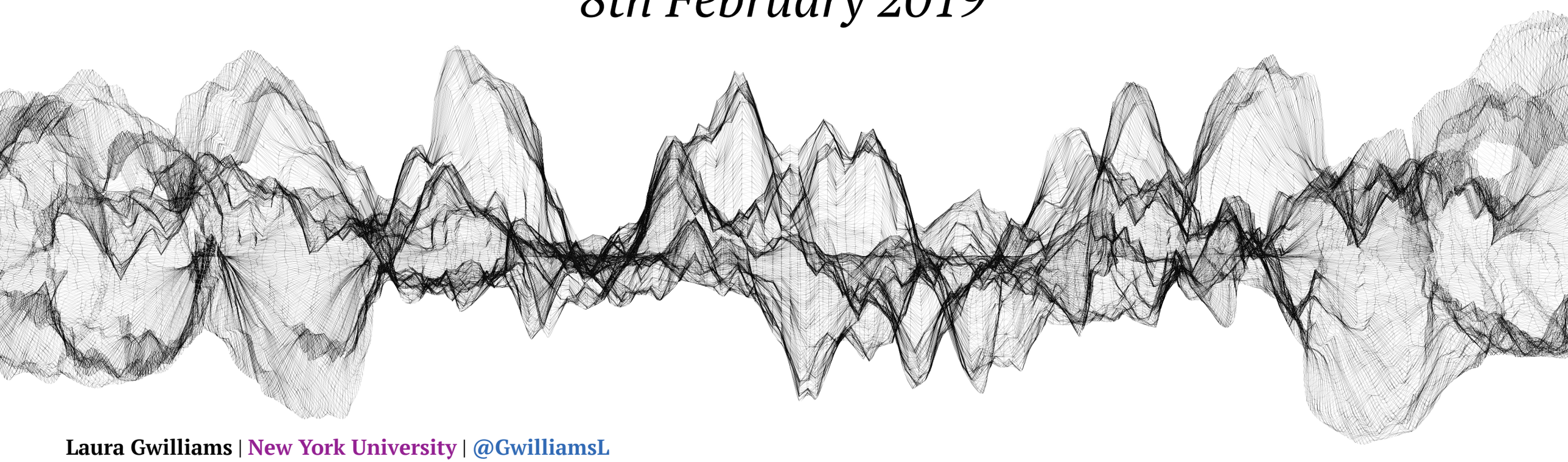
NEW YORK UNIVERSITY

Transforming acoustic input into a hierarchy of linguistic representations

Laura Gwilliams, David Poeppel & Jean-Rémi King

8th February 2019



Laura Gwilliams | **New York University** | **@GwilliamsL**

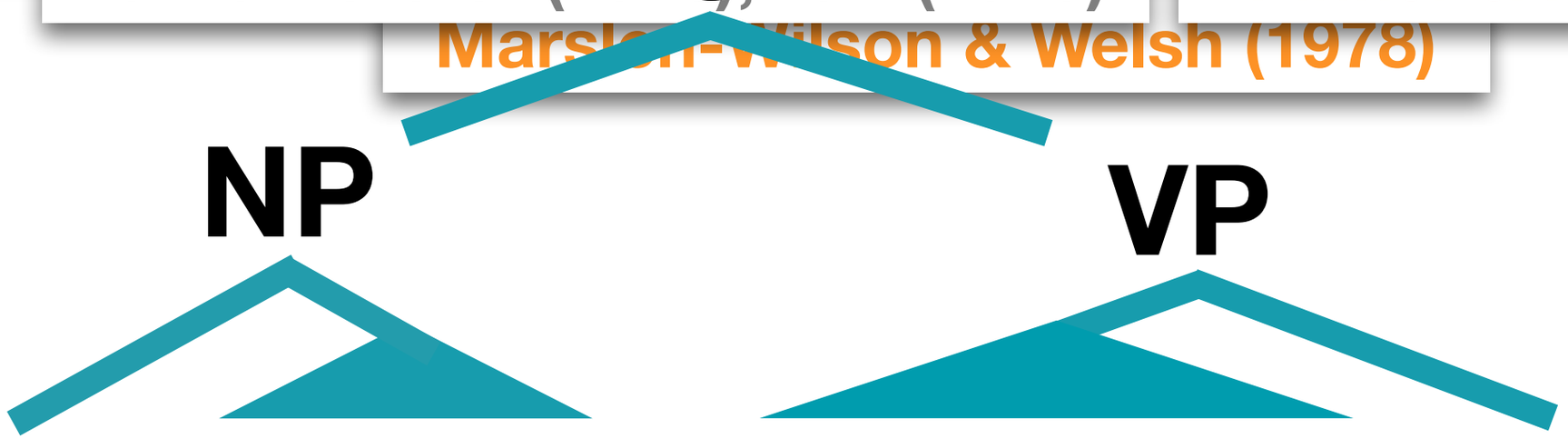
Eimas & Corbit (1973)

Cutler et al. (1986); Barry (1980; 1984)

Taft & Forster (1975); Taft (1979)

Pinker & Prince (1988)

Marslen-Wilson & Welsh (1978)



sentence structure

phrasal structure

the fat cat dis | appear | ed

lemmas

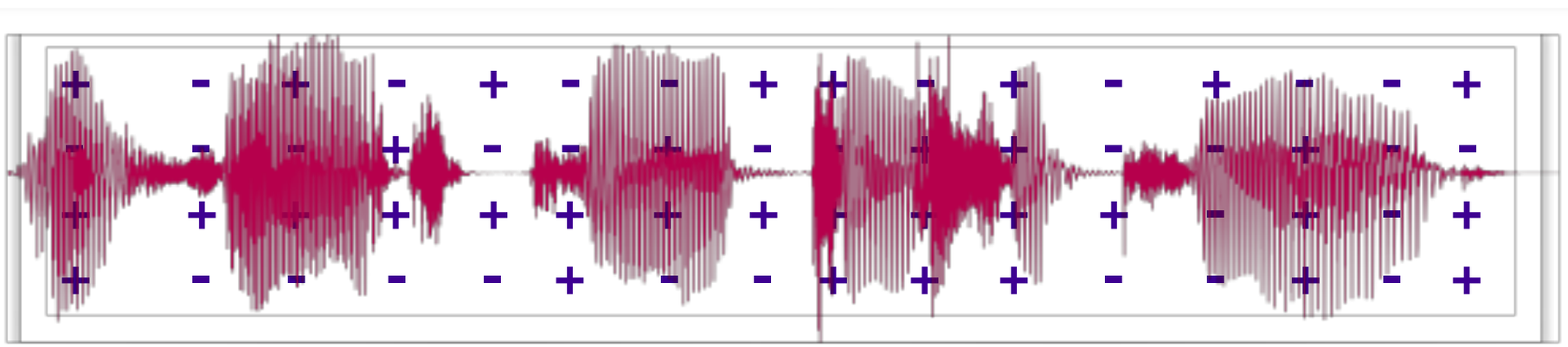
morphemes

dah fat kat dis ah pee ud

syllables

DH AH F AE T K AE T D IH S AH P IH R D

phonemes



phonetic features

acoustics

S

1) which linguistic units are encoded in brain activity?

2) what is the relative

VP

phrasal

LANGUAGE, COGNITION AND NEUROSCIENCE
https://doi.org/10.1080/23273798.2018.1499946

Routledge
Taylor & Francis Group

REGULAR ARTICLE

OPEN ACCESS Check for updates

The revolution will not be controlled: natural stimuli in speech neuroscience

Liberty S. Hamilton[a,b] and Alexander G. Huth[c,d]

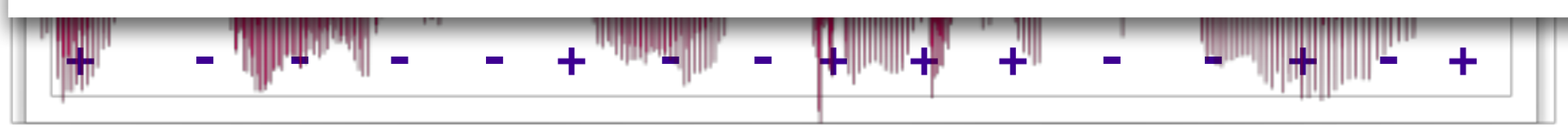
[a]Communication Sciences & Disorders, Moody College of Communication, The University of Texas at Austin, Austin, USA; [b]Department of Neurology, Dell Medical School, The University of Texas at Austin, Austin, USA; [c]Department of Neuroscience, The University of Texas at Austin, Austin, USA; [d]Department of Computer Science, The University of Texas at Austin, Austin, USA

ABSTRACT

Humans have a unique ability to produce and consume rich, complex, and varied language in order to communicate ideas to one another. Still, outside of natural reading, the most common methods for studying how our brains process speech or understand language use only isolated words or simple sentences. Recent studies have upset this *status quo* by employing complex natural stimuli and measuring how the brain responds to language as it is used. In this article we argue that natural stimuli offer many advantages over simplified, controlled stimuli for studying how language is processed by the brain. Furthermore, the downsides of using natural language stimuli can be mitigated using modern statistical and computational techniques.

