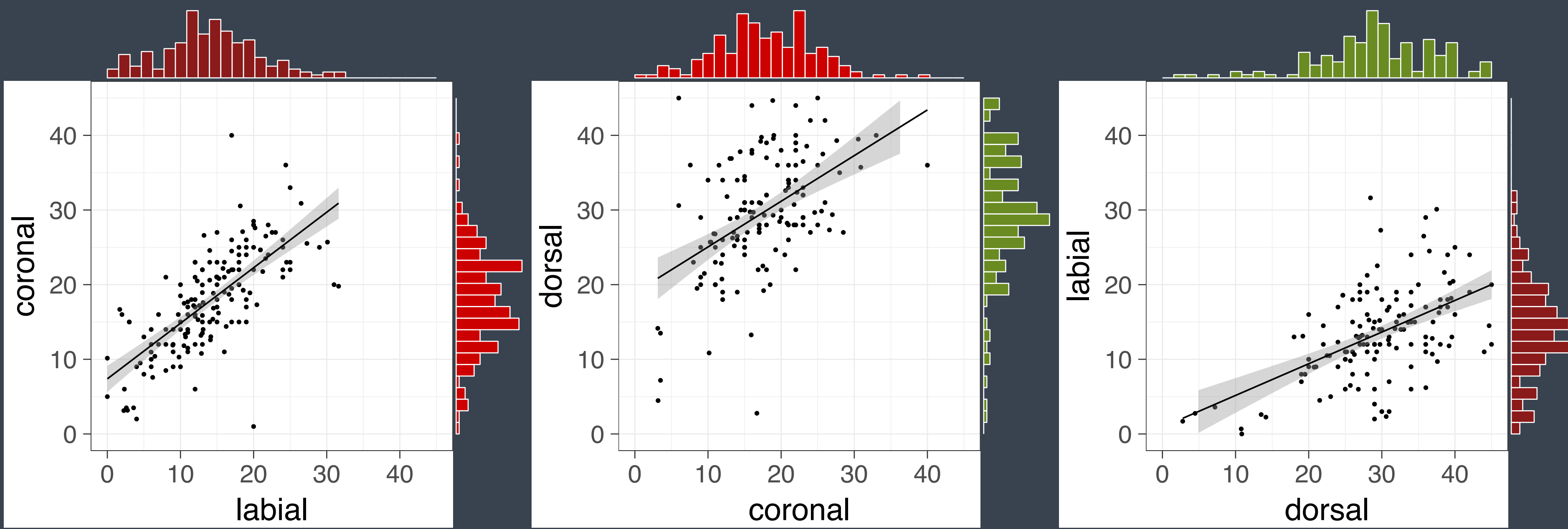
r = 0.83*

r = 0.78*

r = 0.79*

Linear relation

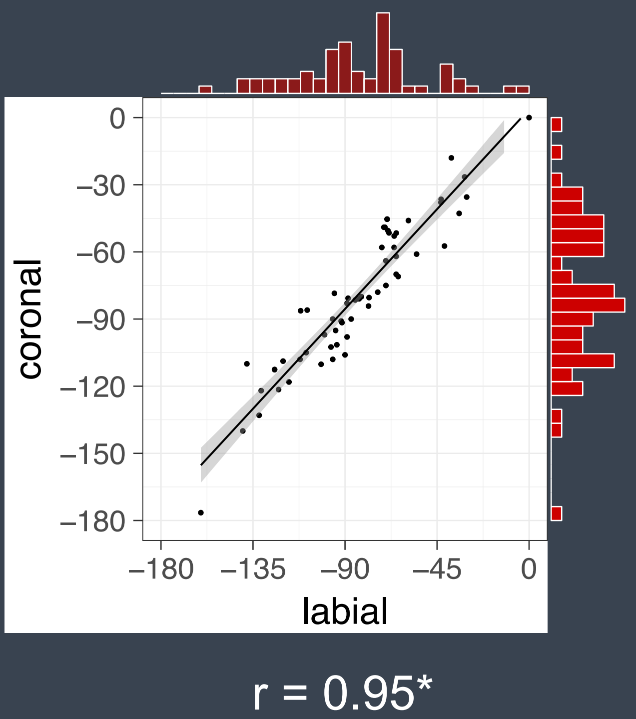
Short-lag VOT

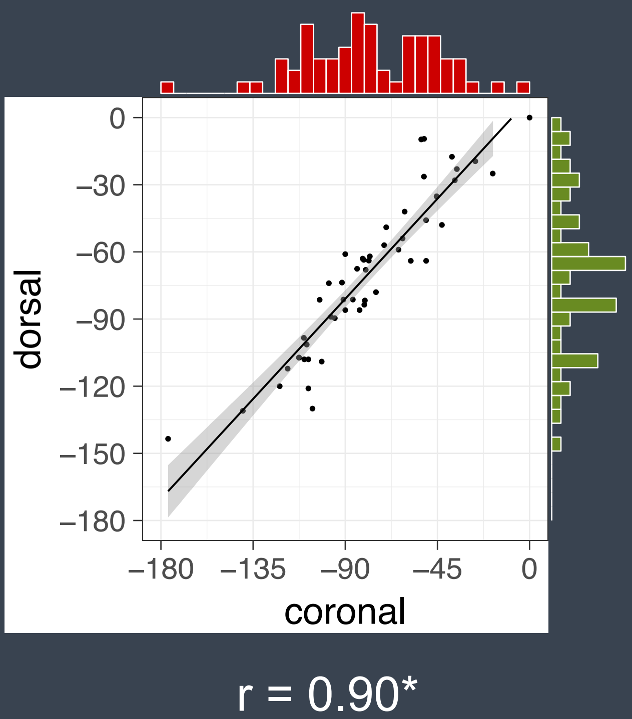


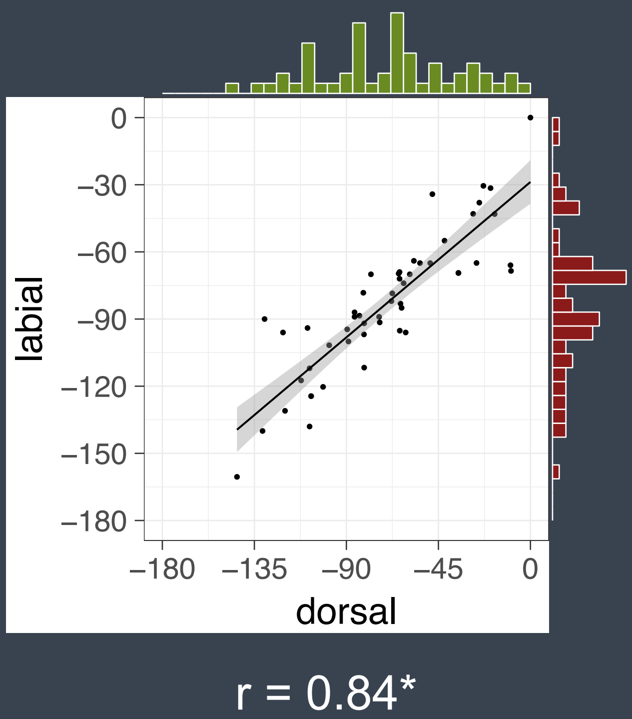
r = 0.66*   r = 0.46*   r = 0.62*

Linear relation

Negative VOT







