Chunking in the production of tap/flap sequences

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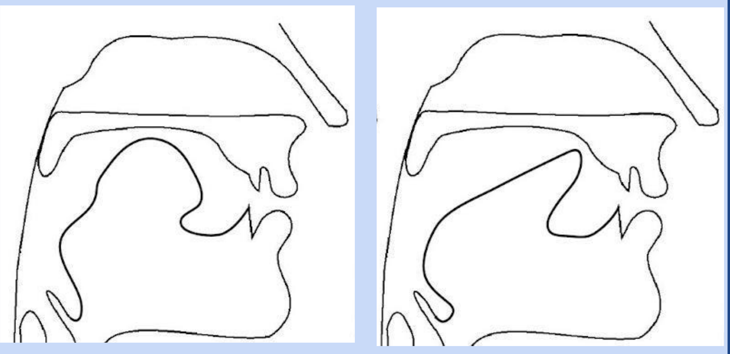
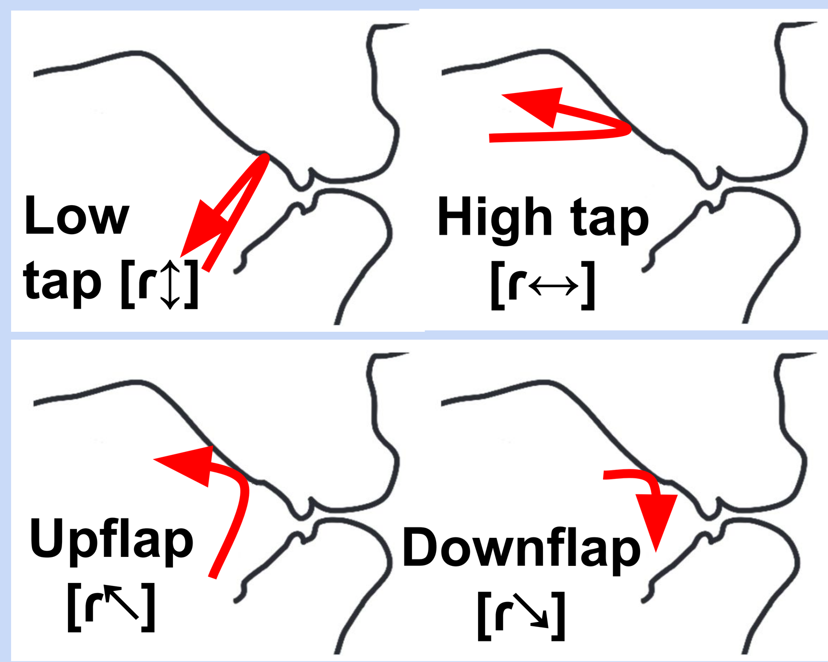
1. Categorical variation in two English sounds

Rhotics



Taps/flaps



2. Gait change in tap/flap sequences [1,2]

Input: /VTVTV/ (e.g. 'edit a')

North American English (NAE) - gait change

[V_Lɾ↕V_Lɾ↕V_L] → (Faster speech rate) [V_Lɾ↖V_Hɾ↘V_L]

New Zealand English (NZE) - no gait change

[V_Lɾ↕V_Lɾ↕V_L] → (Faster speech rate) [V_Lɾ↕V_Lɾ↕V_L]

3. Why doesn't NZE show gait change? [2]

Rhotic vowels induce variability in adjacent taps based on mechanical ease [8]

'Berta': [ɹɾ↘] 'Otter': [ɾ↖ɻ] 'Murder': [ɹɾ↔ɹ], [ɹɾ↖ɻ], …

Chunking: more efficient to reuse highly-practiced movement patterns than to compute new ones [3,4, 5, 6, 7]

NAE has rhotic vowels

- Speakers build a repertoire of diverse strategies (chunks)
- **Speakers draw from this repertoire in new contexts**

NZE does not

- Speakers learn fewer strategies (chunks)
- **Speakers' repertoire of strategies is limited**

NAE: [V_L ɾ↖] ɻ [ɾ↘ V_L] — Saturday → [V_L ɾ↖] V_H [ɾ↘ V_L] — edit a (**chunk reuse in new context**)

