Vowels are “stretchier” than consonants

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

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Background

- **Rate** is an important aspect of within- and between-speaker variation
  - Rate := “the number of output units per unit of time” (Tsao, Weisner & Iqbal, 2006)
  - Speaking/speech rate: pause intervals are included
  - Articulation rate: pause intervals are **not** included
- Articulation rate variation is well-documented (e.g., Wood, 1973; Port, 1981; Miller, Grosjean, Lomanto, 1984; Gay, 1978; Crystal & House, 1988; Crystal & House, 1990)
  - 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 (Miller, Grosjean, Lomanto, 1984)
  - Listeners are sensitive to articulation rate at both global and local levels (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 (Crystal & House, 1982, 1988)
  - Conflicting findings when consonants are contrasted with vowels
    - Change in duration that occurs with articulation rate takes place in **vowels** (Kozchevnikova & Chistovich, 1965; Port, 1976)
    - Constant consonant proportion at different articulation rates (Wood, 1973)
  - 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]; 1 speaker per language in Wood [1973])

Research Questions

- How does the duration of different types of segments vary in response to **local** changes in articulation rate?
  - By comparing [1] consonants vs. vowels, and [2] among different consonant types (e.g., stops, fricatives, etc.)
  - With corpus data from seven unrelated languages
  - Using recordings of read / semi-spontaneous / spontaneous speech **without** instructions regarding how fast / slowly they should talk
  - 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 young female + 5 young male speakers (20 - 30 years)
  - 5 old female + 5 old male speakers (50+ years)
- Recordings were made online on participants' own device
- Read speech from reading a short essay + prompted semi-spontaneous monologue

Methods

Data annotation and management

- OoPS-Lab data was 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 (McAuliffe et al., 2017a)
- Duration data managed and extracted using PolyglotDB (McAuliffe et al., 2017b)
- Statistical models and visualization carried out with R

Methods

Data annotation and management (cont.)

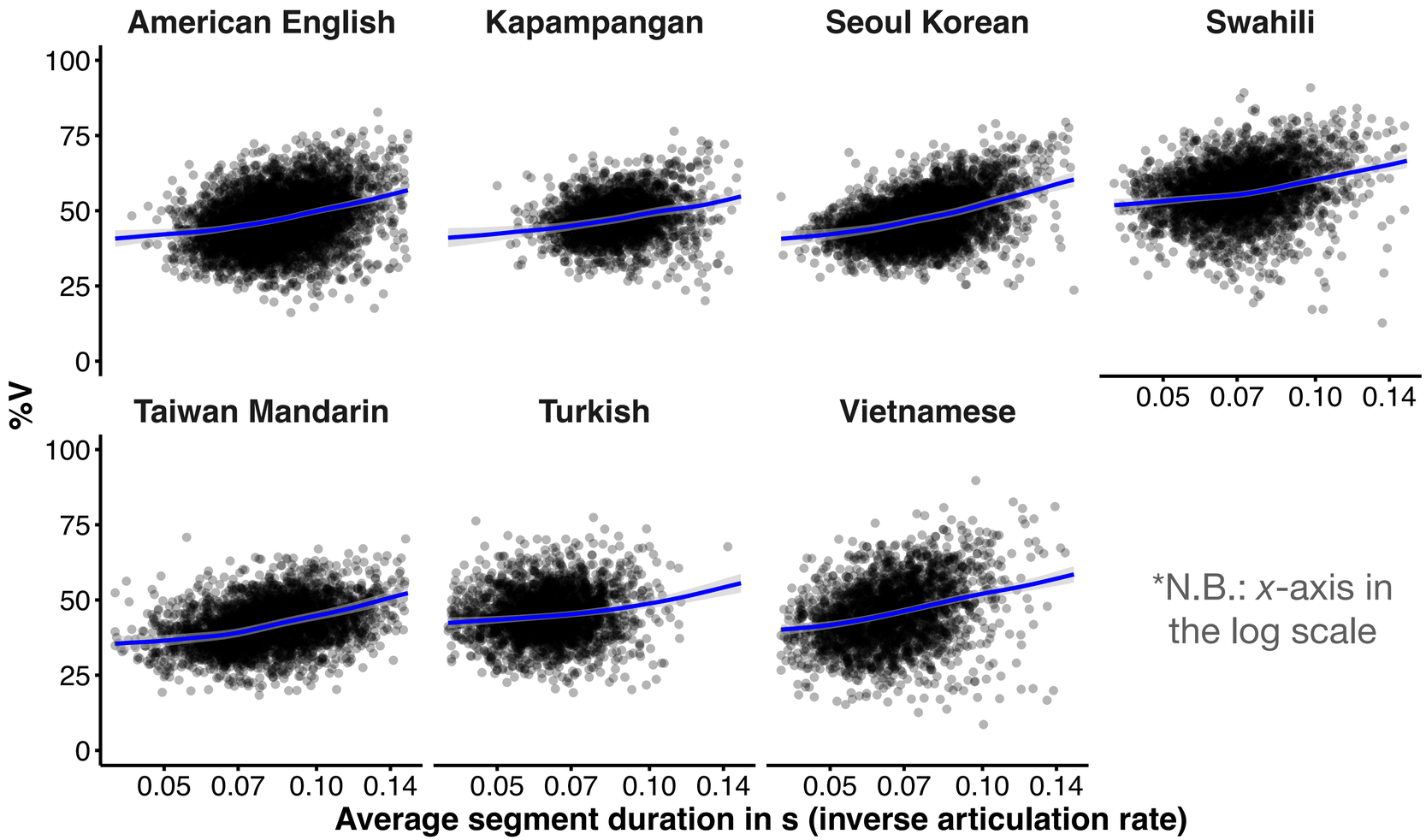
- Recordings were first parsed into utterances
  - Utterances defined as speech segments bounded by non-speech intervals of > 150 ms
- Measurements
  - Local articulation rate := segment rate within each utterance = #segments / utterance duration
  - Average segment duration = 1 / local articulation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