ARTICLE HISTORY
Received 21 February 2018
Accepted 3 July 2018

KEYWORDS
Natural language; encoding models; fMRI; ECoG; EEG



es

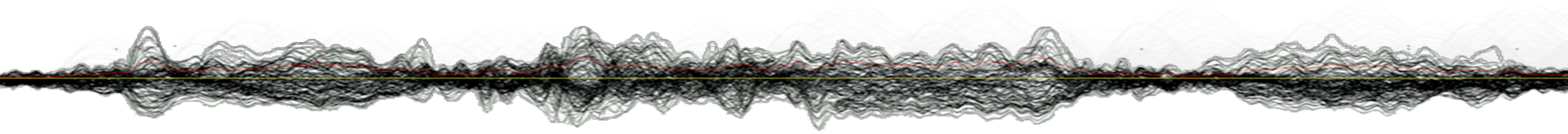
s

c

s

acoustics

Setup



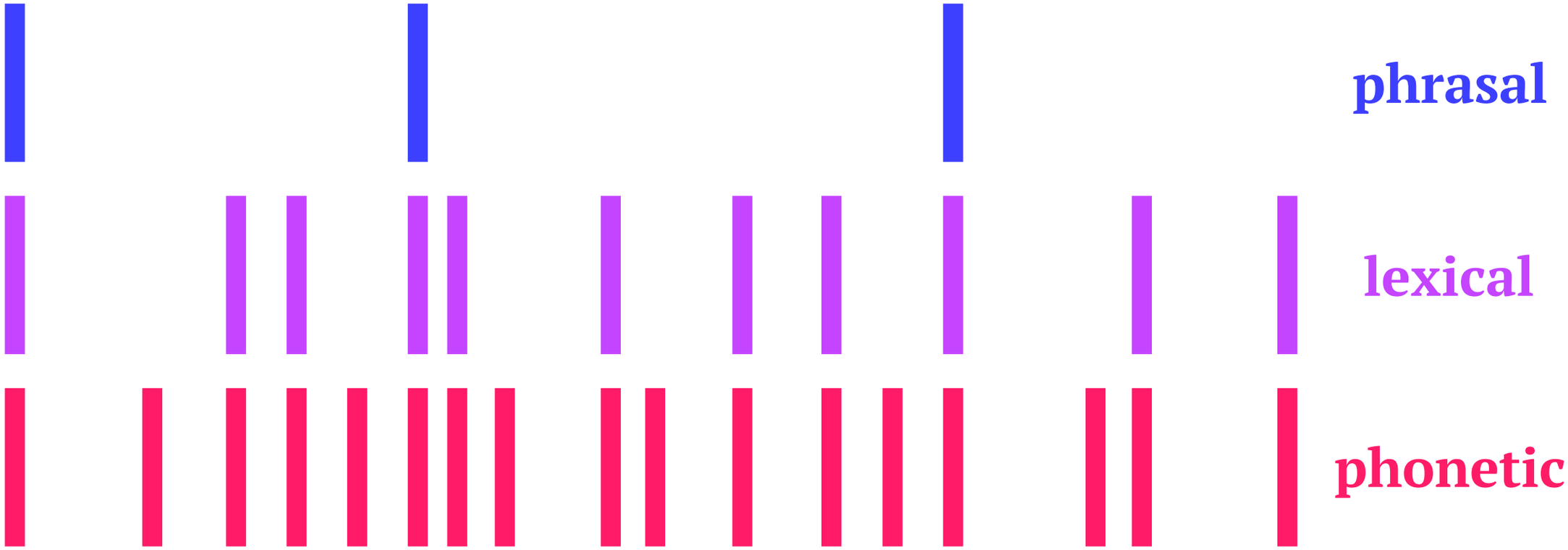
- 18 participants
- Listening to four narrative stories (twice)
- 2 x one hour recordings
- KIT 208 channel MEG system
- Engagement task

- ~40,000 phonemes per participant
- ~16,000 words per participant

جامعة نيويورك أبوظبي

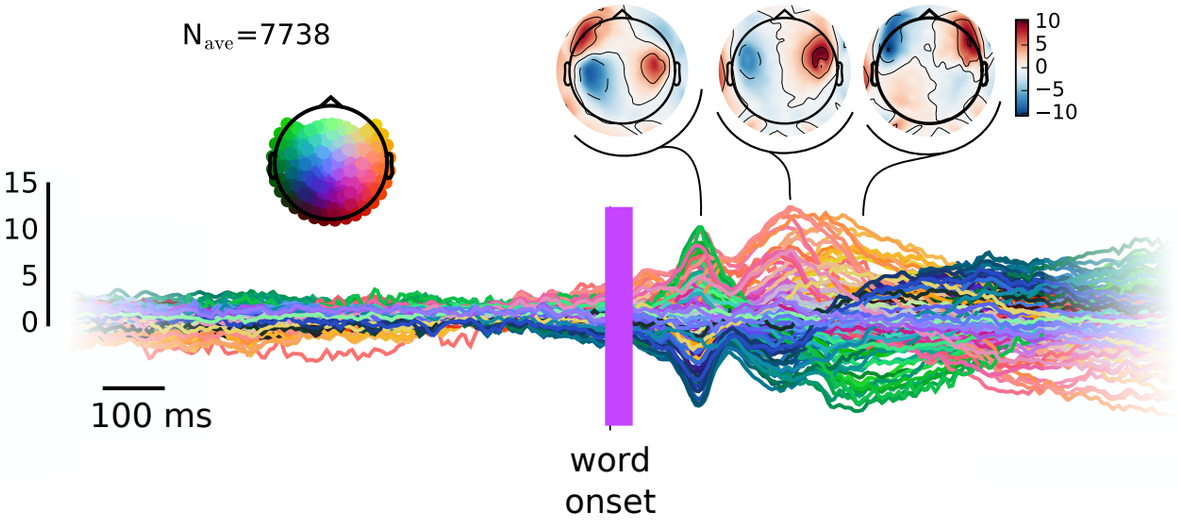
NYU | ABU DHABI

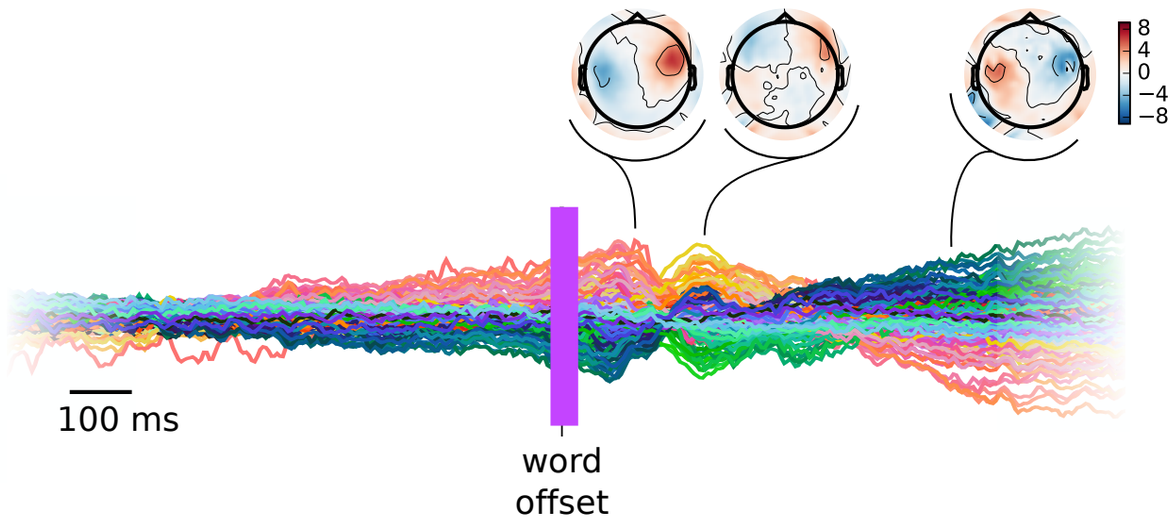
Annotate for features and unit boundaries