NZE: V_L ɾ↕ V_L ɾ↕ V_L — Saturday; V_L ɾ↕ V_L ɾ↕ V_L — edit a

4. Simulation study

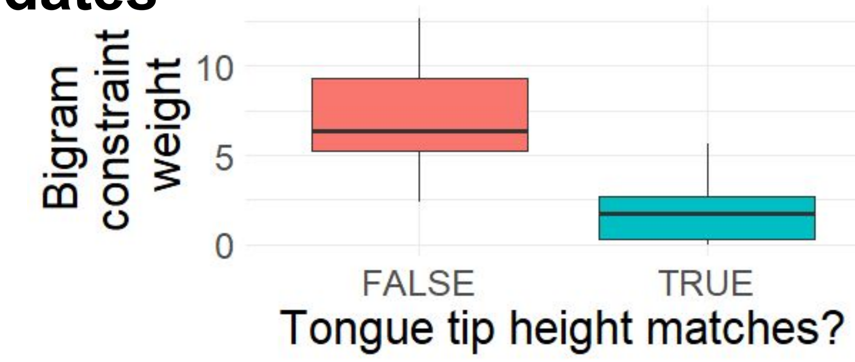
Integrating the concept of chunking into a model that learns to produce tap/flap sequences qualitatively replicates the differences between NAE and NZE speakers

Basic model

Implemented in maximum entropy optimality theory [9]

- Uses **weighted constraints** to generate **probability distributions over candidates**

/V/ → [V_L, V_H]
/R/ → [ɹ, ɻ]
/T/ → [ɾ↕, ɾ↖, ɾ↘, ɾ↔]



Markedness constraints:

- all unigram (e.g. *ɾ↔) and bigram (e.g. *ɾ↖V_L) constraints
- Weights fit to frequencies from ultrasound study [8]

Constraints for chunking - weights set by hand

- **UseListed:** Violation is sum of costs of all chunks in form
  - Chunk cost decreases as its usage frequency increases
- **Share**: One violation per chunk

NAE input: {VTV, VTVTV, VTVTVTV, VTR, VTVTR, RTV, …}
NZE input: {VTV, VTVTV, VTVTVTV}

Outputs: Chunked candidates ("|" = chunk boundary)
[V_Lɾ↕V_Lɾ↕V_L], [V_Lɾ↕|V_Lɾ↕V_L], [V_L|ɾ↕|V_L|ɾ↕|V_L], [V_Lɾ↖V_Hɾ↘V_L], …

