Head movement correlates with increased effort in an accelerating speech production task

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Overview

3D EMA has been used to observe the motion of speech articulators and related movement of the head during repeated productions of word pairs synchronized to the beats of an accelerating metronome.

Previous work (Pouplier 2003, Goldstein et al. 2007) has established that speech gestures produced in repeated sequences with alternating onsets (e.g., ***t*op *c*op**) will reorganize spontaneously from a less stable **2:1** pattern to a **1:1** mode, resulting in a speech error.

In such errors an inappropriate constriction (which may be incomplete) is formed coincident with the intended target (e.g., velar closure coproduced with intended apical closure).

Overview

This study builds on these results in two ways:

First, production of alternating word pairs is driven by an accelerating rather than fixed rate metronome. By eliciting data at an initial relatively stable rate, and then smoothly increasing rate pressure, the likelihood of observing frequency reorganization is increased.

Second, in tandem with observation of the speech articulators, the motion of the head is tracked, to investigate the possibility that as rate and effort increase peripheral structures are recruited to help reinforce and sustain the 2:1 rhythmic pattern.

Motivation

Why look at the head?

• Hadar et al. (1984) found abrupt head movements associated with dysfluencies in running speech

• Hadar (1991) measured head movement of aphasics and normal controls engaged in speech during interviews and found that head movement was positively correlated with speaking rate for both groups

• Goebl & Palmer (2009) showed that pianists performing a duet with manipulated auditory feedback increase the magnitude and coherence of their head movements as feedback is degraded

Because we now can: EMA systems transduce movement with unrestricted head motion

Methods

Participants

- 4 females, 4 males
- native speakers of AE

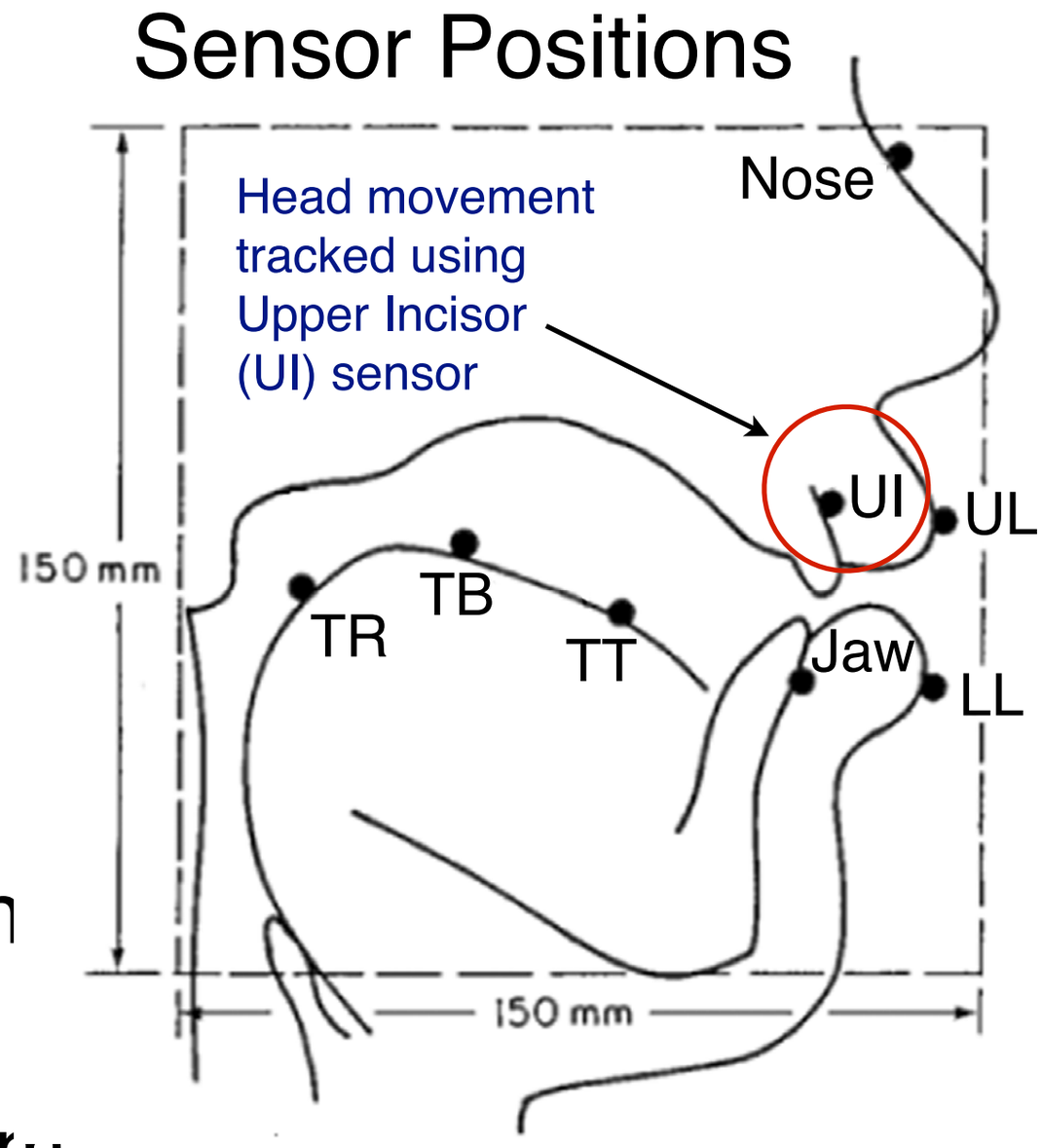
Recordings

- audio, metronome @ 16 kHz
- 3D EMA @ 200 Hz (Carstens AG500)