Laura Gwilliams | New York University | @GwilliamsL

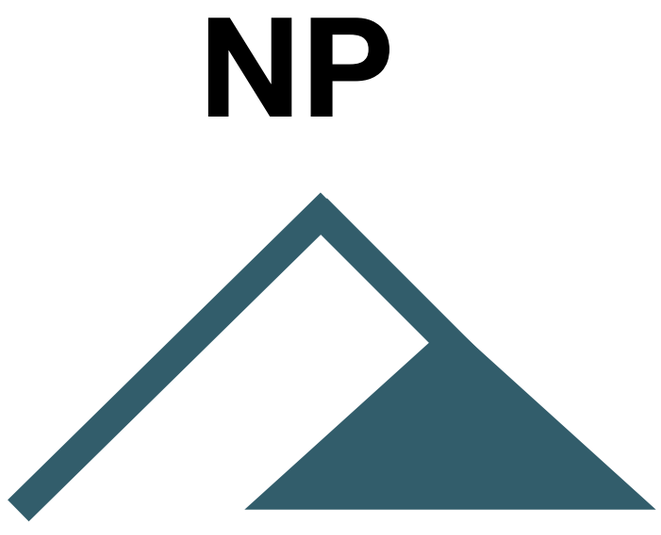
Event-locked average response





Laura Gwilliams | **New York University** | **@GwilliamsL**

Stimulus features

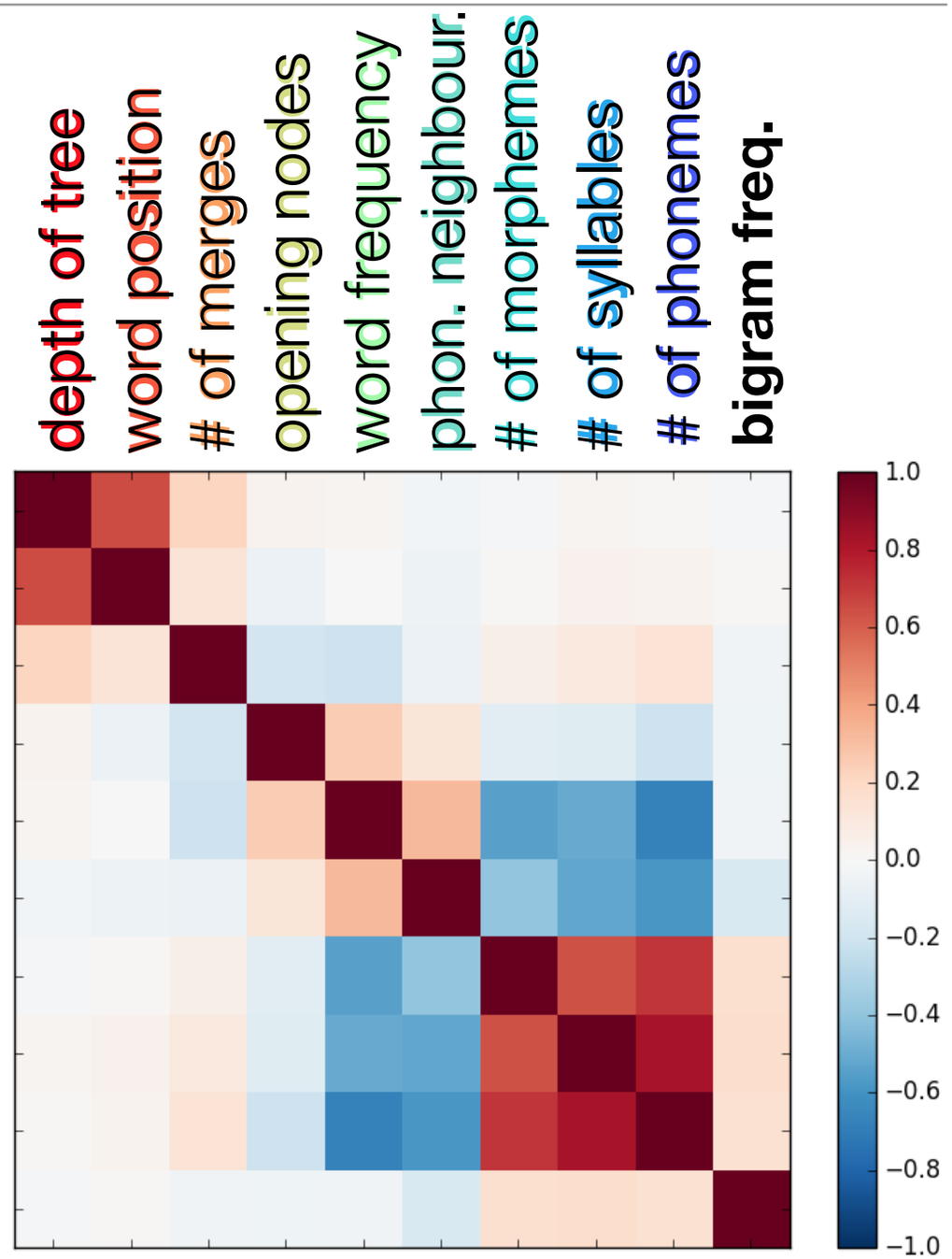


syntactic

word use

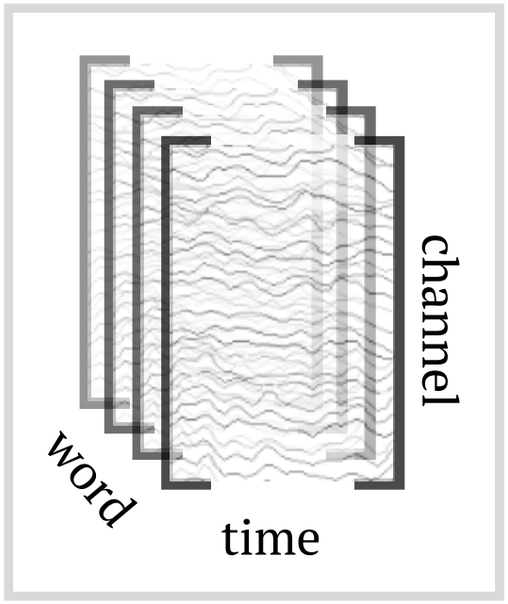
word structure

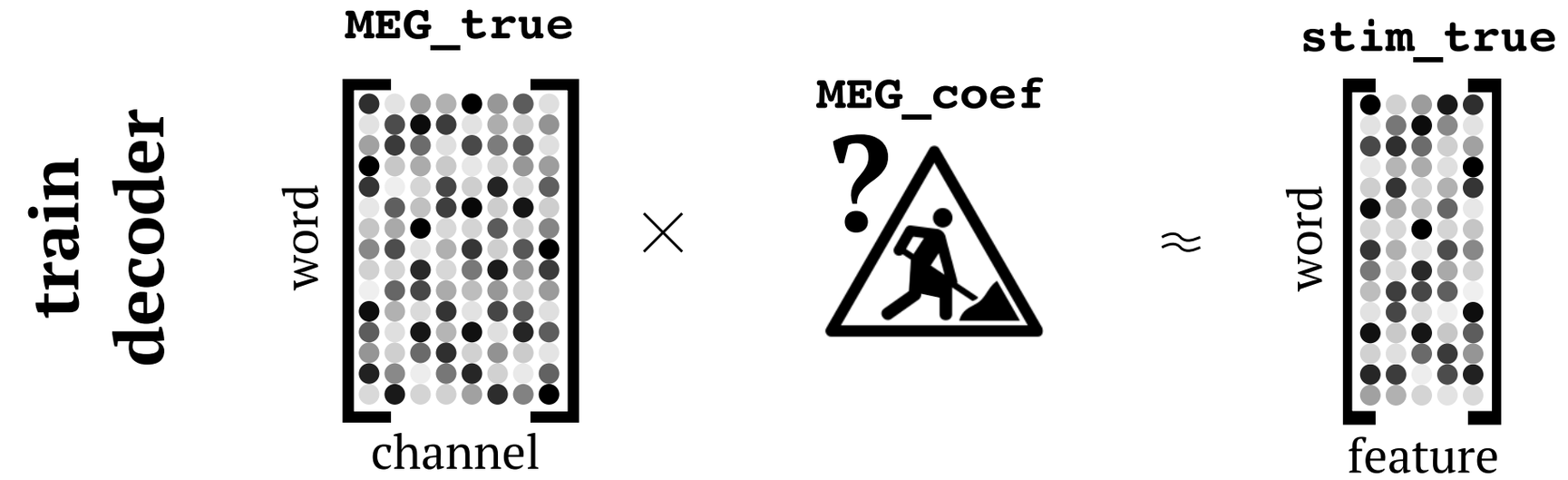
depth of tree
word position
# of merges
opening nodes
word frequency
phon. neighbourhood
# of morphemes
# of syllables
# of phonemes
bigram frequency



