Vowels are “stretchier” than consonants

A cross-linguistic corpus study of the segmental implementation of articulation rate

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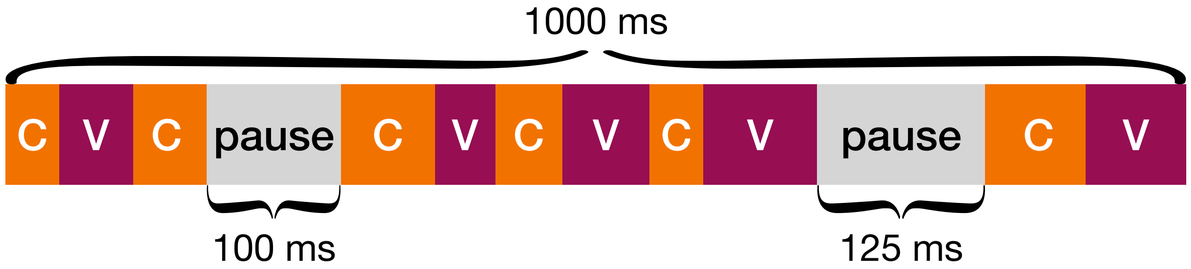
Background



- **Rate** an important aspect of within- and between-speaker variation
  - “the number of output units per unit of time”[1]
  - Speaking/speech rate: pause intervals are included = (6 C + 5 V) / 1000
  - Articulation rate: pause intervals are **not** included = (6 C + 5 V) / (1000 - pause - pause)
    (100 ms; 125 ms)
- **Articulation rate** variation is well-documented[2]
  - Almost all studies focus exclusively on English
  - Articulation rate tends to be measured at the syllable level (e.g., #syllable / time unit)
  - Articulation rate varies substantially at both global (i.e., measured over large stretches of speech) and local (i.e., measured over a single pause-free utterance) levels[3]
  - Listeners perform normalization to articulation rate at both global and local levels[4]

1 Tsao, Weisner & Iqbal, 2006
2 Wood, 1973; Port, 1981; Miller, Grosjean, Lomanto, 1984; Gay, 1978; Crystal & House, 1988; Crystal & House, 1990
3 Miller, Grosjean, Lomanto, 1984
4 Port, 1978; Plug & Smith, 2021

Background

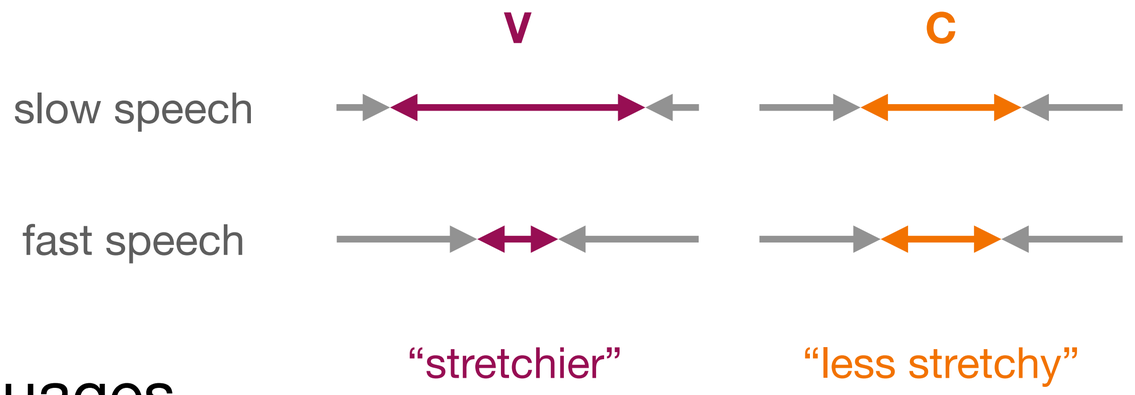
- Relatively little is known about how **segments** respond to changes in articulation rate
  - Early studies have established that both consonants and vowels are shortened at a higher rate[1]
  - Conflicting findings when consonants are contrasted with vowels
    - Change in duration that occurs with articulation rate takes place in vowels[2]
    - Constant consonant proportion (%C) at different articulation rates[3]
  - Involved explicit instructions to speak fast / slowly in a lab setting
  - Limited by the number of participants (e.g., 2 English speaker for K&C [1965];[2] 1 speaker per language in Wood [1973][3])

1 Crystal & House, 1982, 1988
2 Kozchevnikova & Chistovich, 1965; Port, 1976
3 Wood, 1973

Research Questions

- How does the duration of different types of segments vary in response to **local** changes in articulation rate?