  ⇒ higher average segment duration → slower speech
- Utterance inclusion criteria
  - Had more than 5 syllables
  - Had an average segment duration between 40 ms and 250 ms
  - Had a log average segment duration that is within ±3 SD of mean log average segment duration over all utterances across languages
  - In total, A. English: 4,930; Kapampangan: 2,587; S. Korean: 4,259; Swahili: 2,893; T. Mandarin: 3,158; Turkish: 2,453; Vietnamese: 2,329

Methods

Analyses and 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)
  - With radon smooths by speakers and languages
- Vowels accounts for more and more portion as speech slows down

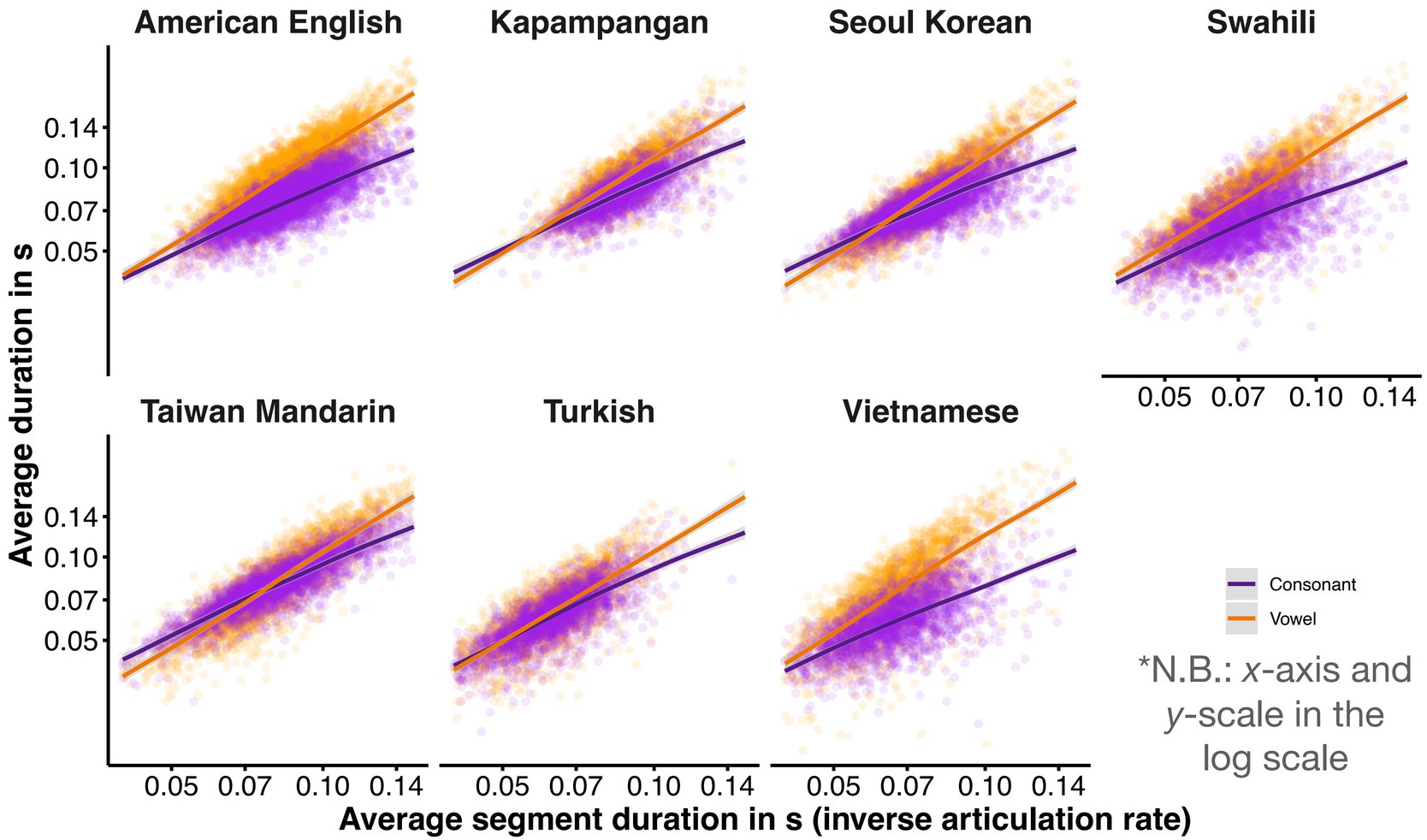


*N.B.: *x*-axis in the log scale

Methods

Analyses and results (cont.)

- Average C and V duration
  - GAMM: log avg. dur. ~ seg. type + s(log art. rate, by = seg. type)
  - With radon 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