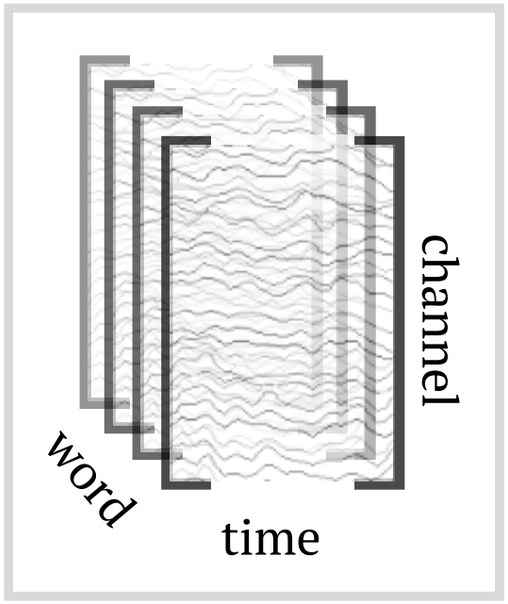
stimulus similarity matrix

Analysis technique

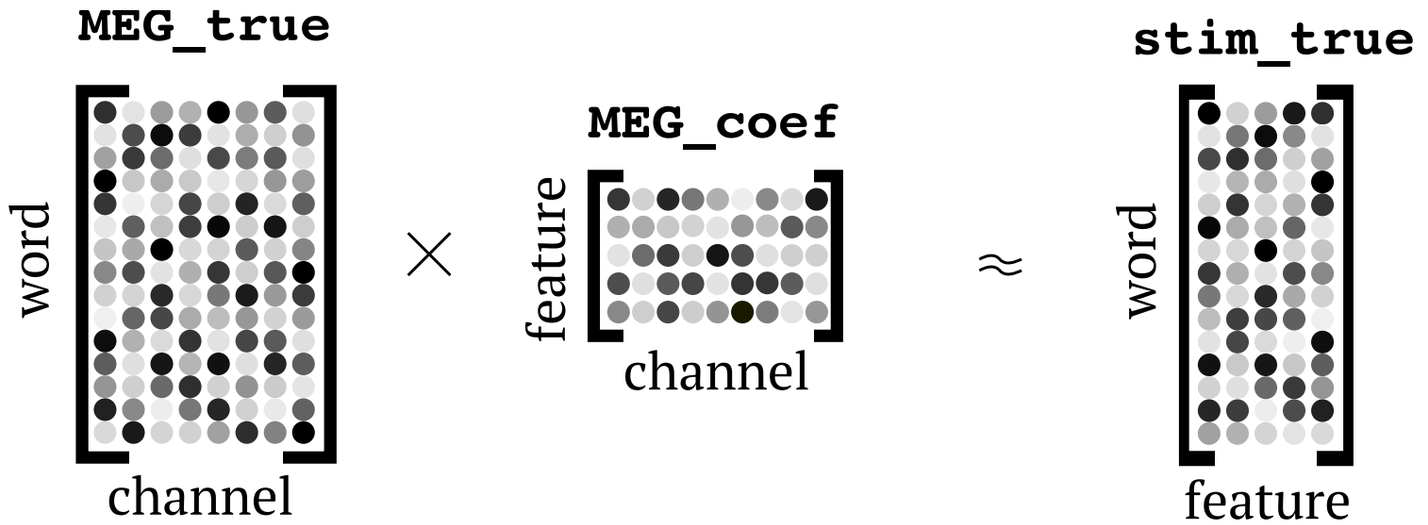




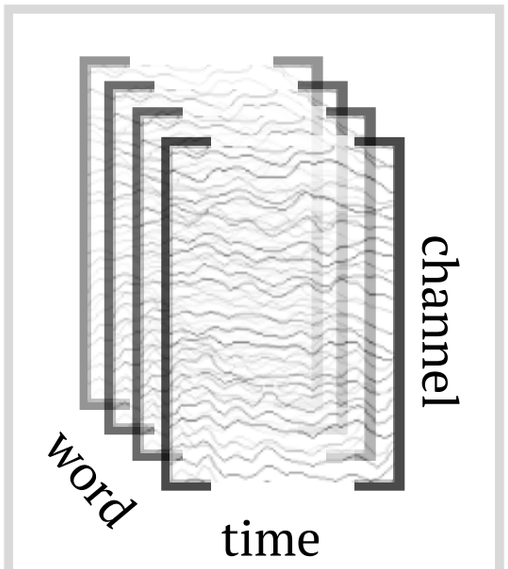
Analysis technique

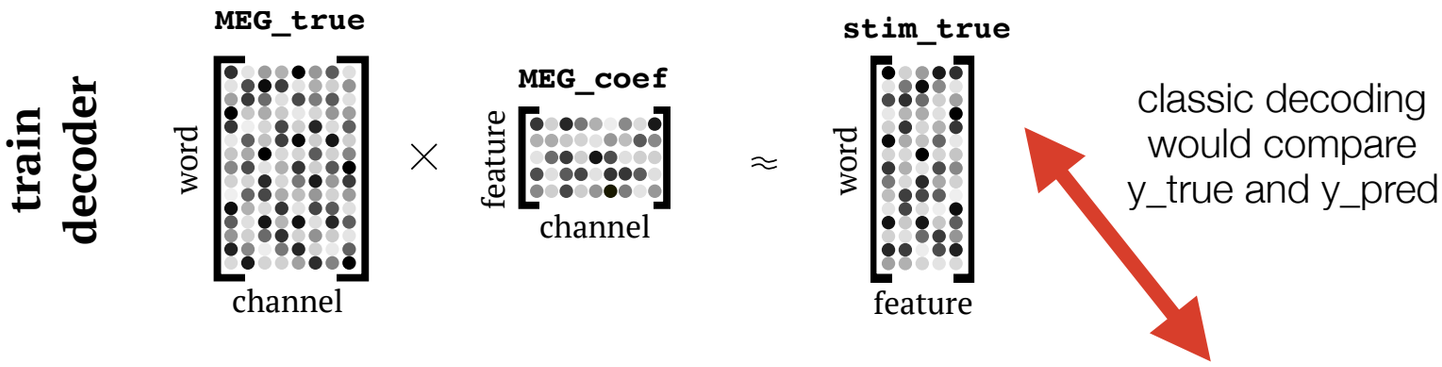


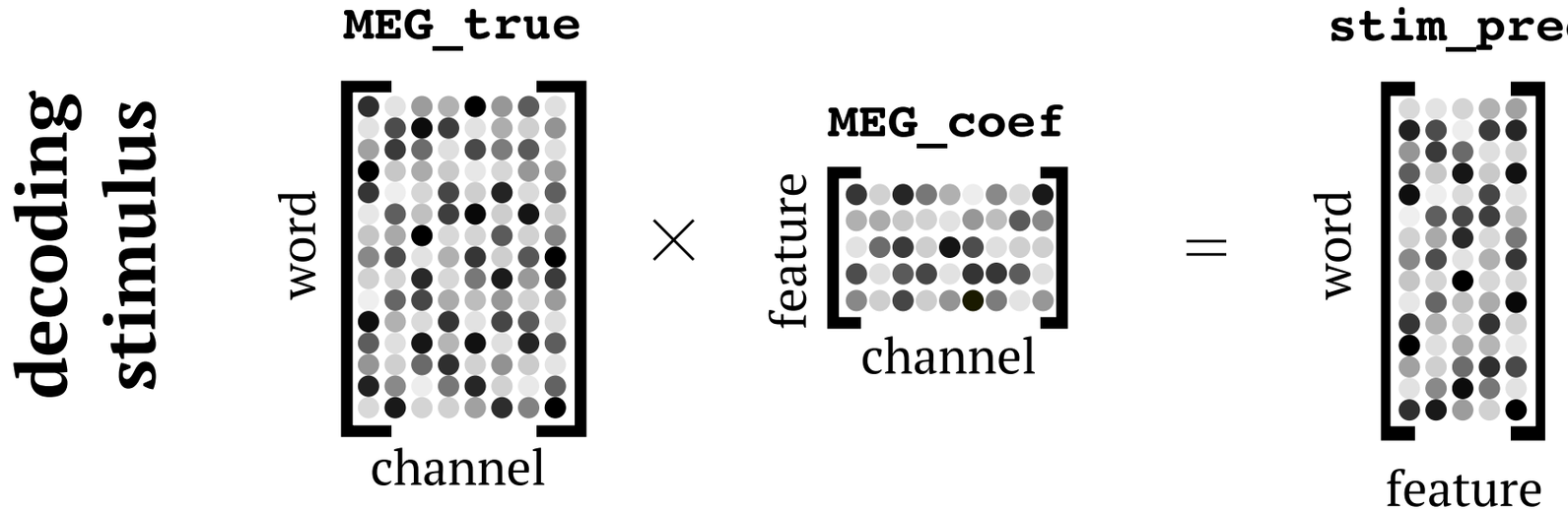
train decoder



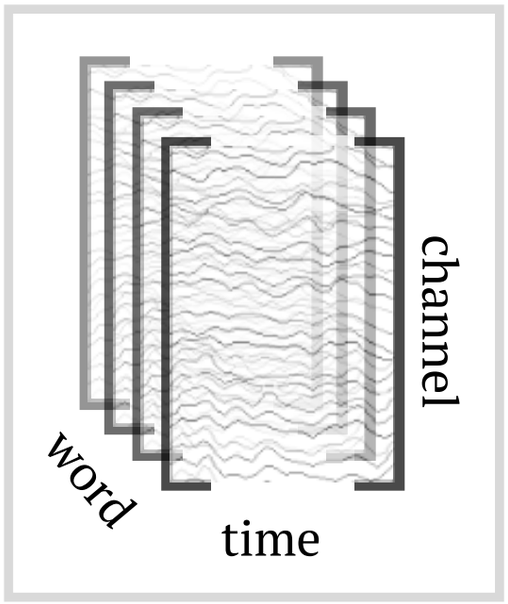
Analysis technique

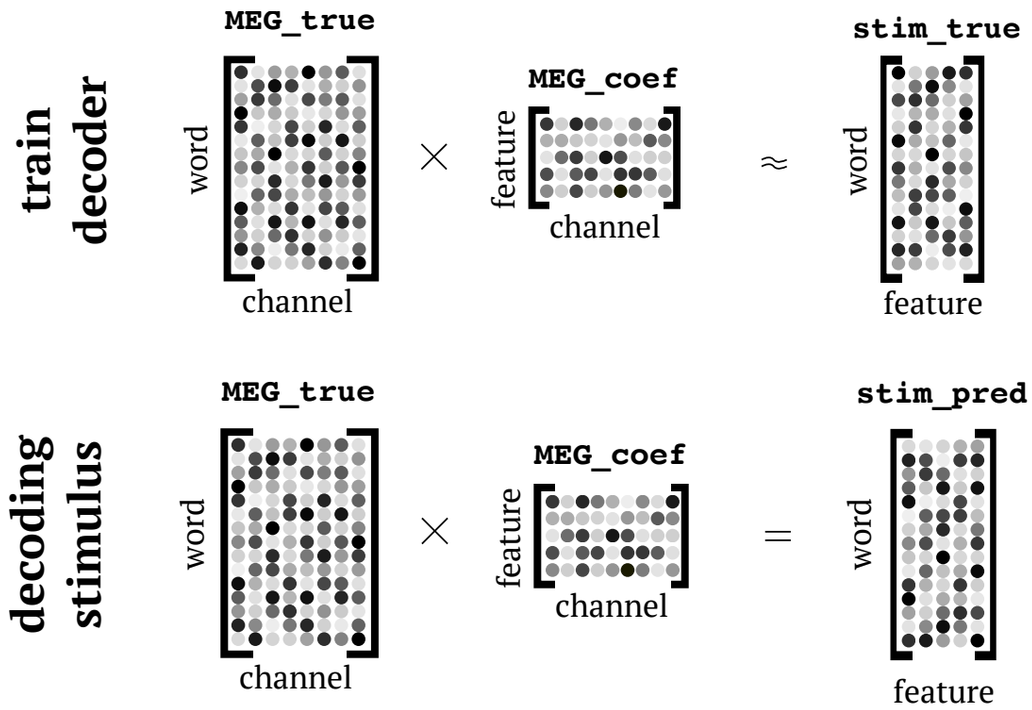


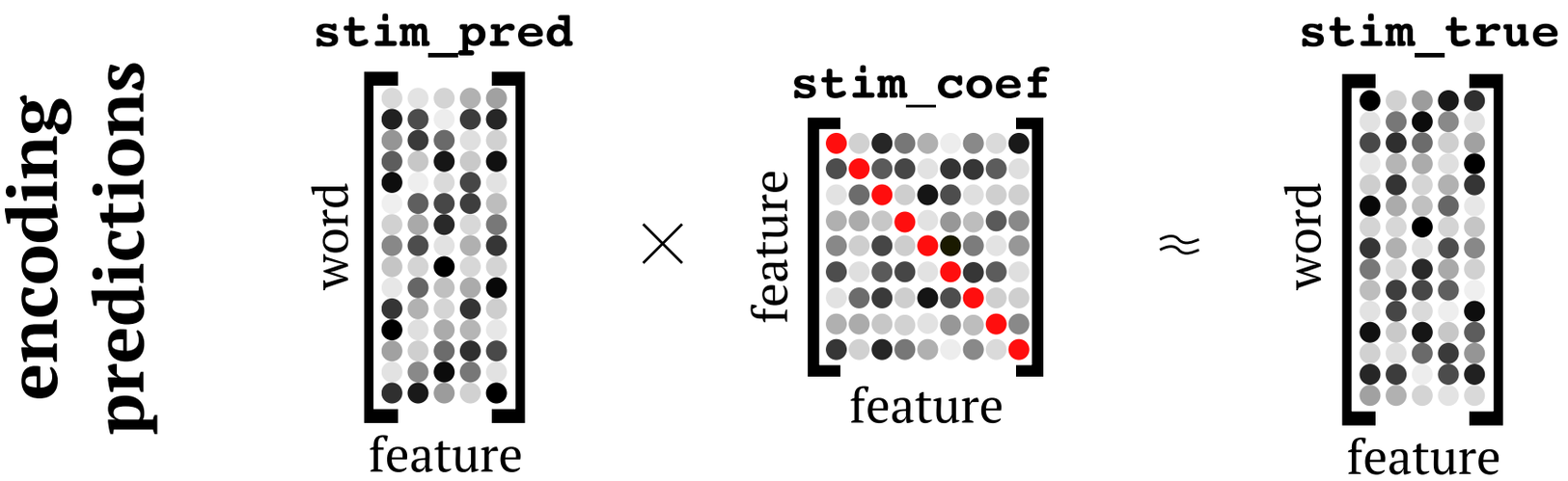




Analysis technique







which linguistic units are encoded in brain activity?