Procedures

- word pair presented to subject on computer screen
- "get ready, breathe, GO" paradigm
- subjects instructed to produce word pair sequence in one breath, using trochaic stress (e.g. *tóp cop tóp cop* ...)
- each produced word synchronized to a metronome click

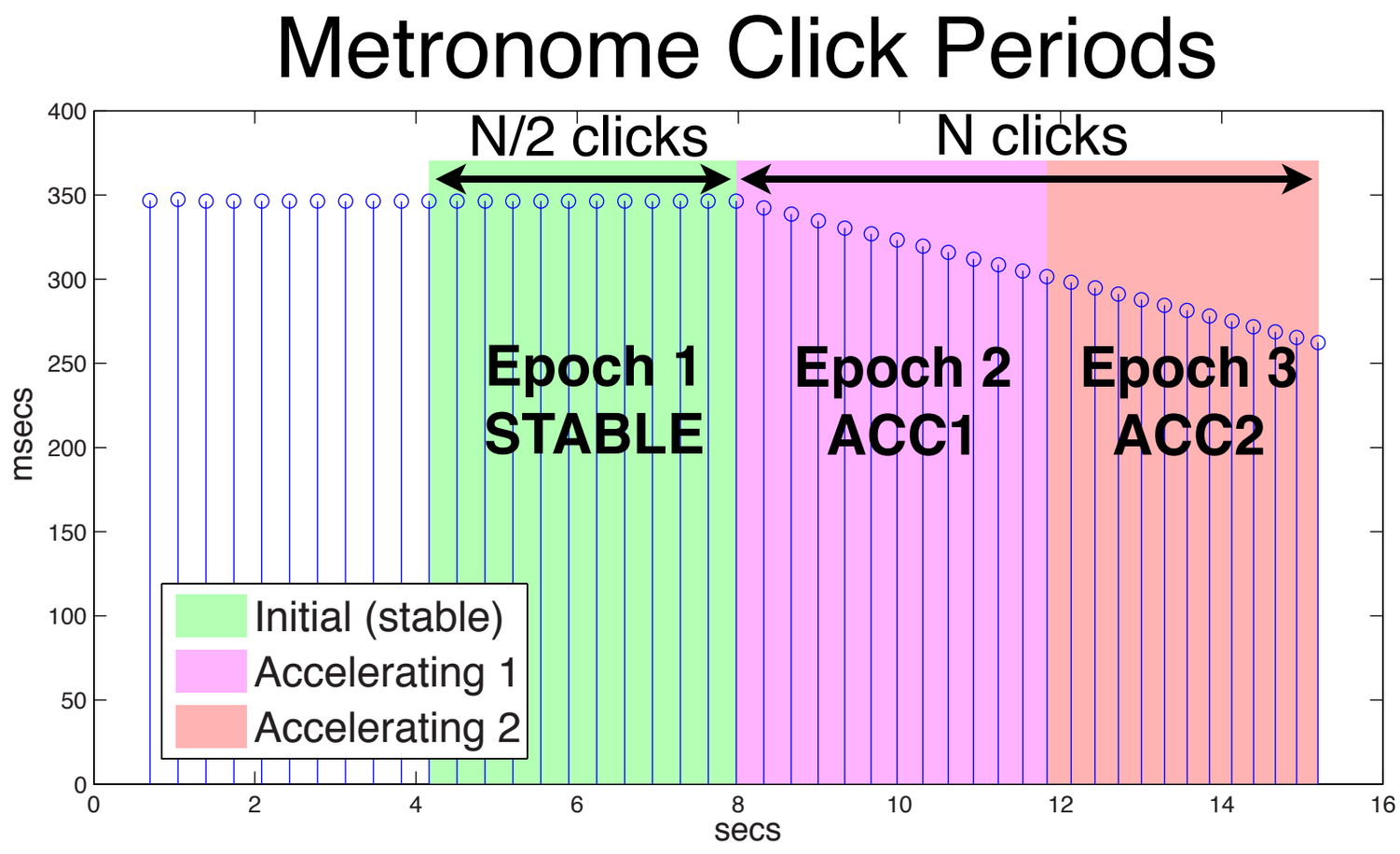
Sensor Positions



Methods

Procedures (cont.)

- clicks played through earphone and recorded as 2nd audio channel
- initial 170 clicks/min accelerating to 230 halfway through trial under computer control



Post-processing

- all sensor trajectories (except UI) corrected for head movement and rotated to occlusal plane
- Lip Aperture (LA) derived from Euclidian distance between upper/lower lip sensors

Materials

Word Pairing Types (CONTEXT)

1. **SAME** (e.g. *top top*)
2. different **ONSET** (e.g. *top cop*)
3. different **CODA** (e.g. *cop cot*)
4. **BOTH** onset and coda different (e.g. *pop tot*)