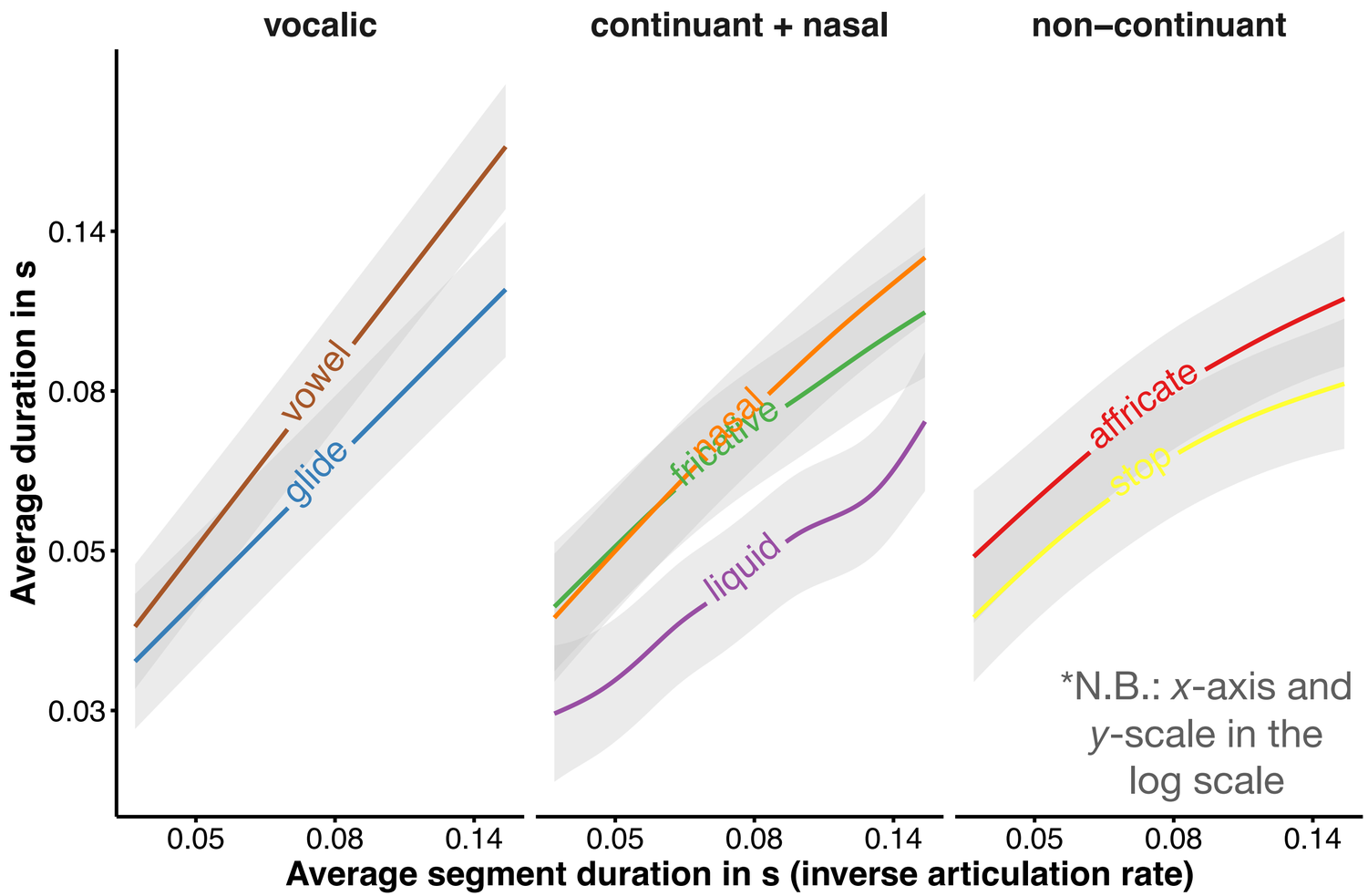


*N.B.: *x*-axis and *y*-scale in the log scale

Methods

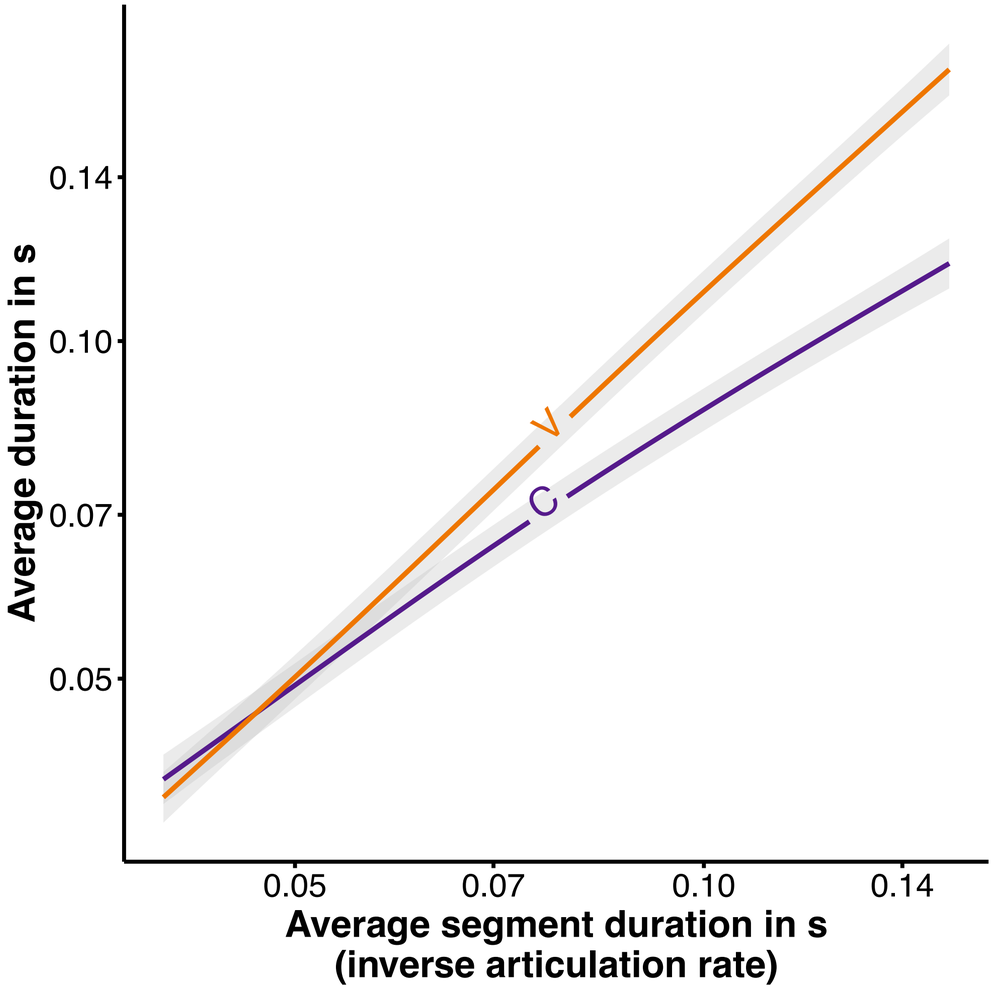
Analyses and results (cont.)

- Average duration of different C types
  - GAMM: log avg. dur. ~ C type + s(log art. rate, by = C type)
  - With radon 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 distinct stretchiness
- "Stretchiness" of a segment is primarily determined by its temporal and aerodynamic mechanism
- Future direction: rate perception by varying vowel and consonant durations



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