Laura Gwilliams | New York University | @GwilliamsL

Across timescales

phrasal

lexical

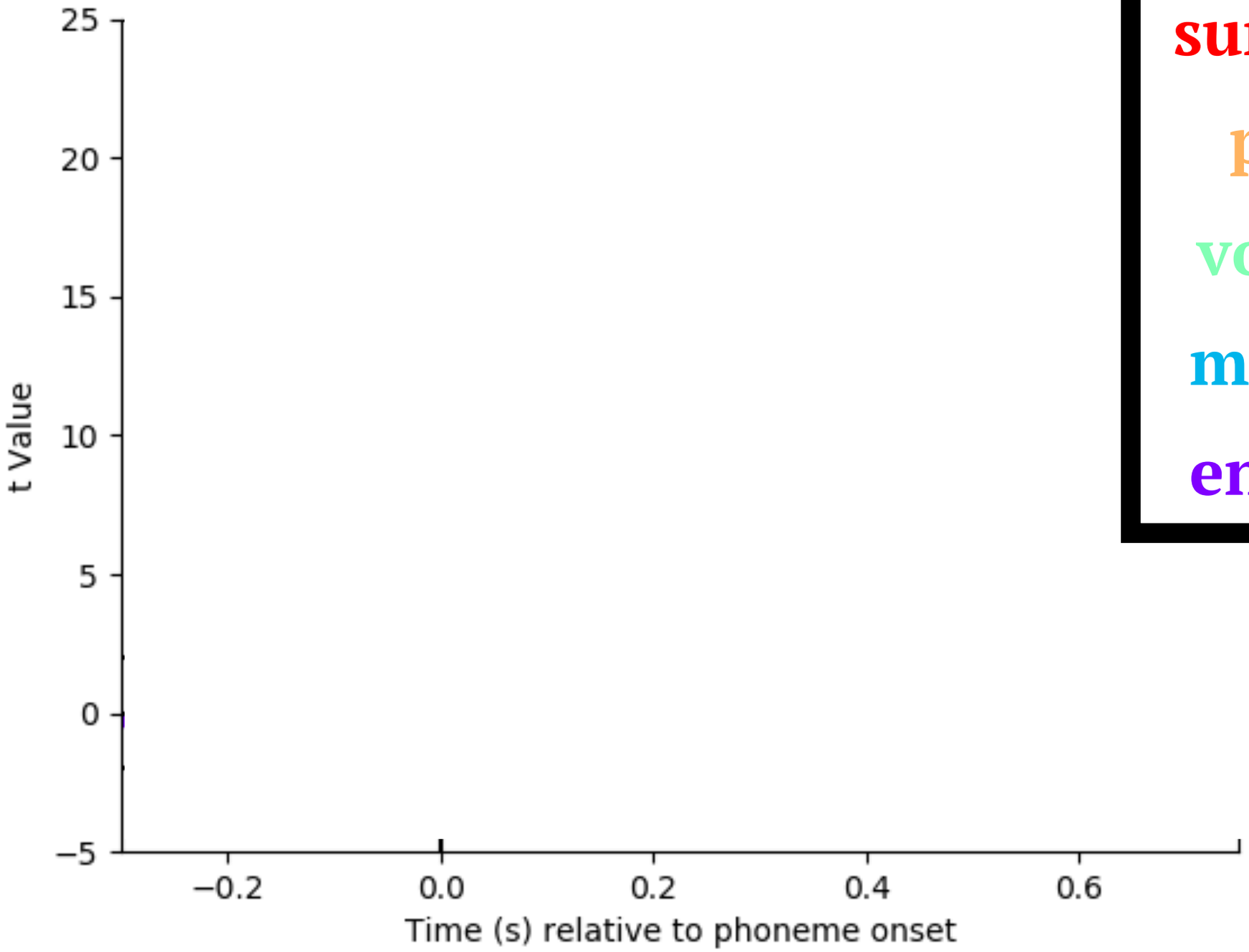
phonetic

MEG

auditory

Laura Gwilliams | New York University | @GwilliamsL

Phoneme-locked analysis: Phonetic properties



surprisal

place