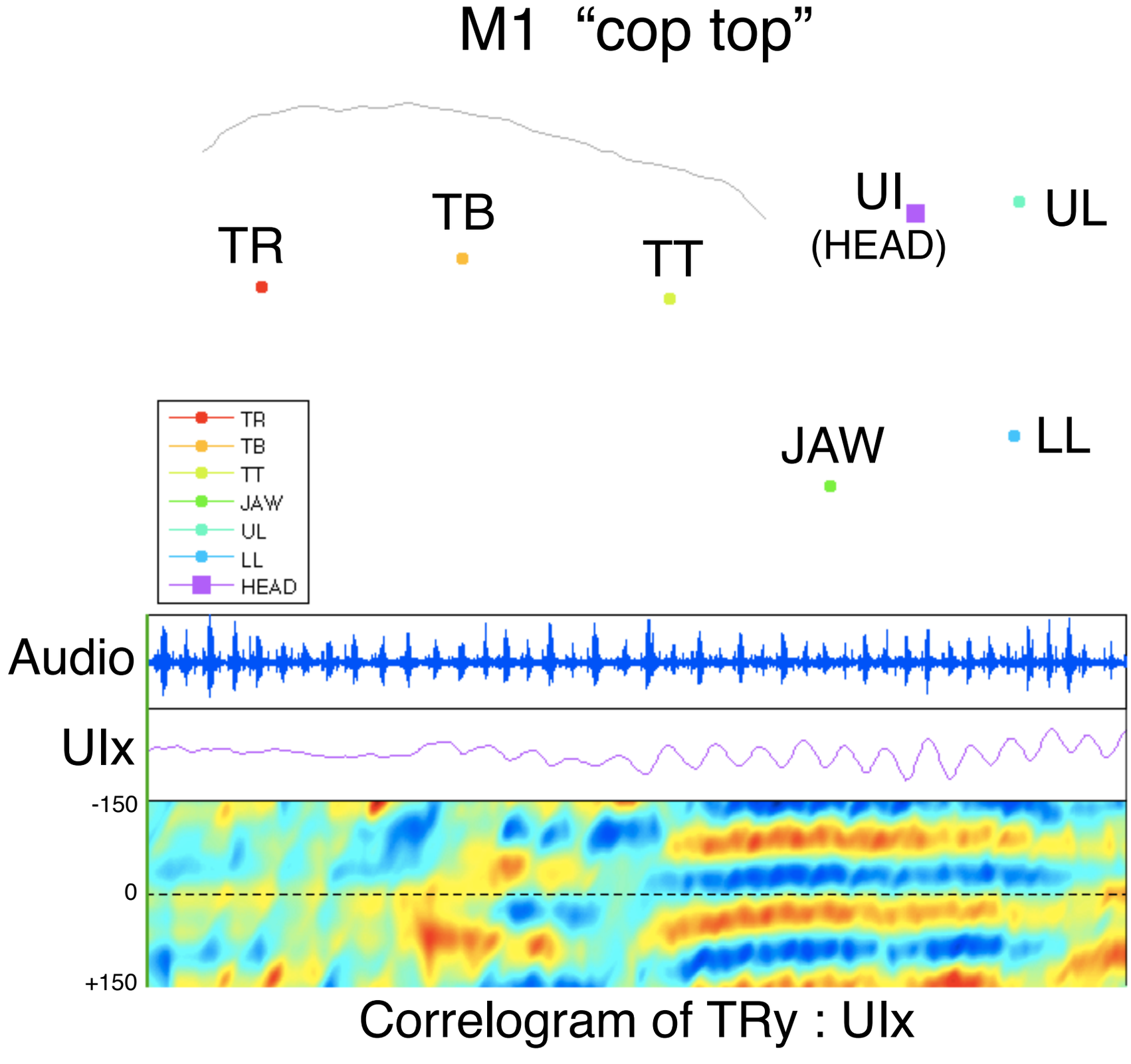
Word List

/p/	/t/	/k/
pack	tack	cape
pat	take	cob
pip	tap	cod
pock	tape	cop
pod	tock	cot
pog	top	Kate
pop	tot	kick

Presentation

- one trial per word pairing
- separate trials for each pair ordering (e.g., *cop top* and *top cop*)
- at least 20 repetitions of each word pair per trial

Example


M1 “cop top”
TR
TB
TT
UI
(HEAD)
UL
JAW
LL
TR
TB
TT
JAW
UL
LL
HEAD
Audio
UIx
-150
0
+150
Correlogram of TRy : UIx

Plan of attack

1) Quantify Head Movement (results reported here)

➠ predict more movement with increased production rate

➠ predict more movement with more complex alternants (e.g., *top cop* > *top top*)

2) Measure Errors (in progress)

• expect more errors under increased rate pressure and alternant complexity

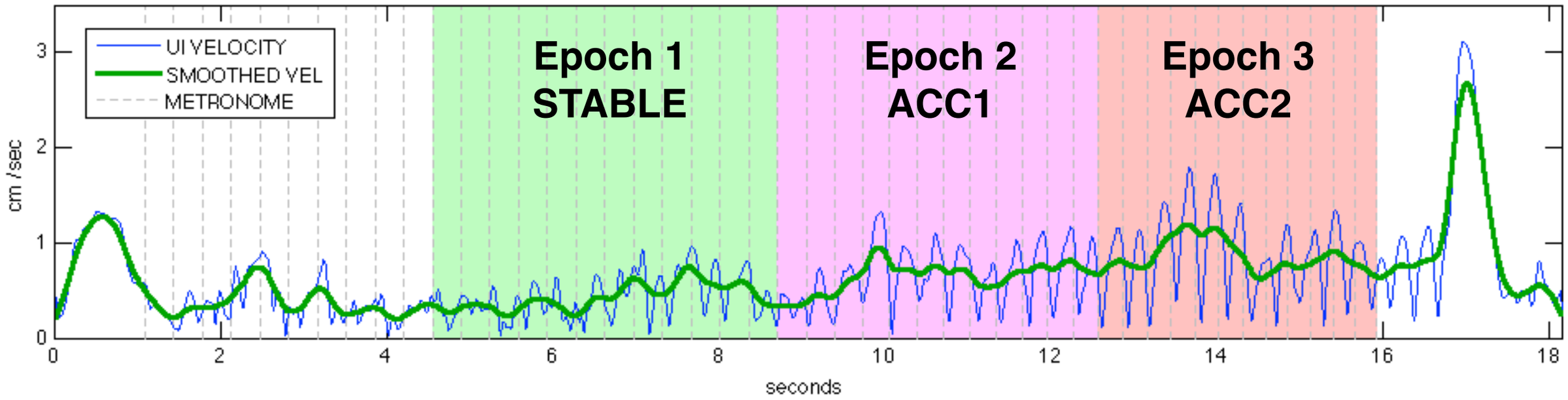
• expect errors to trigger abrupt increase in head movement