Starting chunk inventory: {V_L, V_H, ɹ, ɻ, ɾ↕, ɾ↖, ɾ↘, ɾ↔}

Part 1: Chunk learning

Sample input → /VTV/ → Compute probabilities using grammar →

[V_Lɾ↕V_L]	0.95
[V_L|ɾ↕V_L]	0.03
[V_L|ɾ↕|V_L]	0.01
…	…

→ Sample output → [V_Lɾ↕V_L] → Update chunk inventory, Including sub-chunks →

V_Lɾ↕V_L += 1,
V_Lɾ↕ += 1
ɾ↕V_L += 1
…

x10,000

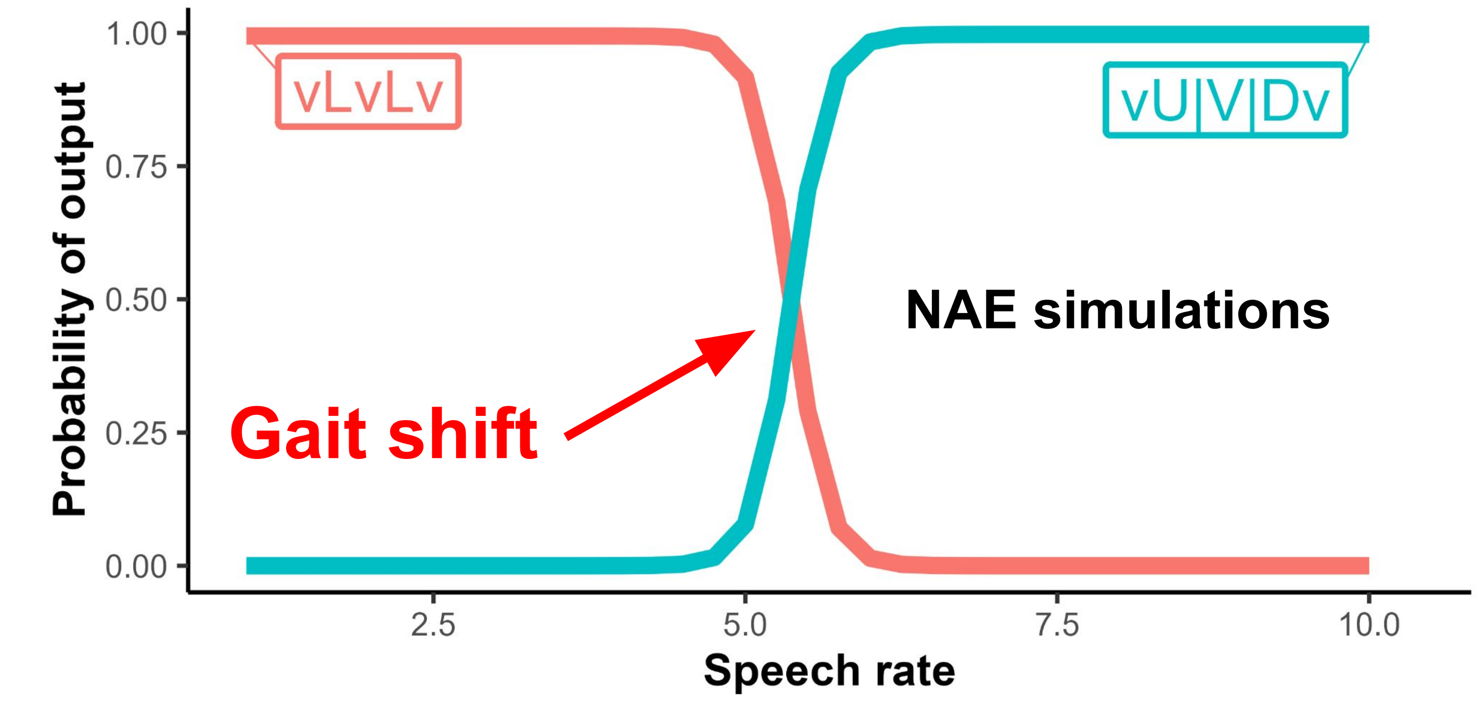
Part 2: Productions under different speech rates

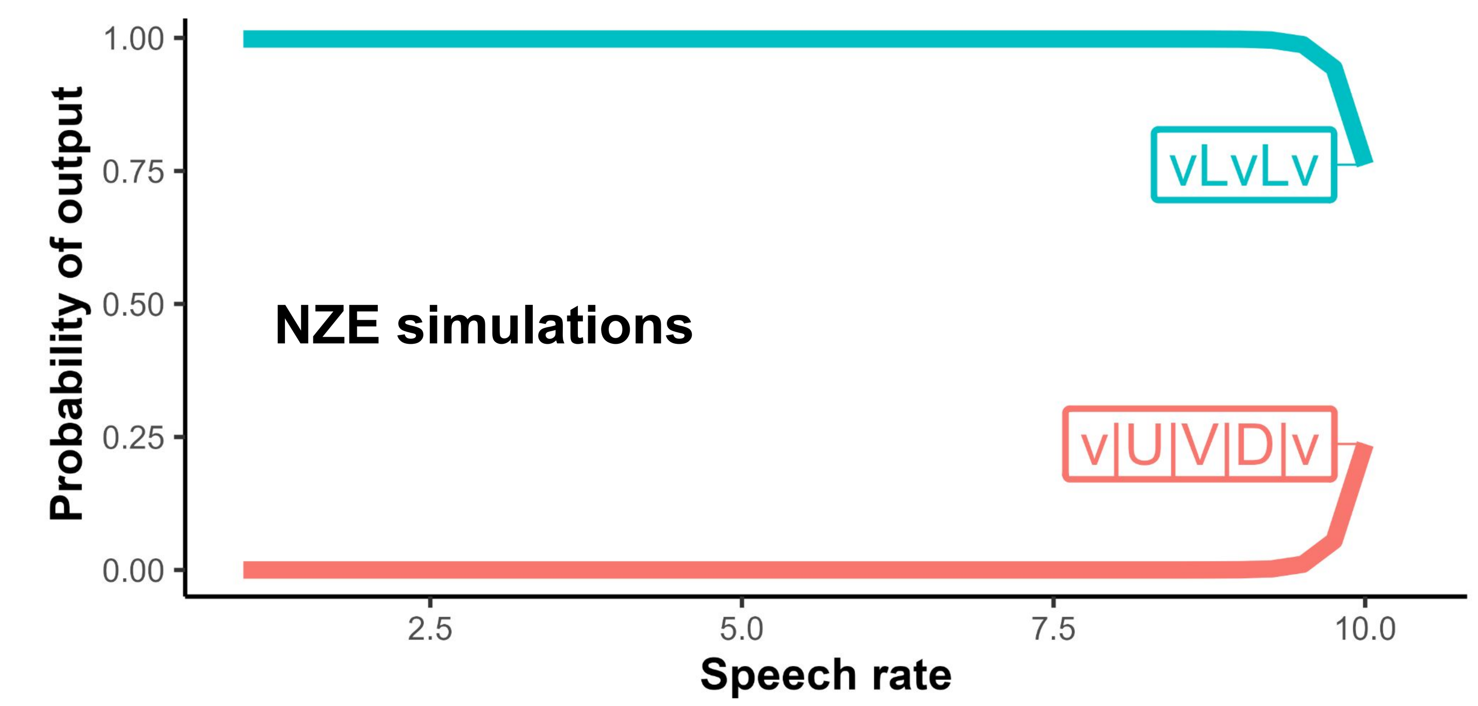
/VTVTV/ → Compute probabilities using grammar and chunk inventory; Scale bigram constraint weights up as speech rate increases (cf. [10]) →

