From Gestural Landmarks to Analysis-by-Synthesis: Tone-driven Gestural Timing in Tibetan

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Introduction

- Aim 1: Use simulation to test the hypothesis that **tone gestures** affect timing of oral articulatory gestures
- Aim 2: Provide proof-of-concept for testing **temporal coordination** with articulatory simulation in TADA

Simulating articulation in the Task Dynamics Application

- TADA: "TAsk Dynamics Application" [5]
- Words + gestural dictionary + syllable structure → gestural score
  gestural score → articulatory trajectories → acoustics
- Highly-parameterized model can be edited at any stage

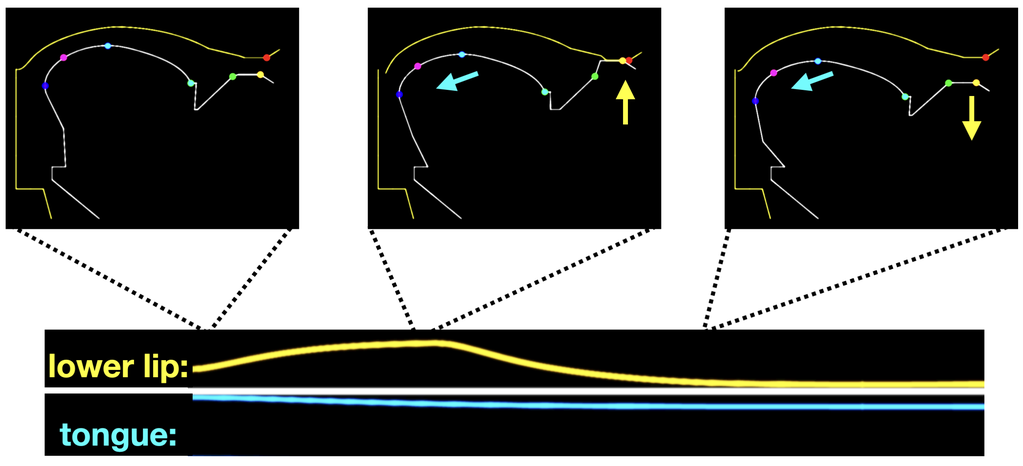
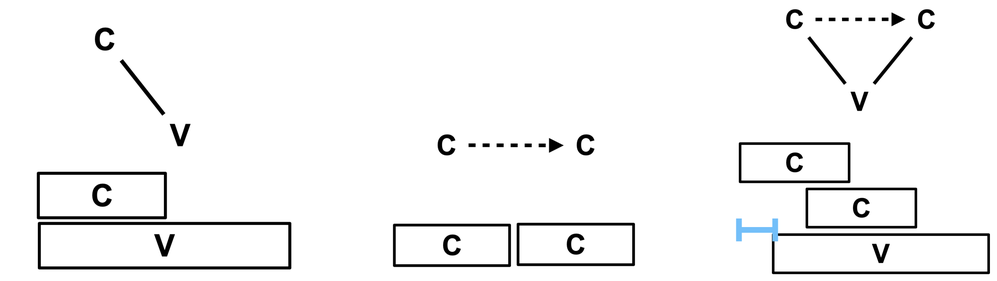


Figure: Simulated articulatory trajectories of lower lip and tongue dorsum in [ma], with in-phase coupling

Coupling modes and tone gestures

- Representations in Articulatory Phonology
  - Gestures: constriction degree, constriction location, duration
  - Coupled Oscillator Model of Syllable Structure
  - Task Dynamics: how implement gestures in movement
- Gestures self-organize according to coupling modes: **in-phase** / synchronous, **anti-phase** / sequential. Combining gestures in **competitive coupling** results in partial overlap; explains "C-Center" effects [5].



(a) In-phase coupling C-V; T-V?

(b) Anti-phase coupling: C-C, V-V, V-C

(c) Competitive coupling: CCV; CTV?

- Tone gestures: in lexical tone languages, CV syllables have timing reminiscent of cluster. Explained by treating tone as a gesture with consonant-like timing [1], [4], [3]
- **Prediction:** CV syllable with tone will have C-V timing like that of CCV syllable, because of competitive coupling between C and tone gestures

EMA Data

- Electromagnetic articulography data of Tibetan speaker living in US (from [2])
- Current: syllable [ma] with high tone (language also has a rising tone)

Acknowledgements

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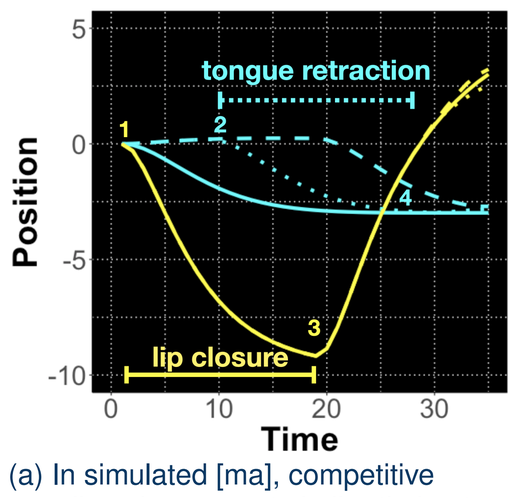
Simulation procedure

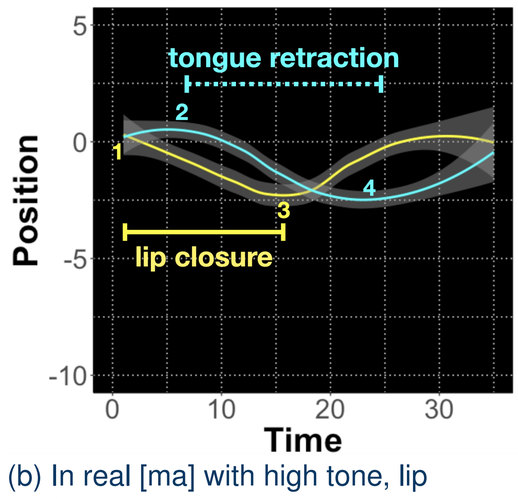
- Generate [ma] in TADA, then manually edit the timing of gestures reflecting presence and absence of hypothesized tone gesture
- Create three versions of [ma]: in-phase C-V (non-tonal); anti-phase C-V; and competitive-coupling C-V timing as predicted by tone gesture hypothesis

Results: looks like competitive coupling

- Subtracted position of each datapoint from value at first timestamp
- Tongue dorsum retraction begins in the middle of the lip closure, and lip closure ends around the middle of tongue dorsum retraction. This most closely resembles **competitive coupling**, and supports the tone gesture hypothesis.



(a) In simulated [ma], competitive coupling shows most similar timing to real data; solid = in-phase, dotted = competitive coupling, dashed = anti-phase.



(b) In real [ma] with high tone, lip gesture is smaller, gestures are slightly shorter, and movement toward targets in the next word is visible. Timing resembles competitive coupling

Discussion

- Relative timing of gestures is most consistent with competitive coupling
- TADA simulations are close enough to observed data to be instructive
- Next steps: do more! More languages, more syllable types, more complex tones.
- Long term: interested in automating the editing of gestural score files, with the goal of making gestural annotations for EMA data, building on [6]

References

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[3] Christopher Geissler et al. "Eccentric CV timing across speakers of diaspora Tibetan with and without lexical tone contrasts". In: *Proceedings of the 12th International Seminar on Speech Production.* 2021.

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