3) Compute phase relations between head and speech articulator movements (still evaluating methods)

• expect head frequency to track and reinforce slower, less stable alternating C

Measurements

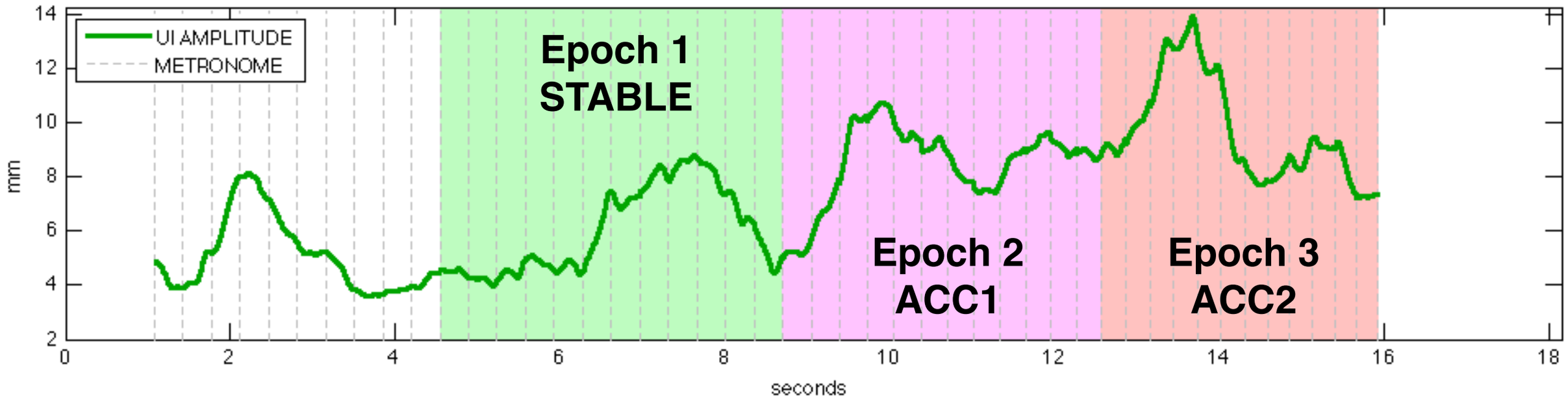
Variable: Head Movement Speed (VEL)



- UI tangential velocity
- smoothed using a 50 sample moving average filter
- aggregated by averaging over each Epoch

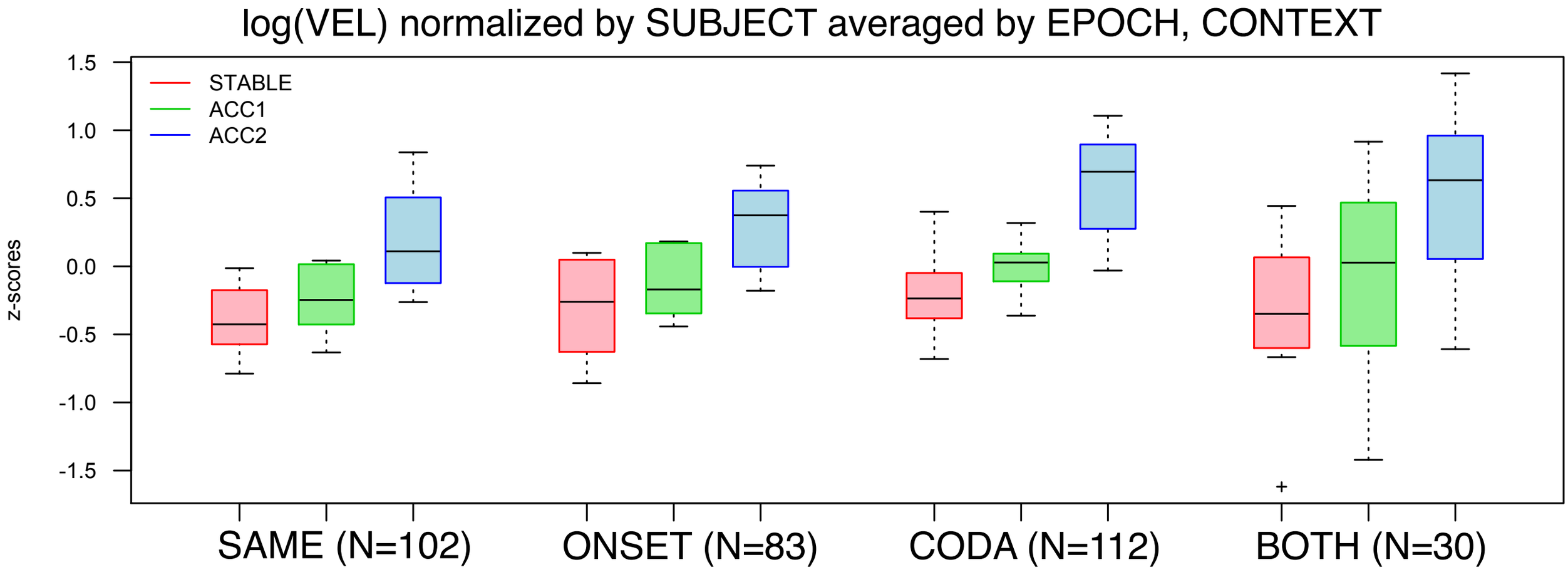
Measurements

Variable: Head Movement Amplitude (AMP)