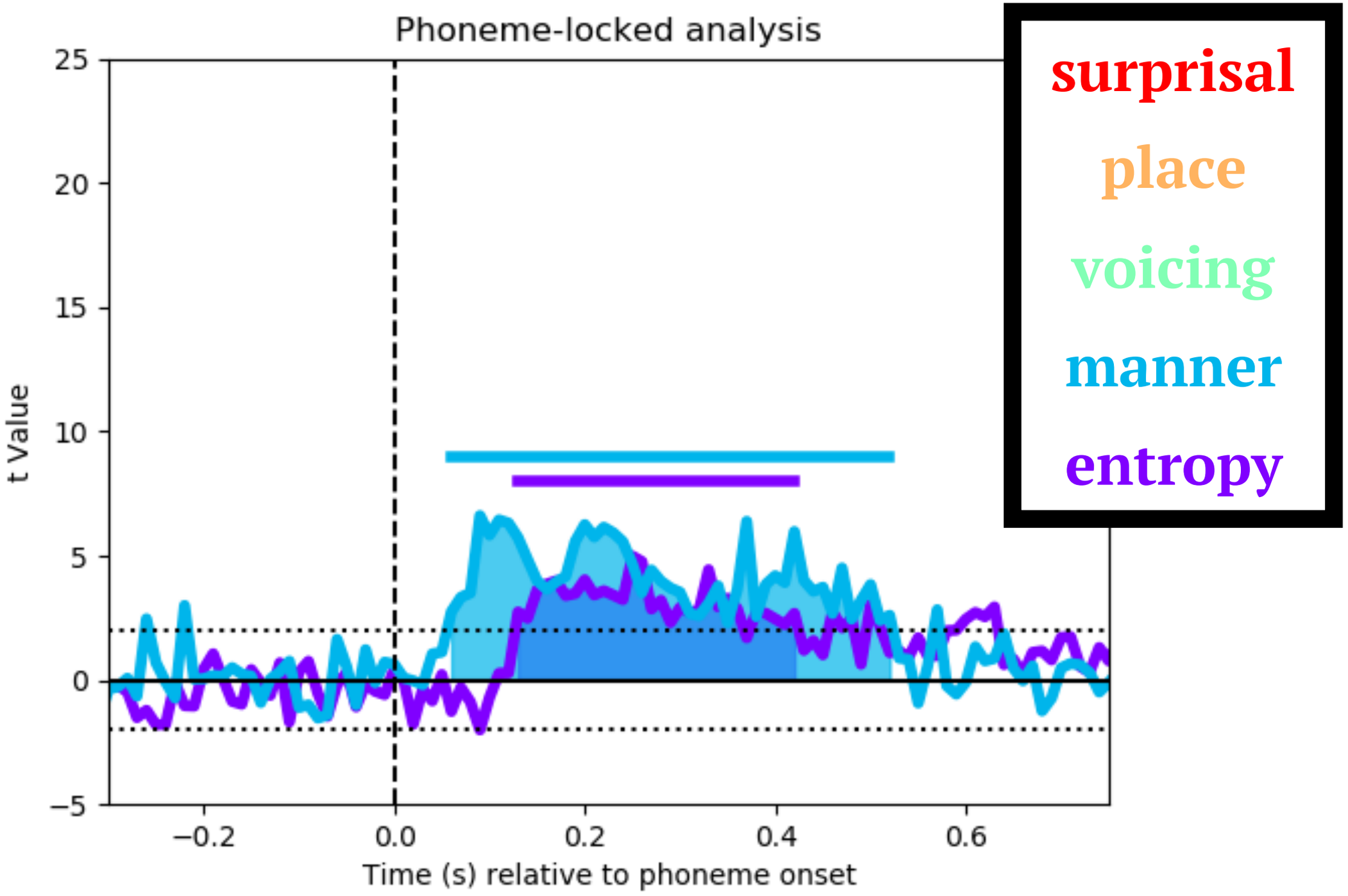
voicing

manner

entropy

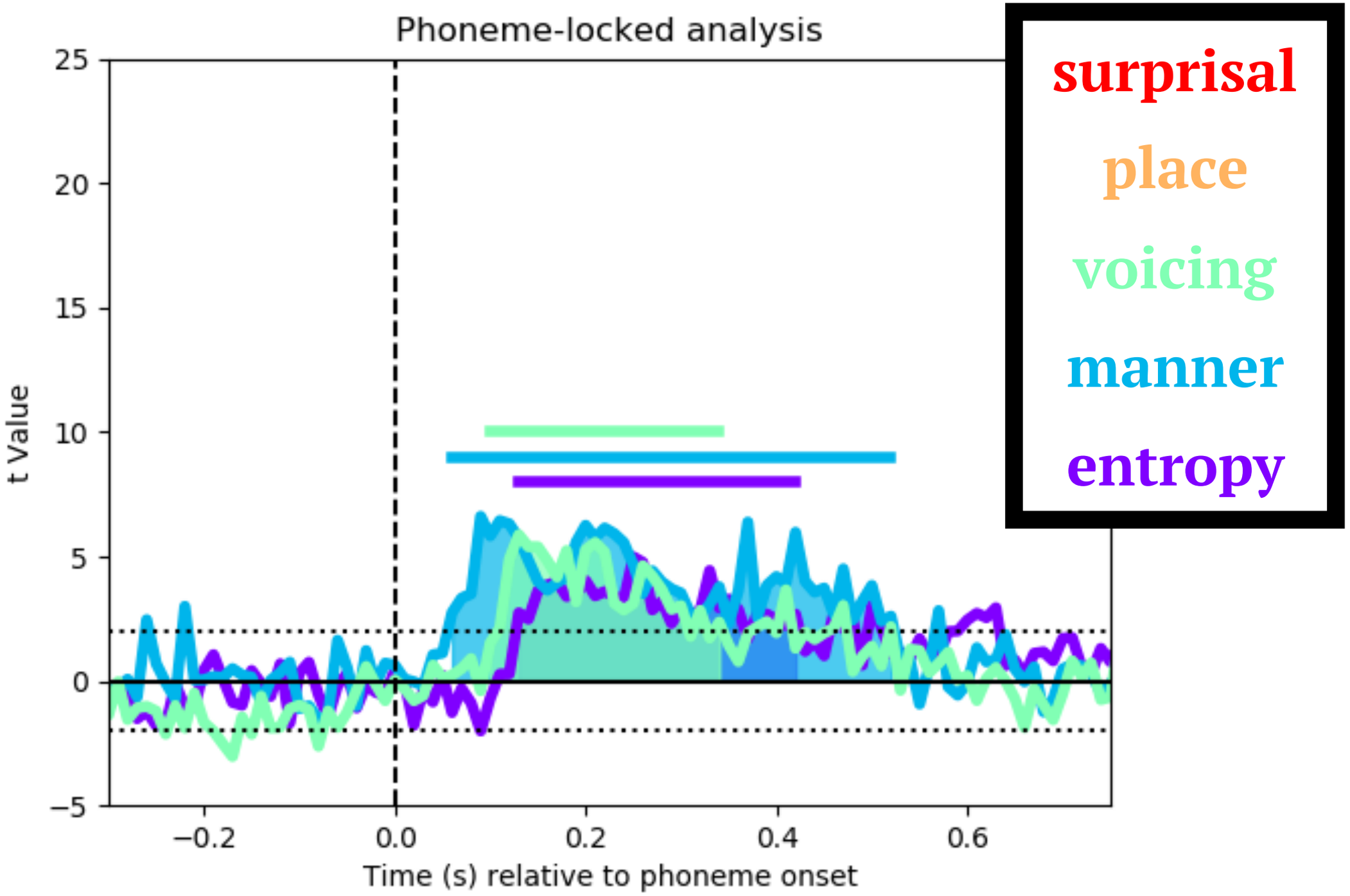
Laura Gwilliams | **New York University** | **@GwilliamsL**

Phoneme-locked analysis: Phonetic properties



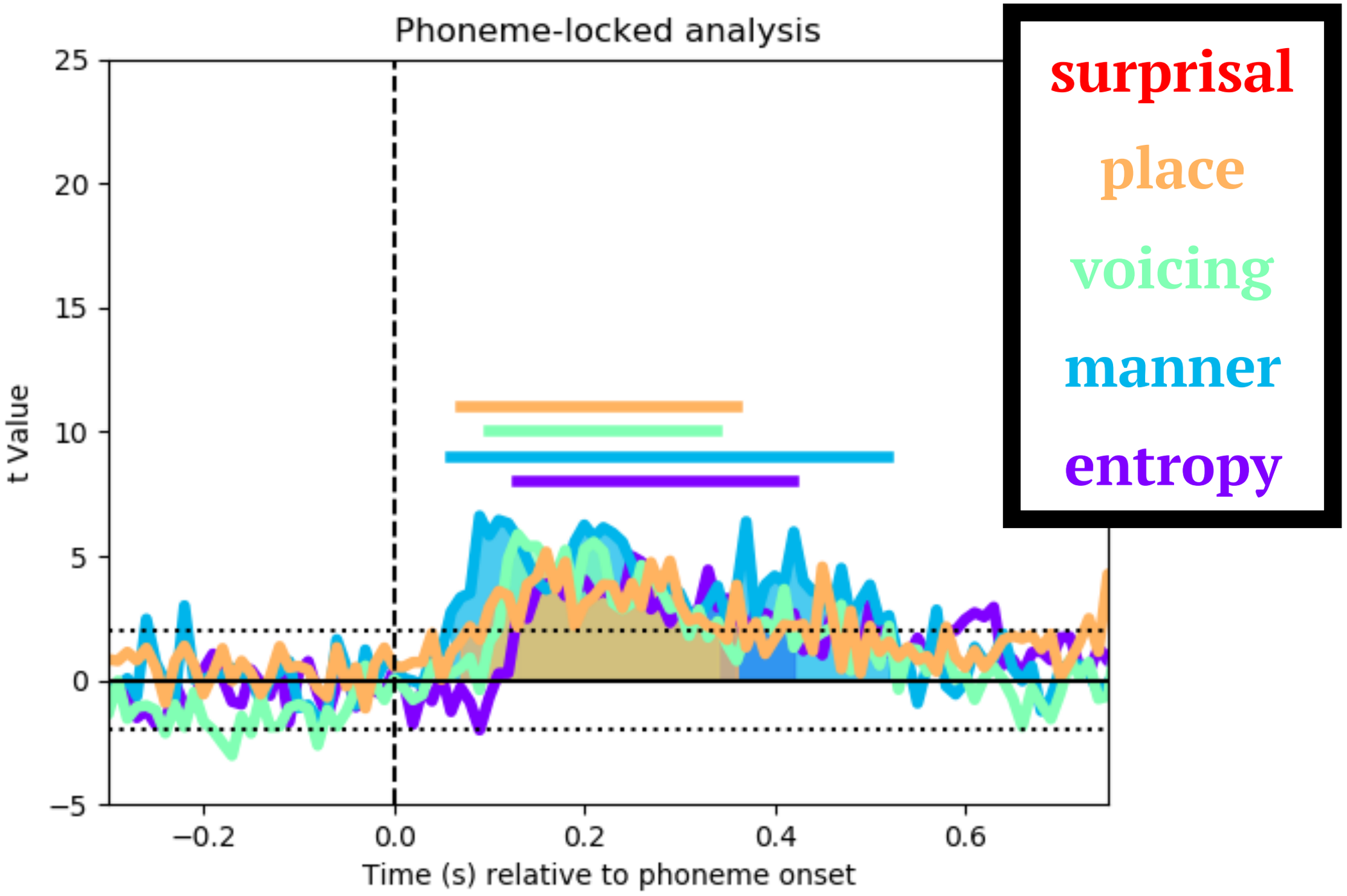
Laura Gwilliams | New York University | @GwilliamsL

