Auditory feedback is used for both online and adaptive control of timing in speech

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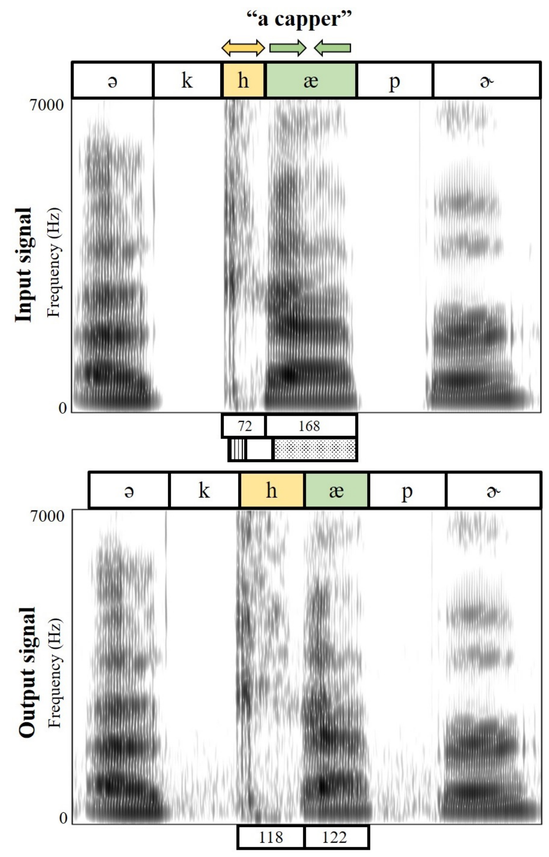
Introduction

The main questions addressed in this study are: Does adaptation differ between relative timing and absolute timing? Is speech timing assessed and controlled via the duration of individual segments, or proportional timing within a larger unit?

- Auditory feedback is used to update forward models of speech motor commands, both in the spectral[3;12;5;2] and the temporal domains
- It is unclear what the limits on temporal adaptation are in speech; some studies have found that speakers adapt the timing of syllable onsets[9], while others have found that only segments in the rime show adaptive behavior[10;4]
- It is also unclear how speech timing is processed and controlled:
  - How does speech timing map to the divide between absolute timing of single events vs. the relative timing of multiple events[14;7;6]?
  - Do speakers attend to the proportional duration of segments in higher prosodic units, or the ms duration of any individual segment[8;11]?

Methodology

- Four target words:
  - Relative timing (VOT): "a **c***a*pper" "a **g***a*pper"*
  - Absolute timing (fricative duration): "a **s***a*pper" "a **z***a*pper"
  - Stressed vowel in each word also absolute timing candidate
- Consonant targets were lengthened and vowel targets were shortened using Audapter[1]
- 20 participants repeated each target word 150 times, in four phases: Baseline (30 trials), Ramp (30), Hold (60), Washout (30)
- Compared[13] production in hold, early washout, and late washout phases to baseline productions



Results: Adaptation in duration of vowel; proportion of consonant target

Consonant target: no adaptation

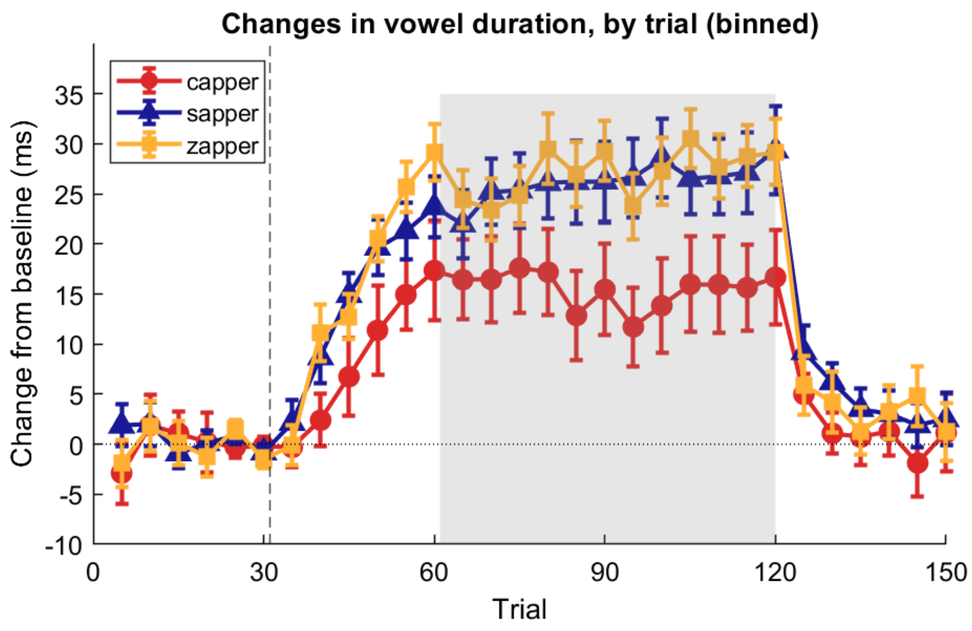
- Participants did not adapt their productions of consonant targets (hold not different from baseline, p = 0.51)
- No difference in adaptation between words ($\chi^2(2) = 2.59$, p = 0.27)

