Long-lag oro-laryngeal timing in onsets is a perceptual cue to voicing in codas

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Introduction

- Vowel duration is famously correlated with the voicing status of the following consonant, an effect found in unrelated languages [1] → longer vowel duration when following C is phonologically voiced than voiceless
- Stressed vowel duration is also positively correlated with preceding oro-laryngeal timing → long vowels correspond to long voice-onset time (VOT) in onset Cs [3]
- Combining the coda voicing and oro-laryngeal timing facts we make the prediction that onset VOT is longer when the coda consonant is voiced
    - Indeed, previous research has found this result in a small study of oral stops [6] and liquid codas [2]

Research goals

1) Can the coda-voicing effect on onset oro-laryngeal timing be replicated with a larger sample size in Canadian English?

- *What is the nature of this effect and how can we explain it in terms of biomechanical constraints?*

2) What is the perceptual import of the effect of coda voicing on onset long-lag oro-laryngeal timing?

- *Can listeners predict coda voicing from only variation in onset aspiration? → what does this imply for our understanding of phonetic knowledge and long-distance perceptual cues?*

EXPERIMENT 1: Production

Methods

- Speakers of Canadian English (*n*=20) participated in the speech production task
- Speakers recorded individually in sound-attenuated booth with high-quality microphone at 44.1kHz

Materials

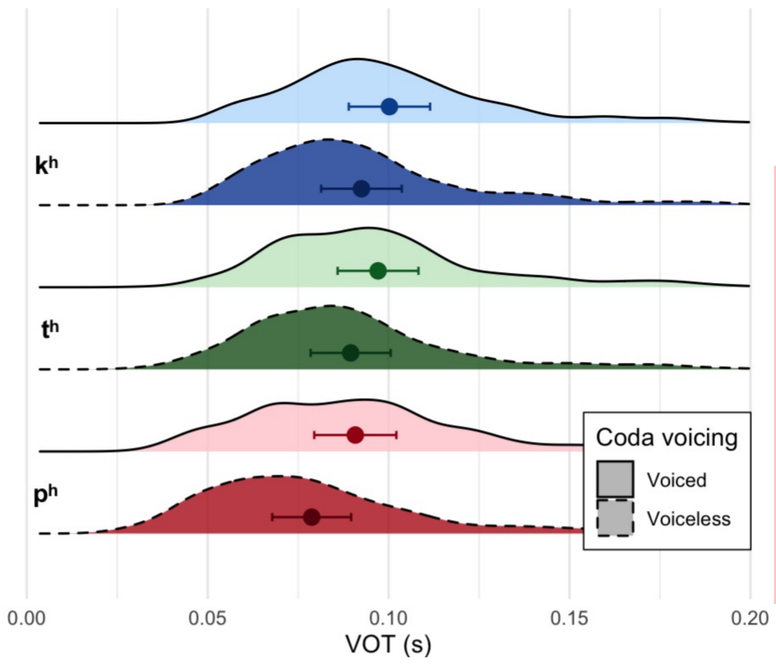
- Real English monosyllabic words (C_1VC_2) embedded in the sentence, "Say the word__quickly."
- C_1={p,t,k}, V={æ,ʌ,ɔ,ɪ,ɛ}, C_2={p,t,k,b,d,g}; All real-word combinations of C_1VC_2 were included → "pack, tug, cod," etc.
- Target words were randomized in a list with non-target monosyllables and recorded twice by each speaker

Measurements

- Measurements on target words extracted (*n*=2376) taken by phonetically trained researchers:

VOT: duration between onset of transient burst noise of plosive release and periodic oscillation of following vowel
Vowel duration: duration of periodic oscillation before coda closure

Coda-voice effects on onset oro-laryngeal timing?

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VOT ~ Onset_POA * Coda_voice + (1|subject) + (1|word)
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- VOT increases with coda voicing (*t*=3.94)
- Diff between Ons VOT (coda[+vc]) vs. Ons VOT (coda[-vc]) ~ 12ms
- Effect is likely result of automatic aerodynamic adjustment necessary for increased vowel duration for coda voicing

Proportional expansion of CV gesture?

Is the VOT ratio (VOT/Vdur) the same in both coda voice contexts? VOT ratio: Coda[+vc] = 0.65; Coda[-vc] = 0.88 → Increase in CV duration before voiced codas in primarily due to vowel expansion; suggesting that VOT increase is automatic and not controlled

EXPERIMENT 2: Perception

Are listeners aware of the long-distance relationship between aspiration duration and coda voicing? → Can listeners predict coda voice from onset aspiration?