1. Consonants vs. vowels
2. Different consonant types



- Corpus data from 7 unrelated languages
- Recordings of read / semi-spontaneous / spontaneous speech **without** instructions regarding speech rate
- At least 20 speakers per language

Methods

Dataset construction

- **American English**
  - Indo-European
  - North American Buckeye corpus
    - 40 speakers (20 f, 20 m)
    - ~40 hours of spontaneous speech in total
- **Kapampangan** / **Seoul Korean** / **Taiwan Mandarin**
  - Austronesian / Koreanic / Sino-Tibetan
  - OoPS-Lab general-purpose speech corpora
    - 20 speakers (10 f, 10 m) per language
    - ~2 hours of read speech and ~2 hours of spontaneous speech per language
- **Swahili** / **Turkish** / **Vietnamese**
  - Niger-Congo / Turkic / Austroasiatic
  - IARPA Babel program
    - 40 speakers (20 f, 20 m) per language
    - ~6.5 hours of spontaneous conversational telephone speech per language

Methods

Dataset construction: OoPS-Lab general-purpose speech corpora

- Languages included so far: Cebuano, French, Kapampangan, Seoul Korean, Taiwan Mandarin
- 20 speakers per language
  - 5 younger female + 5 younger male speakers (20 - 30 years)
  - 5 older female + 5 older male speakers (50+ years)
- Recordings made online on participants' own devices
- Read speech (short essay) + prompted semi-spontaneous monologue

Methods

Data annotation and management

- OoPS-Lab data transcribed manually by native speakers of respective languages
- With the exception of the English data, all speech was forced-aligned with the Montreal Forced Aligner[1]
- Duration data managed and extracted using PolyglotDB[2]
- Statistical models and visualization carried out in R

1 McAuliffe et al., 2017a
2 McAuliffe et al., 2017b

Methods

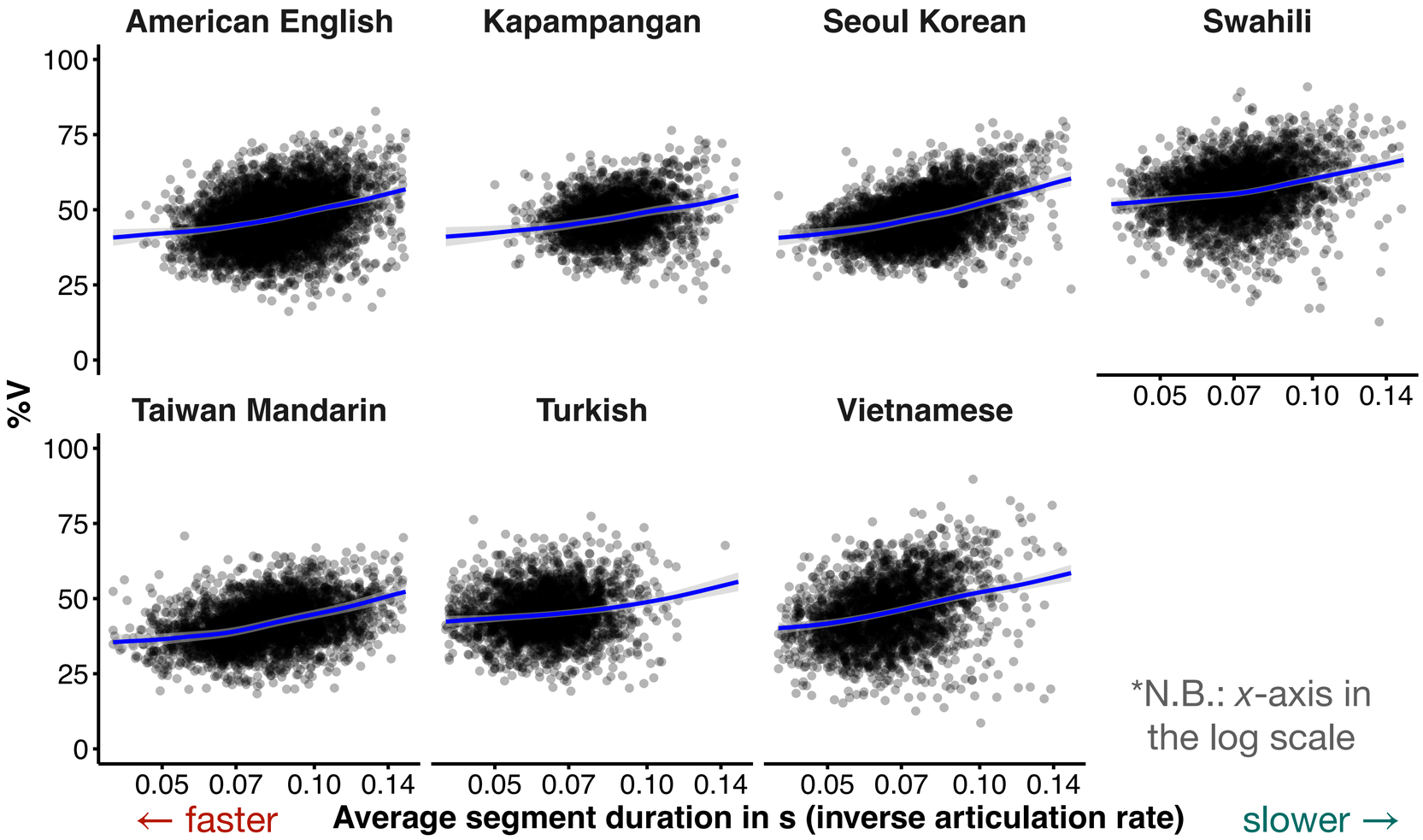
Data annotation and management (cont.)