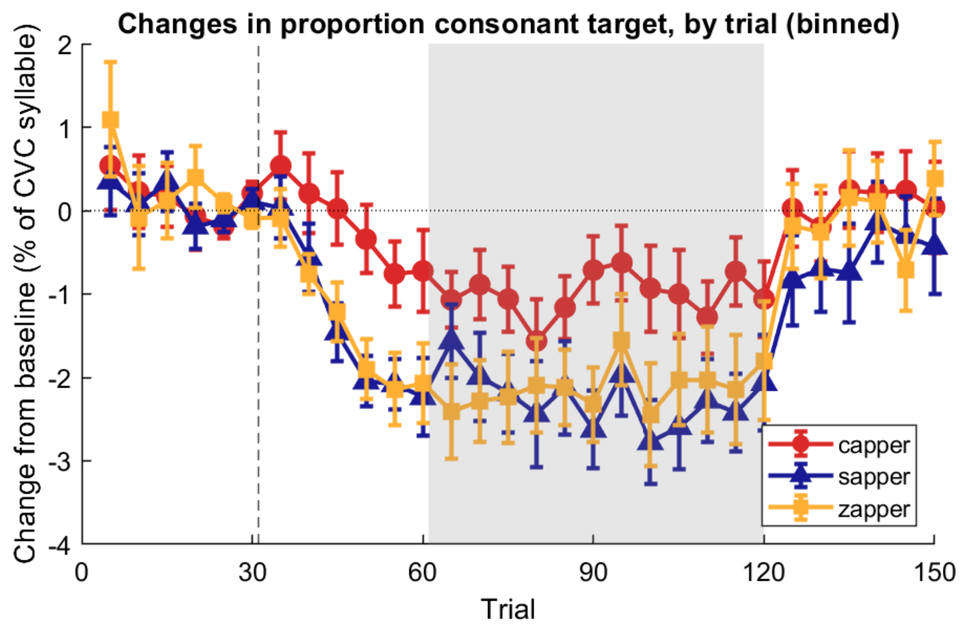
Vowel target: compensation and adaptation

- Participants adapted their productions of vowel targets ($\chi^2(3) = 801.11$, $p < 0.0001$)
- Vowels significantly longer during hold phase by ~80% of perturbation; also remained significantly longer during early washout

Adaptation in consonant target as proportion of CVC syllable

- Consonant target occupies lower proportion of first syllable during hold phase ($\chi^2(3) = 127.24$, $p < 0.0001$), effectively shortening it relative to the rest of the syllable
- Indicates that vowel length difference was not just a speech rate change (initial "a" also unchanged from baseline to hold, $p > 0.17$)
- Suggests that people may attend to proportional duration within larger units rather than absolute duration of particular segments





Discussion

- Speakers adapted the duration of segments only in the rime, aligning with recent research[10]
- Study lends support to the idea that speakers attend to proportional durations, not raw durations[8;11]
  - Difference in response magnitude between hold and early washout phases suggests both compensation and adaptation at work in hold, but how?
  - If using proportions: hear that consonant was longer than expected, compensate by increasing the vowel duration
  - Also hear that vowel shorter than expected and adapt; learning carries over into early washout
- Additional research needed:
  - Why are vowels more amenable to adaptation? Perhaps stiffness, or different mapping of neural timing types[10]
  - How does proportional control interact with absolute vs. relative timing?

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