- value at each sample computed as path integral over a centered buffer, whose length is determined by twice the period of the enclosing clicks
- aggregated by averaging over each Epoch

Results



Mixed Model predicting **VEL** with **EPOCH**, **CONTEXT** as Fixed and **SUBJECT**, **WORD** as Random effects, evaluated with 981 observations of 5 variables:

EPOCH

STABLE < ACC1 < ACC2

*** ***

CONTEXT

SAME < ONSET < CODA < BOTH

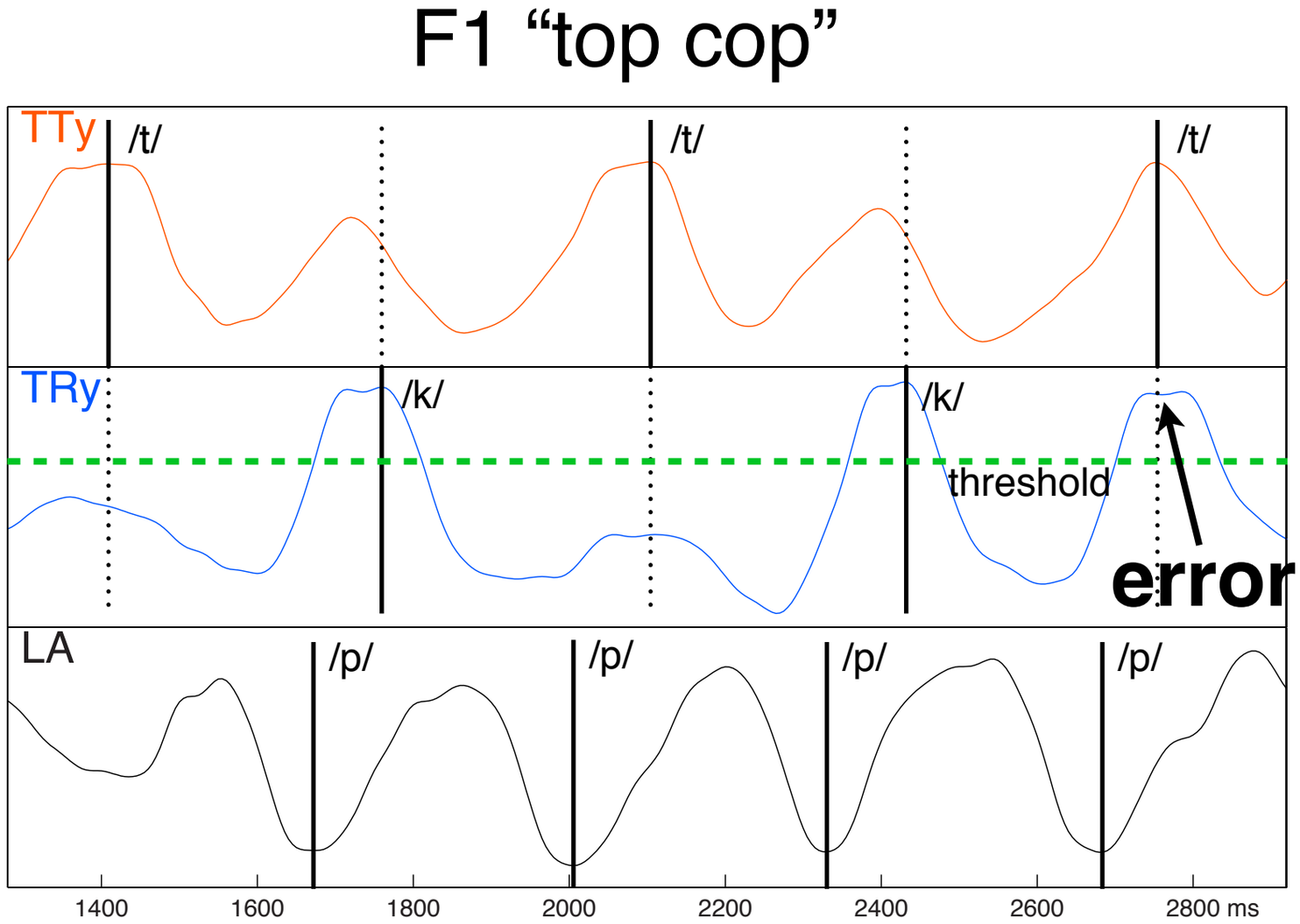
* .