- Recordings first parsed into utterances
  - Utterances defined as speech segments bounded by non-speech intervals of > 150 ms
- Measurements
  - Local articulation rate := #segments / (utterance duration – non-speech)
  - Average segment duration = 1 / local articulation rate

    ⇒ higher average segment duration → slower speech
- Utterance inclusion criteria
  - More than 5 syllables
  - An average segment duration between 40 ms and 250 ms
  - Log average segment duration that is within ±3 SD of mean log average segment duration over all utterances across languages
  - Total: A. English: 4,930; Kapampangan: 2,487; S. Korean: 4,259; Swahili: 2,893; T. Mandarin: 3,158; Turkish: 2,453; Vietnamese: 2,329

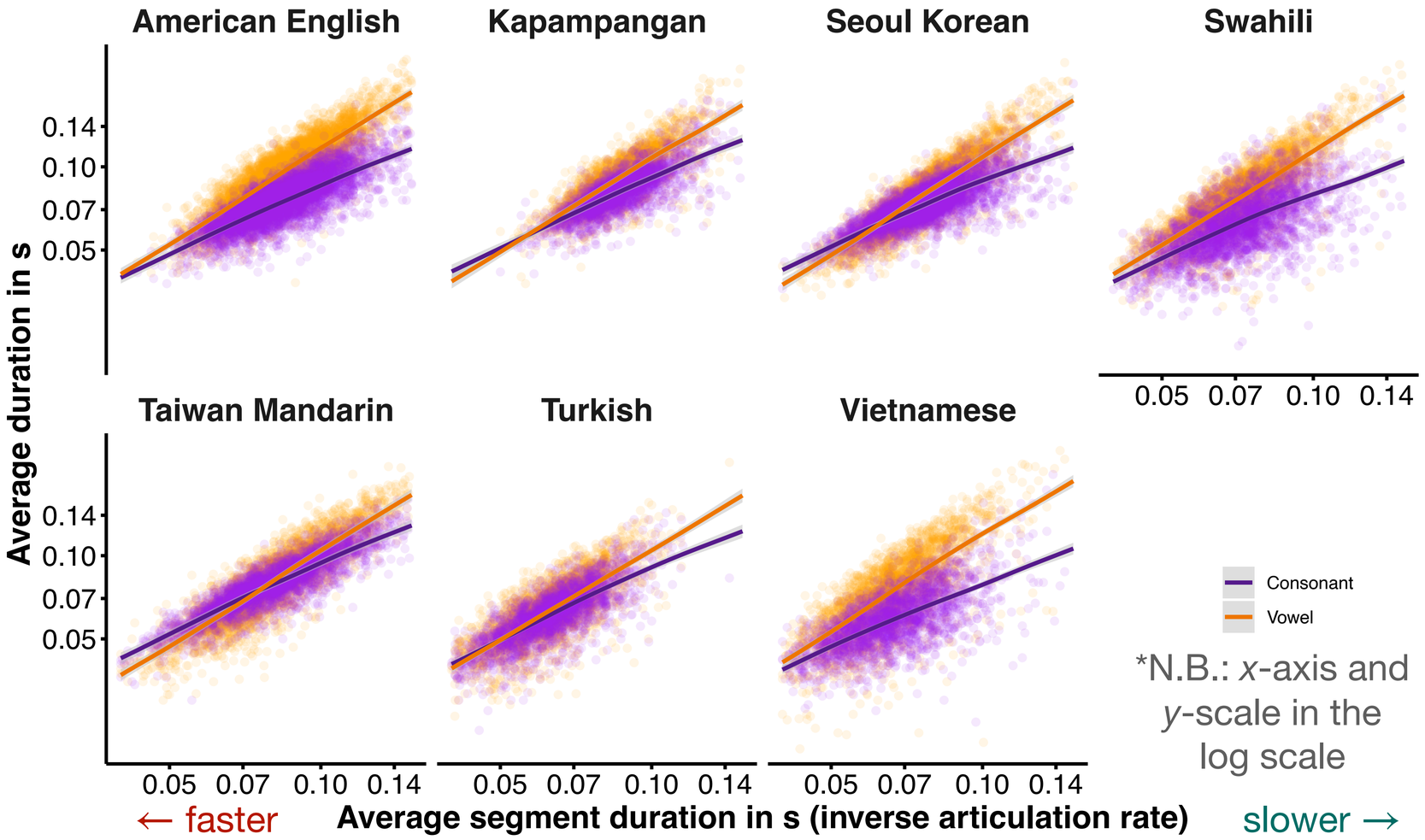
Results

- %V (duration percentage of vowels among all segmental material)
  - Analyzed with a generalized additive mixed model (GAMM; Wood, 2017): %V ~ s(log art. rate)
  - Random smooths by speakers and languages
- %V goes up as speech slows down