Phoneme-locked analysis: Phonetic properties



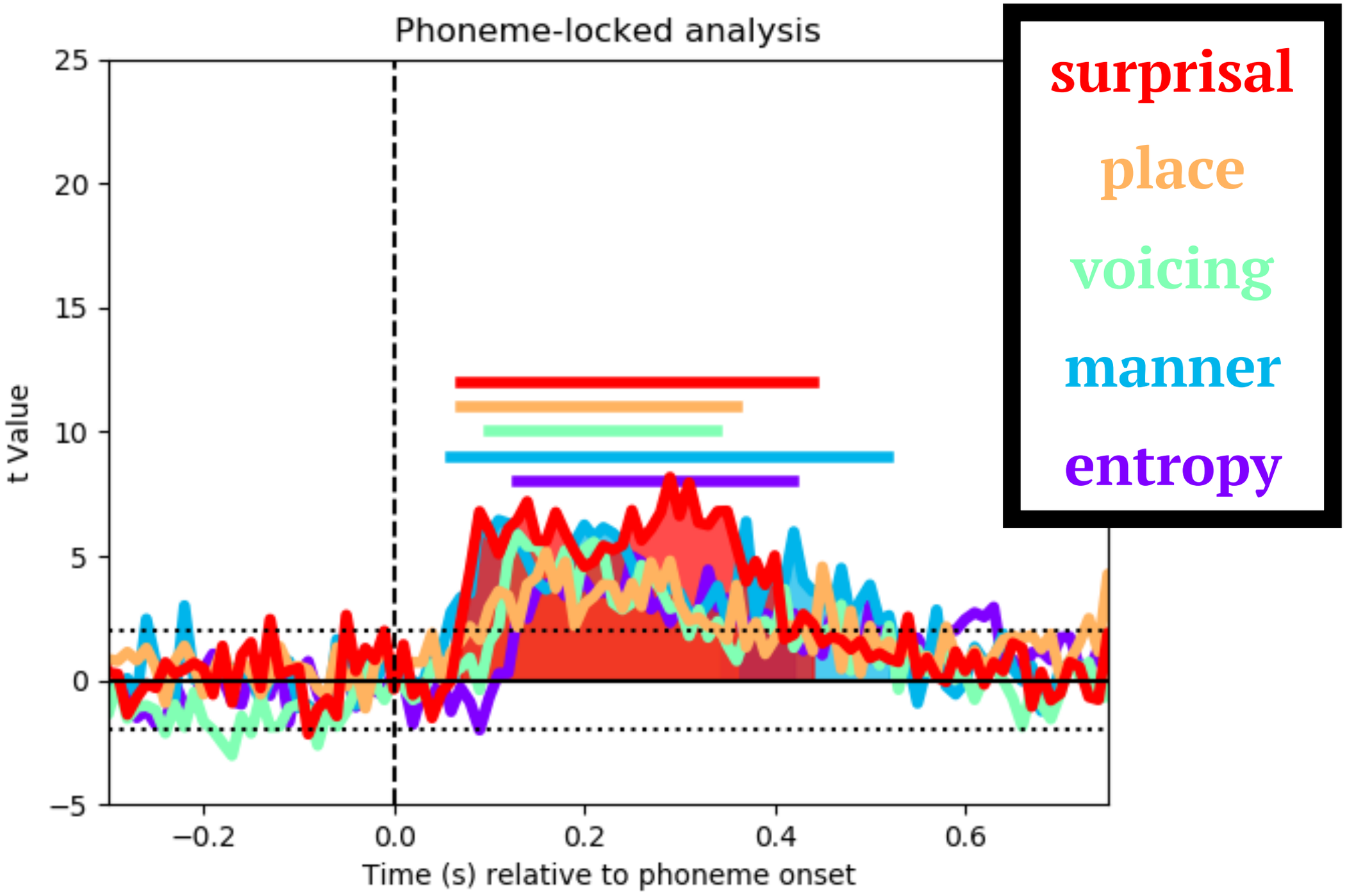
Laura Gwilliams | New York University | @GwilliamsL