VOT duration difference of ~12ms in the 75-100ms aspiration band falls below the threshold of perceptibility → Weber's law for VOT? [4] → Test with endpoints of the long-lag continuum

Methods

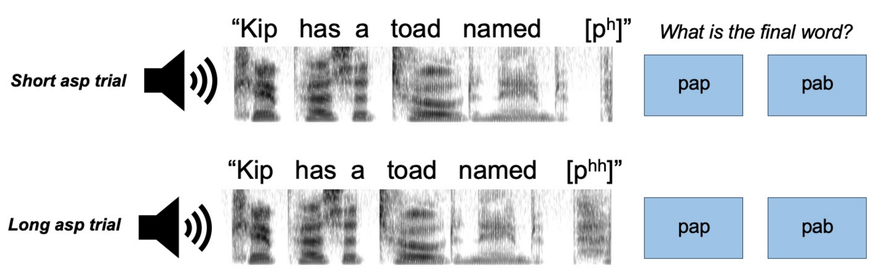
- Canadian English listeners (*n*=26) (in lab) guess the final consonant of a non-word after hearing *only* **short** or **long** aspiration

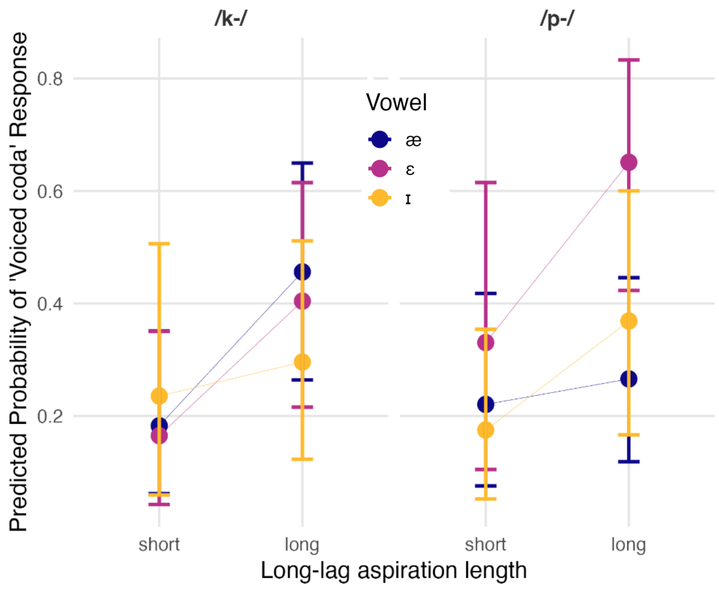
Stimuli

- Targets were burst transient + aspiration + 3 glottal cycles
- *p* targets: **[pʰ]** (25ms), **[pʰʰ]** (125ms); *k* targets: **[kʰ]** (50ms), **[kʰʰ]** (150ms)
- Aspiration from real words with V={æ, ɪ,ɛ} (e.g., pat/pad, cap/cab)
- Targets were embedded in a sentence in final position

2AFC Task

- Listeners hear a sentence with a final target and given two non-word choices (e.g., <pap> or <pab>)



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Coda_vc ~ Onset_POA * Asp_length * Vowel + (1+ Asp_length | Subject)
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- Short aspiration reduces probability that listeners guess that coda is voiced (*z*= -2.13)
- Effect is greater in [ɛ] context relative to the reference [æ] (*z*=2.82)

Discussion

Long-lag VOT variability and coda voicing

- Clear and consistent effect of coda voicing on onset oro-laryngeal timing, replicating previous report of the effect
- Aerodynamic source for longer aspiration duration before voiced stops? → oral volume is greater before voiced stops due to passive larynx lowering to support transglottal pressure differential [5]→ longer time for positive pressure air in larger oral cavity to be equalized with ambient pressure relative to smaller oral cavity
- The increase in VOT may be related to greater *articulatory force* accompanying the implementation of the long vowel preceding the voiced coda consonant [6]
- The effect is small and below the threshold of discriminability and suggests that the process is *automatic* and uncontrolled, unlike the short/long aspiration characterizing word/syllable-initial plosive voicing

Listener knowledge of aspiration duration and coda voicing

- 100ms difference between aspiration durations significantly affected listeners prediction of coda voicing → long aspiration leads to greater "voiced" coda responses
- While the effect is not comparable to aspiration as a primary perceptual cue to onset plosive voicing, the results suggest that listeners *know* that increased aspiration in onsets is a characteristic of the articulatory effort required to implement a long vowel
- Perception results suggest that listeners' phonetic knowledge includes long-distance (by proxy) effect of coda voicing emerging as a sub-phonemic cue in word-onset plosives

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