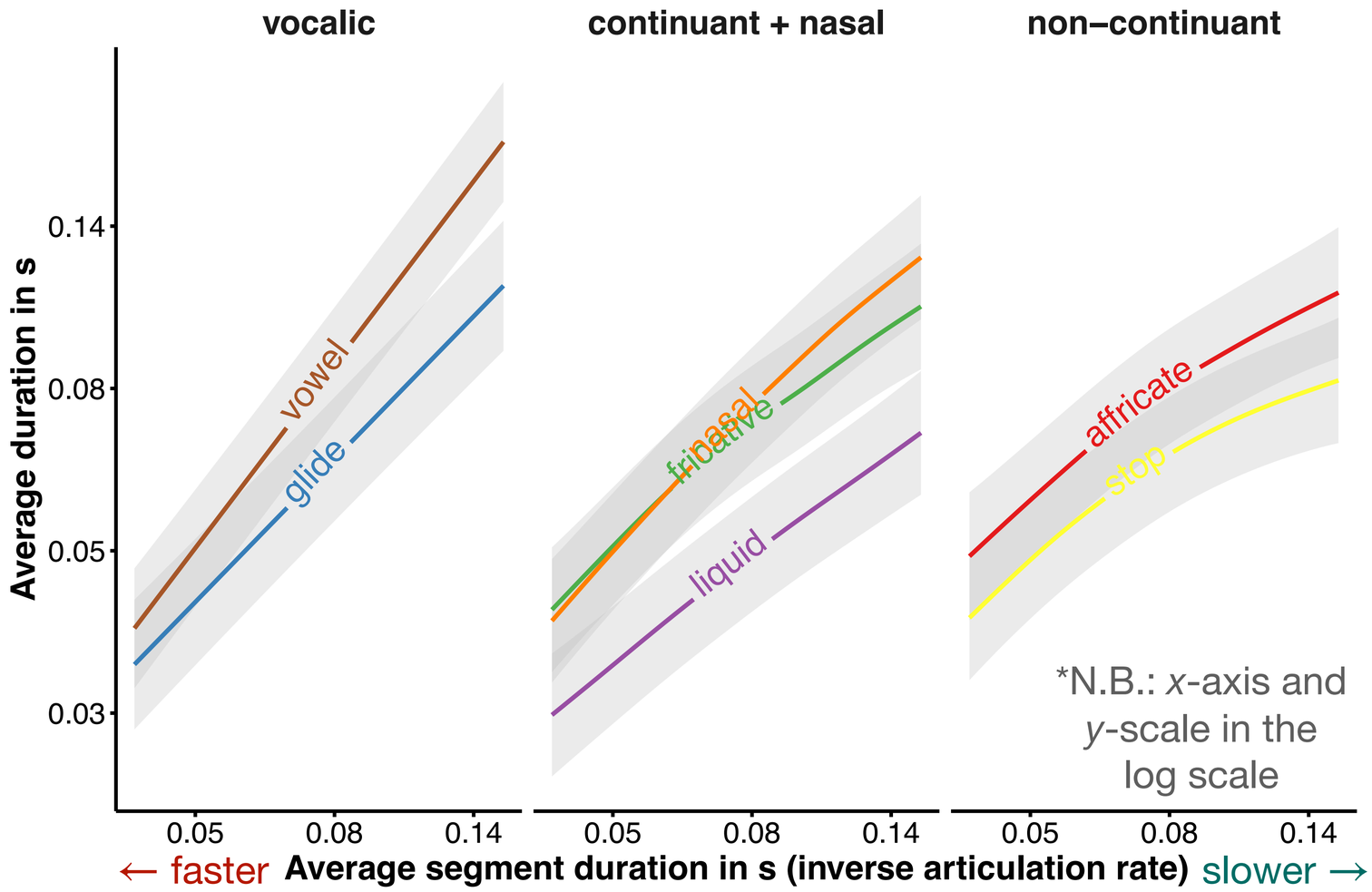
Results

- Average C and V duration
  - GAMM: log avg. dur. ~ seg. type + s(log art. rate, by = seg. type)
  - Random smooths by speakers and languages
- Vs undergo greater duration adjustment than Cs
  - Fast: Vs same or shorter than Cs
  - Slow: Vs up to 1.5x longer than Cs



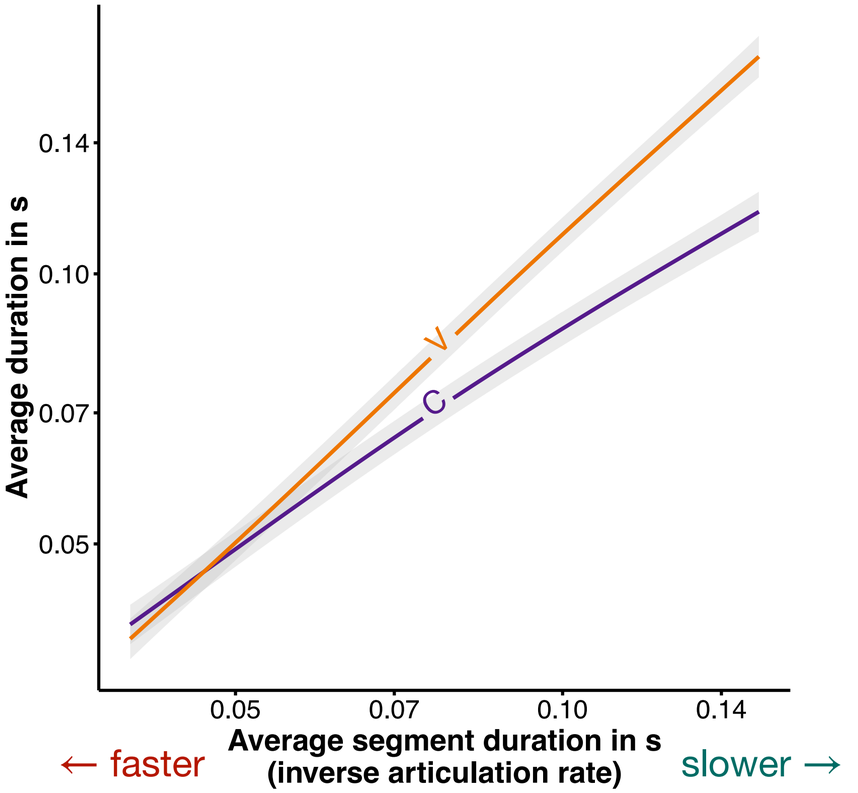
Results

- Average duration of different C types
  - GAMM: log avg. dur. ~ C type + s(log art. rate, by = C type)
  - Random smooths by speakers and languages
- Duration of non-continuants vary less than continuants
  - Vs still stand apart



Summary and Discussion

- Across all languages, vowels are “stretchier” than consonants
  - Agree with Kozchevnikova and Chistovich (1965) and Port (1976)
- Different consonant types (in particular, continuant vs. non-continuant) display different stretchiness
- “Stretchiness” of a segment primarily determined by its temporal and aerodynamic characteristics
- Future direction
  - Interactions with segment reduction / deletion (e.g., vowels might be more resistant to deletion due to their temporal flexibility)
  - Rate perception by varying vowel and consonant durations
  - Implications for sound change (e.g., vowel length contrasts more likely to arise than consonant ones)



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