Phoneme-locked analysis: Phonetic properties



Laura Gwilliams | New York University | @GwilliamsL

Phoneme-locked analysis: Phonetic properties



Laura Gwilliams | New York University | @GwilliamsL

Across timescales

phrasal

lexical

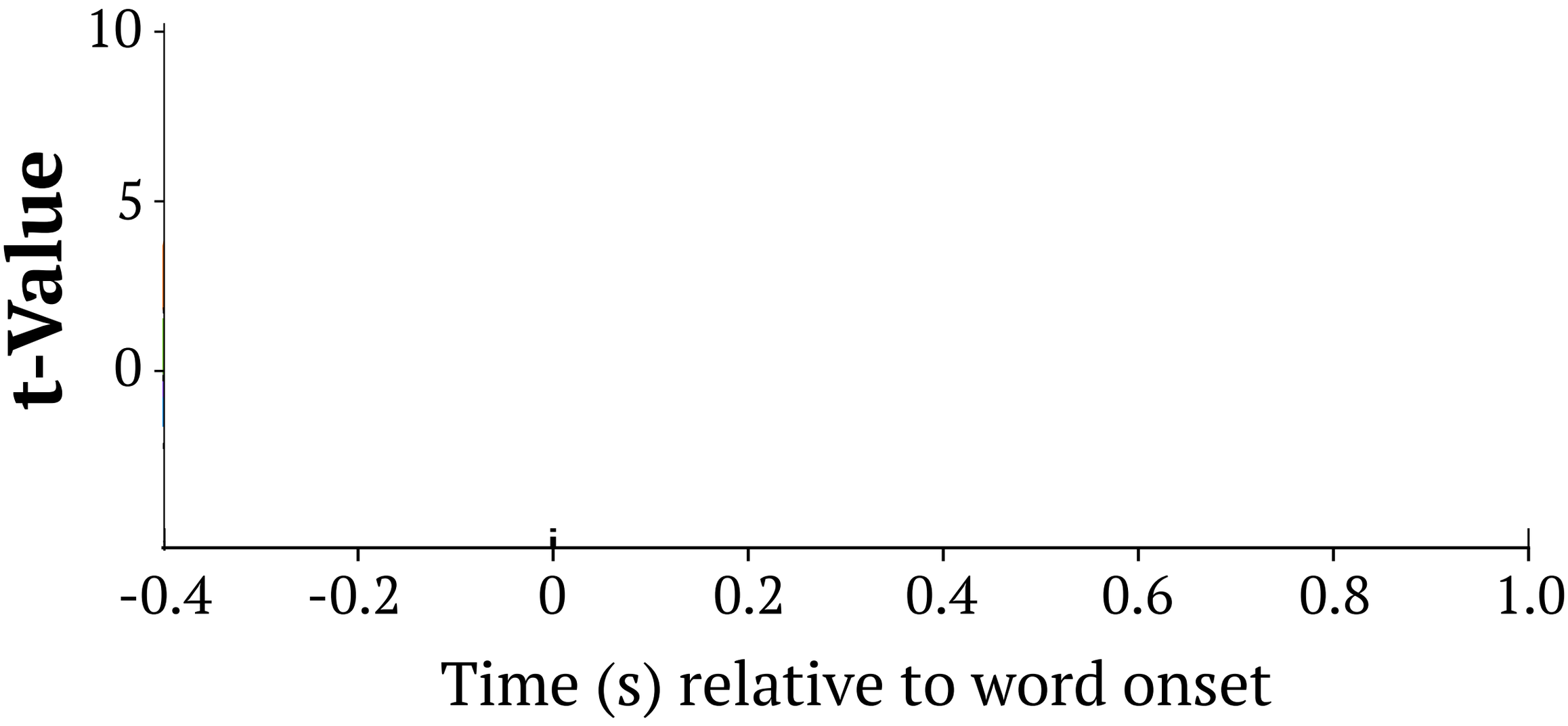
phonetic

MEG

auditory

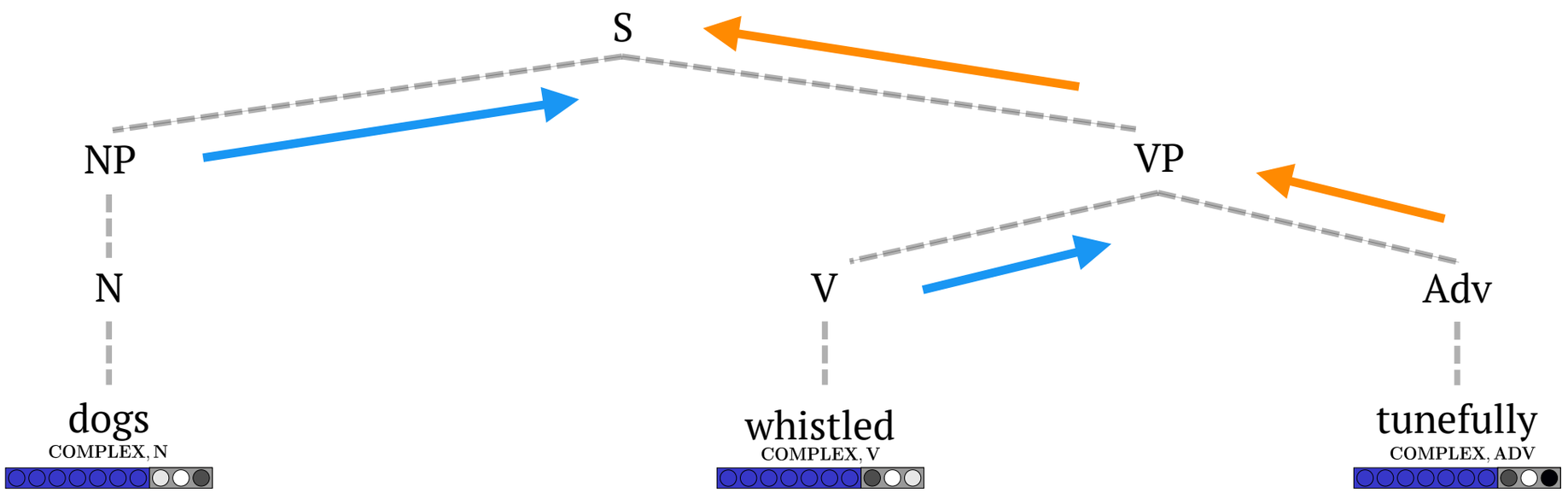
Laura Gwilliams | **New York University** | **@GwilliamsL**

Word-locked analysis: lexical properties



Laura Gwilliams | **New York University** | **@GwilliamsL**

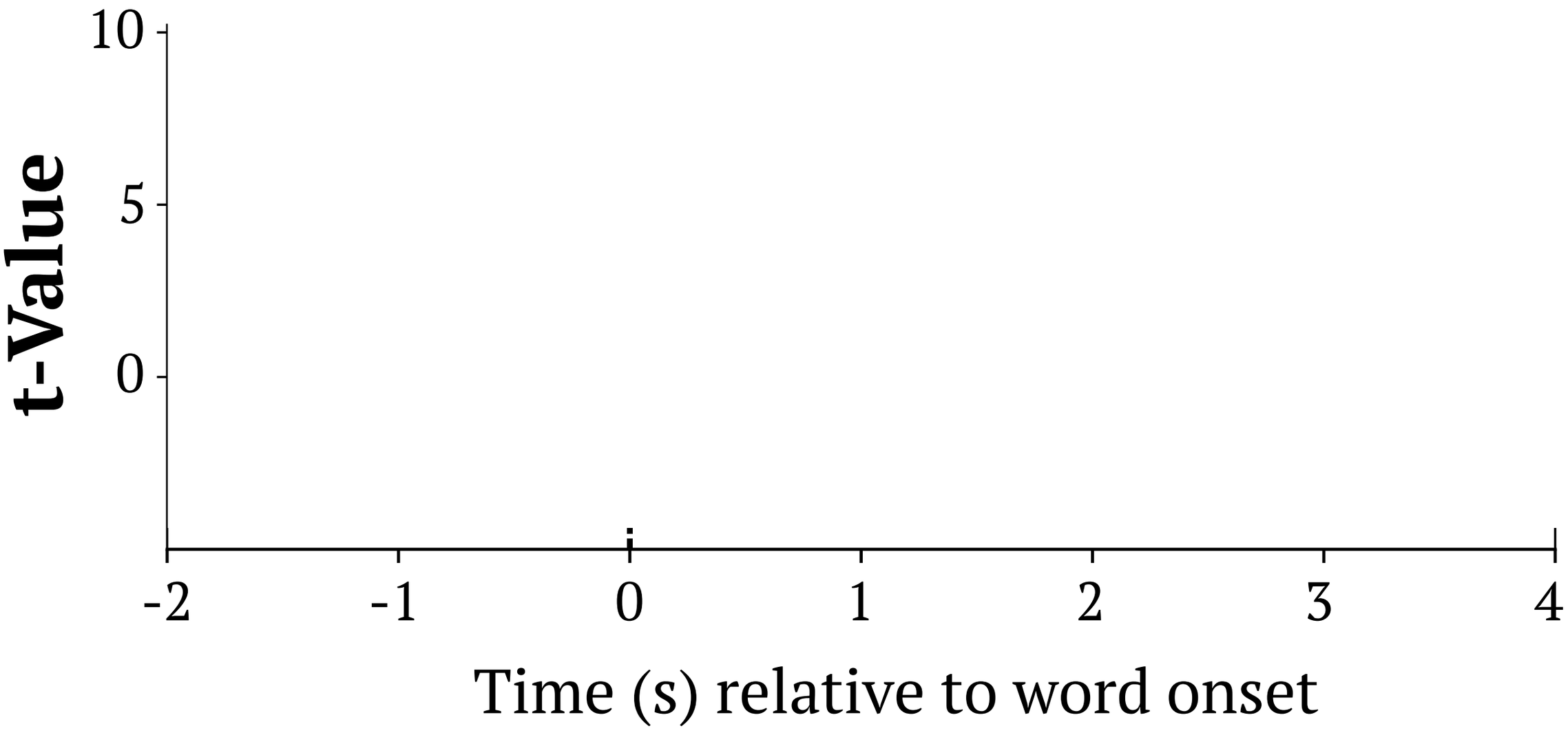
Word-locked analysis: syntactic operations



sentence final word
no. closing nodes
no. opening nodes
word position in sentence

Laura Gwilliams | New York University | @GwilliamsL

Word-locked analysis: syntactic operations



Laura Gwilliams | **New York University** | **@GwilliamsL**

Discussion

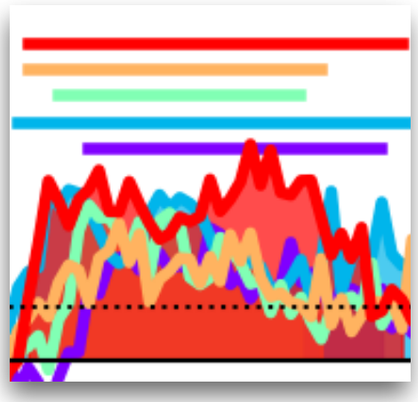
(1) Which linguistic units are encoded?

- Multiple features, **spanning the hierarchy**
- Including # of **syllables**; # of **morphemes**

depth of tree
word position
# of merges
opening nodes
word frequency
phon. neighbourhood
# of morphemes
# of syllables

(2) What is the relative time-course?

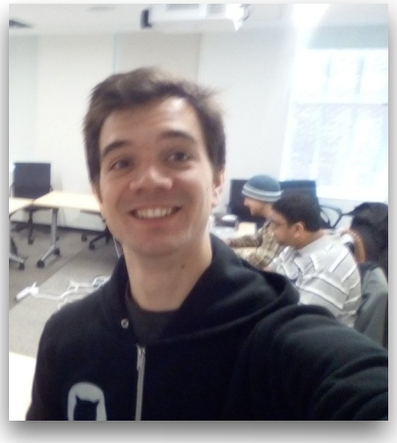
- Overall a highly **parallel** architecture



With big thanks to:

- My supervisors, **Alec Marantz** and **David Poeppel**, as well as everyone in the **Neuroscience of Language Lab** and **Poeppel Lab**!





جامعة نيويورك أبوظبي
NYU | ABU DHABI

NYU

NIH: 2R01DC05660
Abu Dhabi Institute: G1001

Laura Gwilliams | New York University | @GwilliamsL

laura.gwilliams@nyu.edu
@GwilliamsL