[V_Lɾ↕V_Lɾ↕V_L]	0.75
[V_Lɾ↕|V_Lɾ↕V_L]	0.004
[V_Lɾ↖V_Hɾ↘V_L]	0.20
…	…

Rates: [1, 1.25, 1.5, …, 9.5, 9.75, 10]

5. Simulation results





6. Discussion

NAE speakers undergo gait shift because they can repurpose existing chunks in new contexts

- **Chunks learned in rhotic contexts can be deployed in non-rhotic contexts**

NZE speaks have a more limited chunk repertoire

- **Not as flexible in their production strategies**

Considering phonology from an **embodied perspective** provides substantive insights into phonological patterns

- **Speech production is not optimal**, but includes the reuse of frequently produced movements
- May provide substantive account of some frequency and paradigm uniformity effects

References. [1] Derrick, D., & Gick, B. (2021). Gait change in tongue movement. Scientific Reports, 11(1), 16565. [2] Derrick, D., Mayer, C., & Gick, B. (2024). Uniformity in speech: The economy of reuse and adaptation across contexts. Glossa: a journal of general linguistics, 9(1). [3] Verwey, W. B. (2001). Concatenating familiar movement sequences: The versatile cognitive processor. Acta psychologica, 106(1-2), 69-95. [4] Abrahamse, E. L., et al. (2013). Control of automated behavior: insights from the discrete sequence production task. Frontiers in human neuroscience, 7, 82. [5] Keating, P. (2003, August). Phonetic and other influences on voicing contrasts. ICPhS 15 (pp. 20-23). [6] Chodroff, E., & Wilson, C. (2017). Structure in talker-specific phonetic realization: Covariation of stop consonant VOT in American English. Journal of Phonetics, 61, 30-47. [7] Faytak, M. D. (2018). Articulatory uniformity through articulatory reuse: insights from an ultrasound study of Sūzhōu Chinese. University of California, Berkeley. [8] Derrick, D., & Gick, B. (2011). Individual variation in English flaps and taps: A case of categorical phonetics. Canadian Journal of Linguistics/Revue canadienne de linguistique, 56(3), 307-319. [9] Goldwater, S., & Johnson, M. (2003). Learning OT constraint rankings using a maximum entropy model. In Proceedings of the workshop on variation within Optimality Theory (pp. 111-120). [10] Coetzee, A. W. (2016). A comprehensive model of phonological variation: Grammatical and non-grammatical factors in variable nasal place assimilation. Phonology, 33(2), 211-246.