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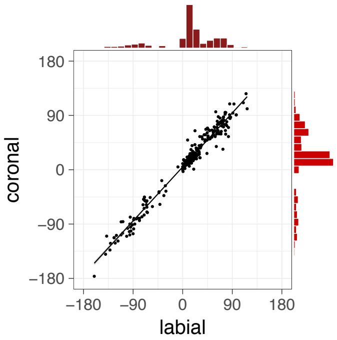
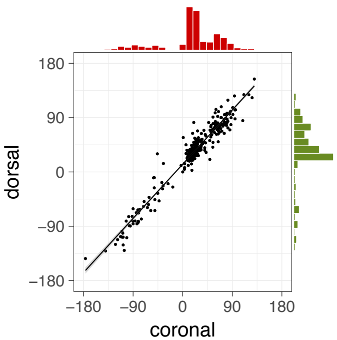
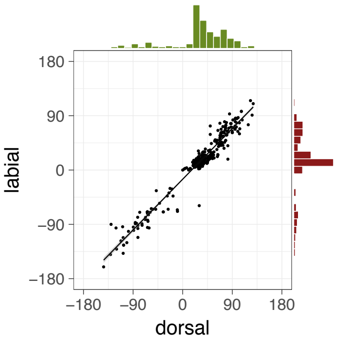
Uniformity constraint

Mapping from distinctive features to phonetic targets is *not independent* across segments within a language