Measuring Errors

Closure Labelling

Kinematic extrema:

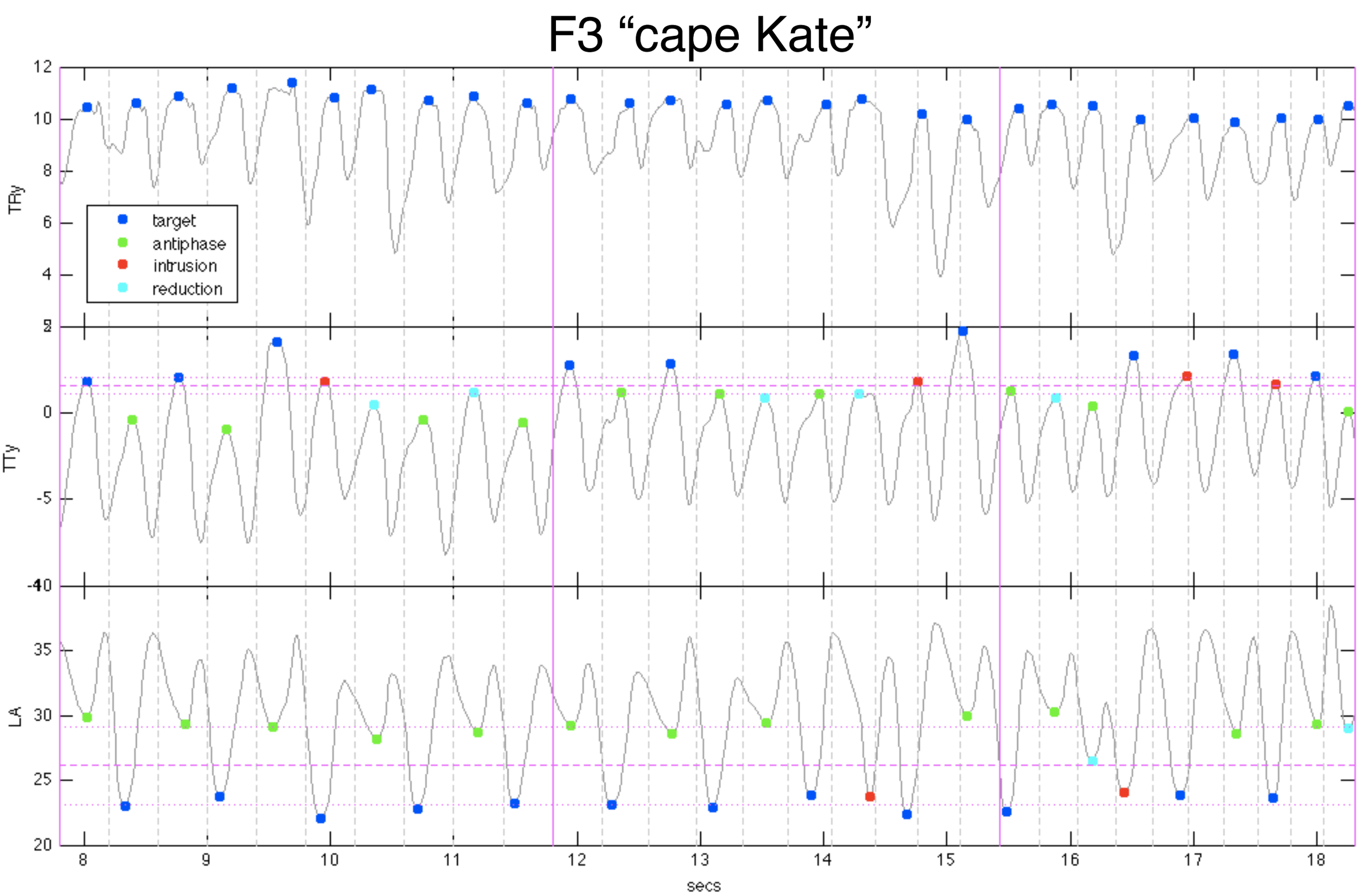
- /t/ on TTy
- /k/ on TRy
- /p/ on LA



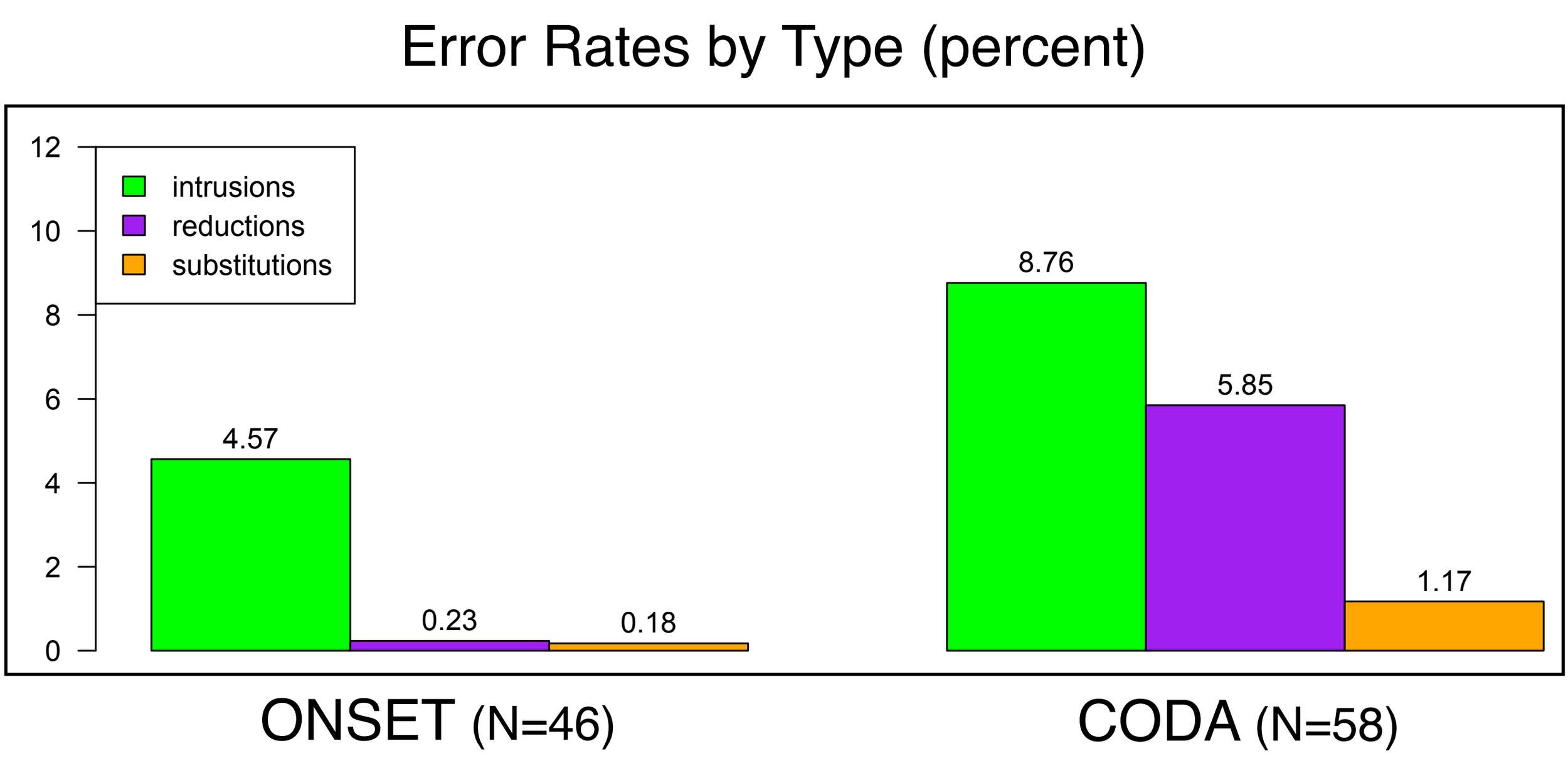
Error Identification

- offsets of intended closures projected onto alternate articulator positions
- errors defined as alternate articulator exceeding split between median of intended (target) and antiphase (alternate) amplitudes