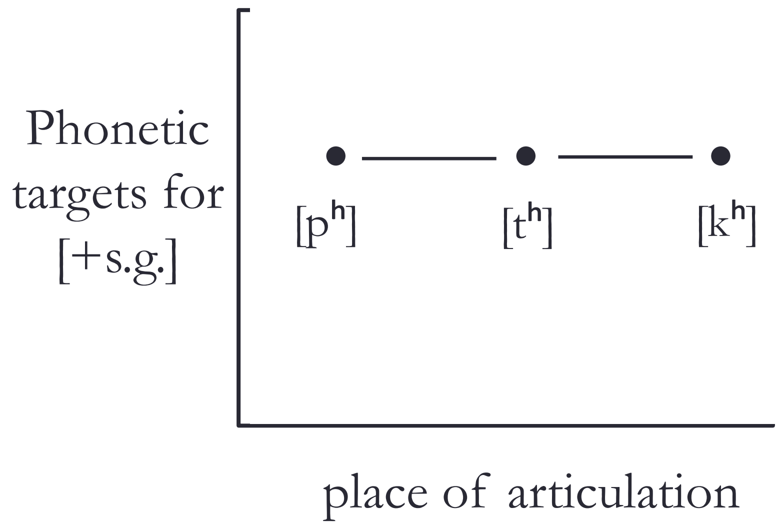
LABIAL – continuant … **α laryngeal**	Lips	closed, labial	
	Glottis	spread	
CORONAL – continuant … **α laryngeal**	Tongue tip	closed, alveolar	
	Glottis	spread	
DORSAL – continuant … **α laryngeal**	Tongue body	closed, velar	
	Glottis	spread	

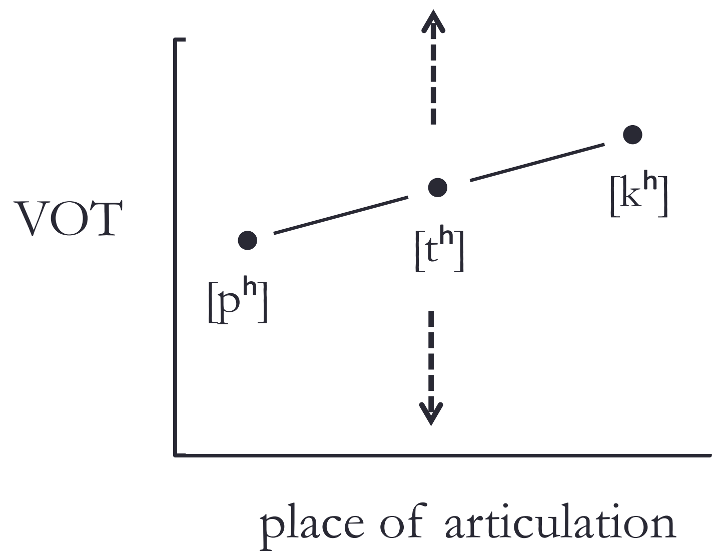






Uniformity constraint



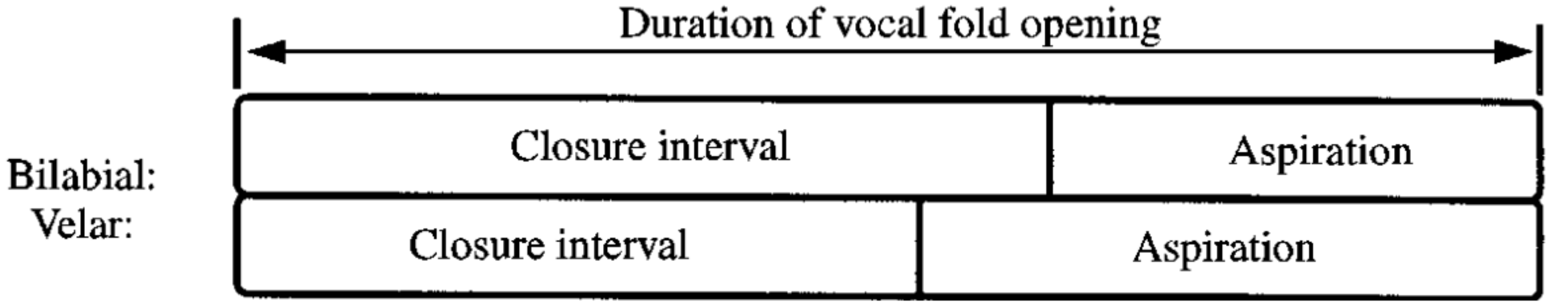


Within the phonetic grammar of a language/talker,
the phonetic targets corresponding to a phonological feature value [αF]
are (ideally) identical for all segments that are specified [αF]

Uniformity constraint

Applied to long-lag stops:

Within a language/speaker, duration and timing of glottal opening gesture relative to stop closure interval should be uniform for all stops specified [+s.g.]



Maddieson 1997, Cho & Ladefoged 1999

Uniformity constraint

Previous research on VOT: Are place differences in VOT planned or automatic / mechanistic?

Several aerodynamic and biomechanical explanations for VOT variation by place of articulation

- Volume of cavity posterior and anterior to constriction
- Movement of articulators
- Extent of articulatory contact area
- Change of glottal opening area
- Fixed duration for glottal gesture timed relative to a single point in the closure

Maddieson 1997, Cho & Ladefoged 1999

Claim that differences are automatic presupposes that, for all stops within a laryngeal series, phonetic targets for the laryngeal feature are *uniform*

Westbury & Keating 1984, Keating 1985

Uniformity constraint

Can uniformity be reduced to other known effects and constraints on phonetic realization?

Talker physiology / aerodynamics

- Cross-linguistic evidence: even within a laryngeal subcategory (e.g., long-lag), it is physically possible to produce [p^h] with a consistently longer VOT than [k^h]

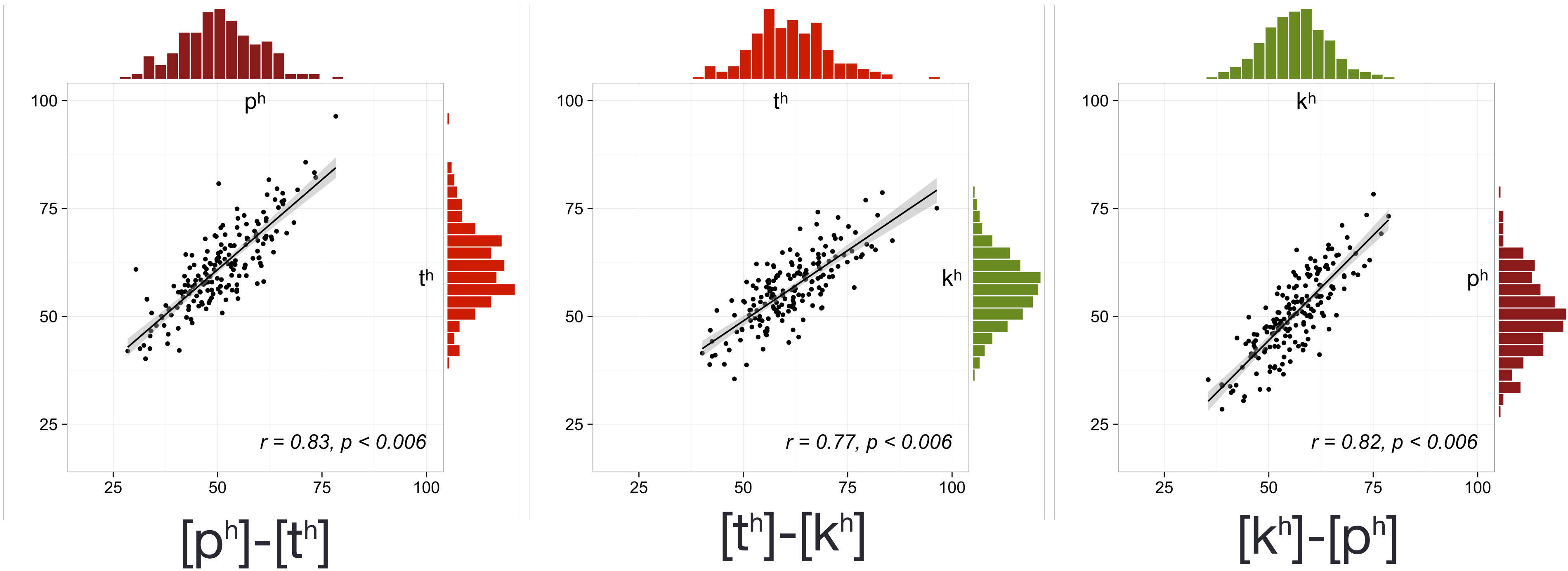
Perceptual dispersion

- VOTs of stop categories within a laryngeal series are *more similar* to one another than would be predicted by dispersion alone

Liljencrants & Lindblom 1972, Schwartz et al. 1997, Flemming 2004

Uniformity constraint

Applies strongly to languages and speakers, thereby ensuring cross-talker relational invariance / restricting individual differences



Each point = pair of VOT means (ms) for a speaker of American English

Chodroff & Wilson 2017

Summary

Strong evidence for a uniformity constraint operating on the phonetic implementation of stop consonant laryngeal features

Evidence from VOT covariation cross-linguistically
Evidence from VOT covariation across talkers of American English

Linear relation arises from underlying identity (or near-identity) in the phonetic implementation of laryngeal feature value within each series

→ Uniform duration and timing of glottal gestures (abduction and adduction) relative to supralaryngeal closure

Future directions

Role of contrast

→ Does uniformity apply as strongly to ‘unpaired’ stops as to those with in minimal laryngeal contrasts (e.g., languages with /p t k/ but /b d/)

Examine cross-linguistic patterns for other features and segments

→ Is uniformity specific to stop VOT?
Evidence from fricatives in American English and Czech
Chodroff 2017

→ Do some languages deviate from uniformity (e.g., as the result of recent sound change)?

Relate to phonological theories of feature hierarchies

→ Identify natural classes (e.g., stops) strongly bound by uniformity

Thanks to…

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