Measuring Errors

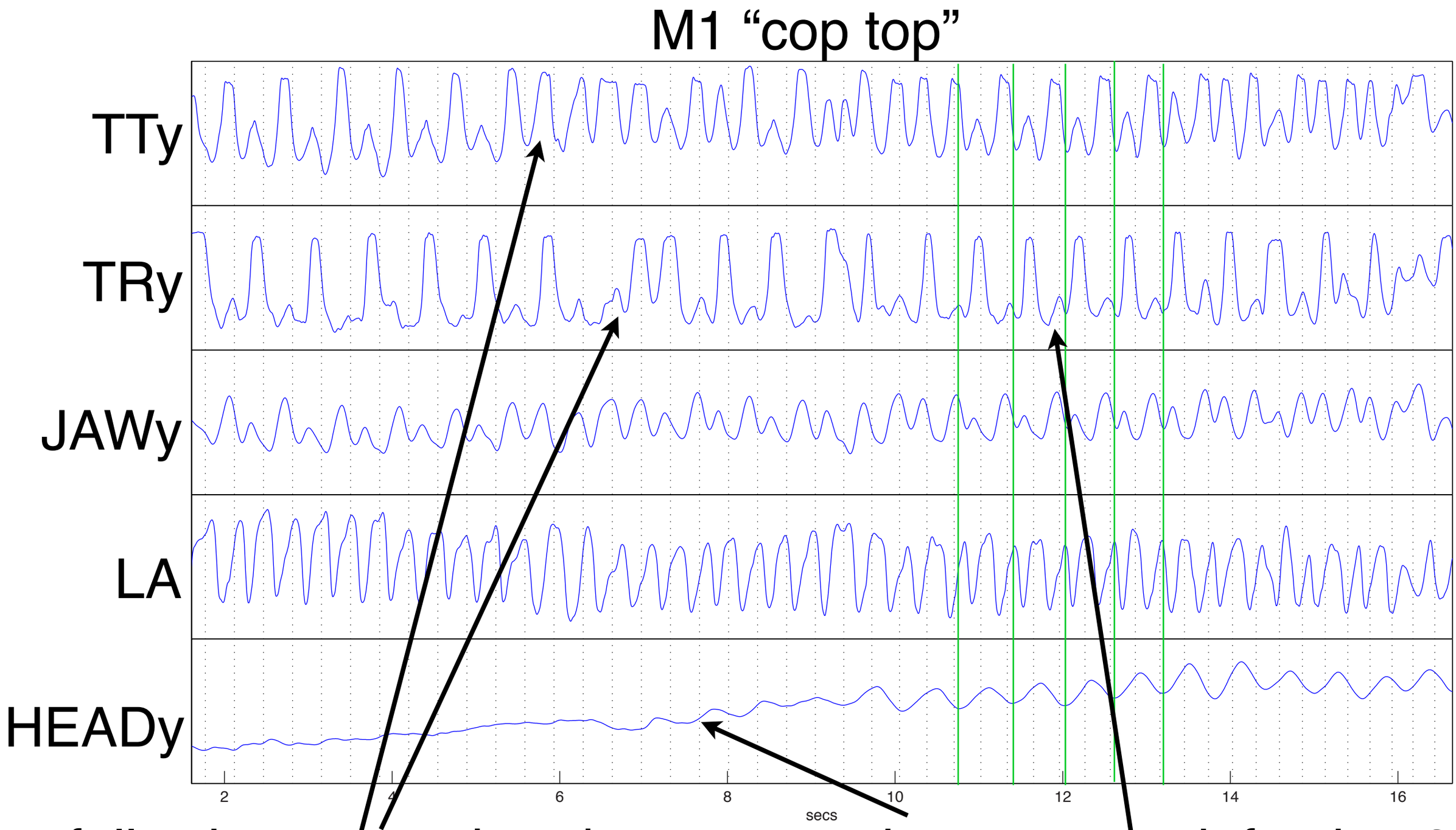


Error Rates



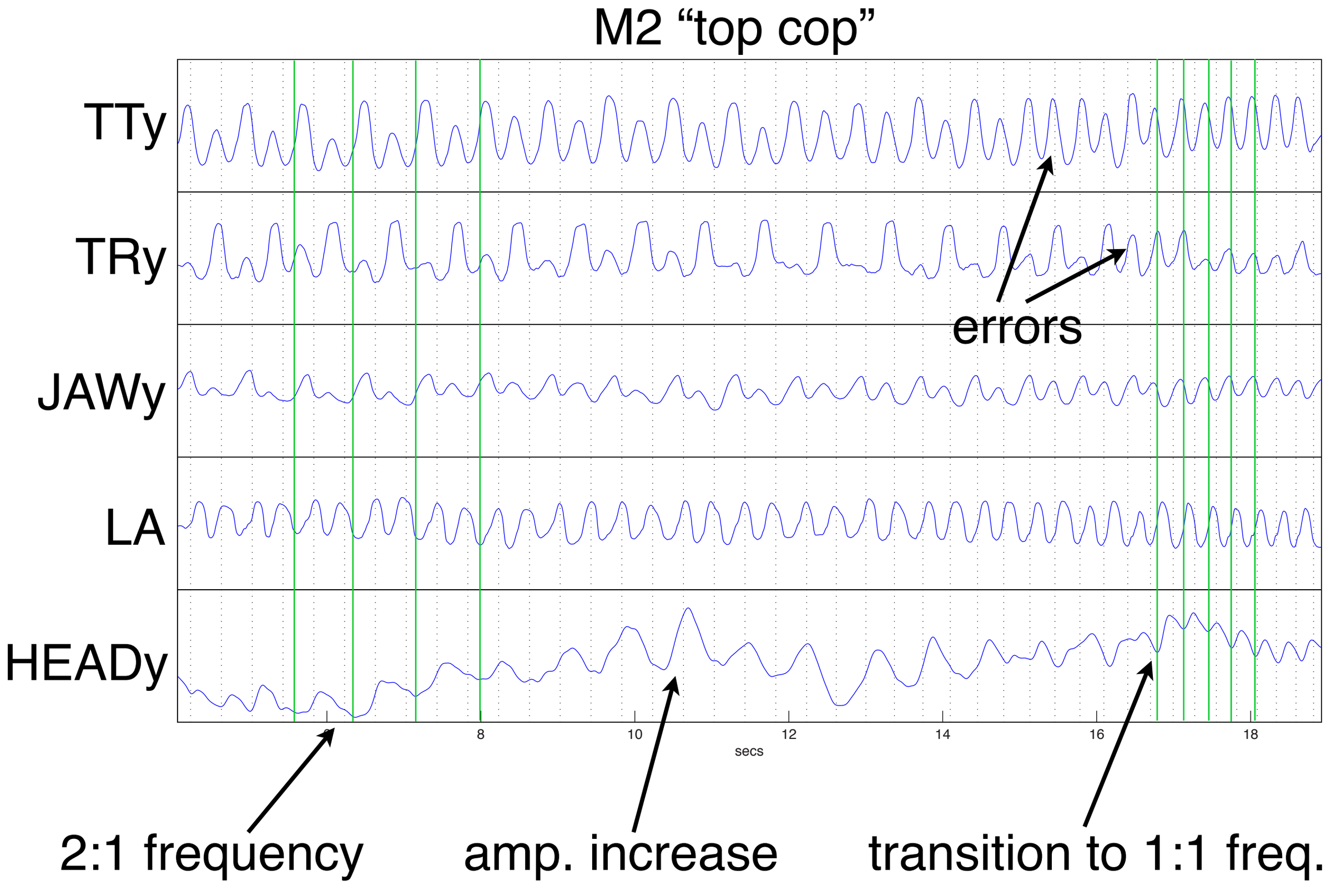
- not separated by EPOCH
- partial data (does not include F3, F4, M3, M4)

Entrainment examples



following errors, head movement increases, reinforcing 2:1 frequency pattern and restoring stable alternation

Entrainment examples



Discussion

Although some variation between subjects and among trials was observed, the overall trend of the results is clear:

⇒ as rate pressure on the 2:1 production pattern increases, so does entrained movement of the head

• there is some indication (increased head movement, higher error rate) that CODA alternations are less robust than ONSET alternations

• although not yet evaluated systematically, results also suggest that the frequency of entrained head motion tracks that of the alternation (i.e., 2:1 *vice* 1:1)

Discussion

Results are consistent with Mooshammer et al. (submitted) who obtained RT results showing that words with VC structure take longer to initiate than words with CV structure

Nam & Saltzman (2003) suggest that VC coupling (anti-phase) is slower to settle and less stable than in-phase CV

Recruitment of the head (and other peripheral extremities) may reflect a van Holst *Magneteffekt*, the tendency of one rhythmic unit to attract another to its tempo

Kelso et al. (1980): "[A] system containing a set of active components that have been self-organized for a particular movement pattern is [...] no longer able to support that behavior in a stable fashion when a control parameter (here the frequency of motion) crosses a critical value."

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Acknowledgments

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