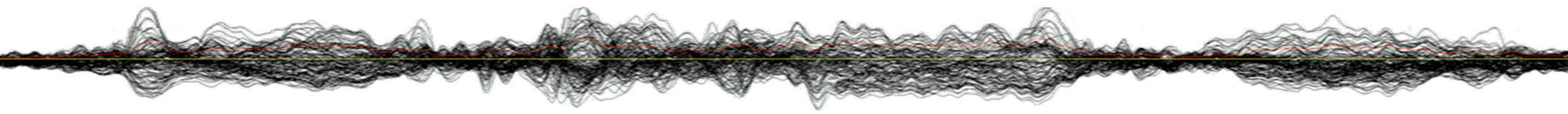
Tracking lexical garden-path resolution with MEG: Phonological commitment and sensitivity to subphonemic detail are independent

Laura Gwilliams, Tal Linzen, Kyriaki Neophytou,
David Poeppel & Alec Marantz



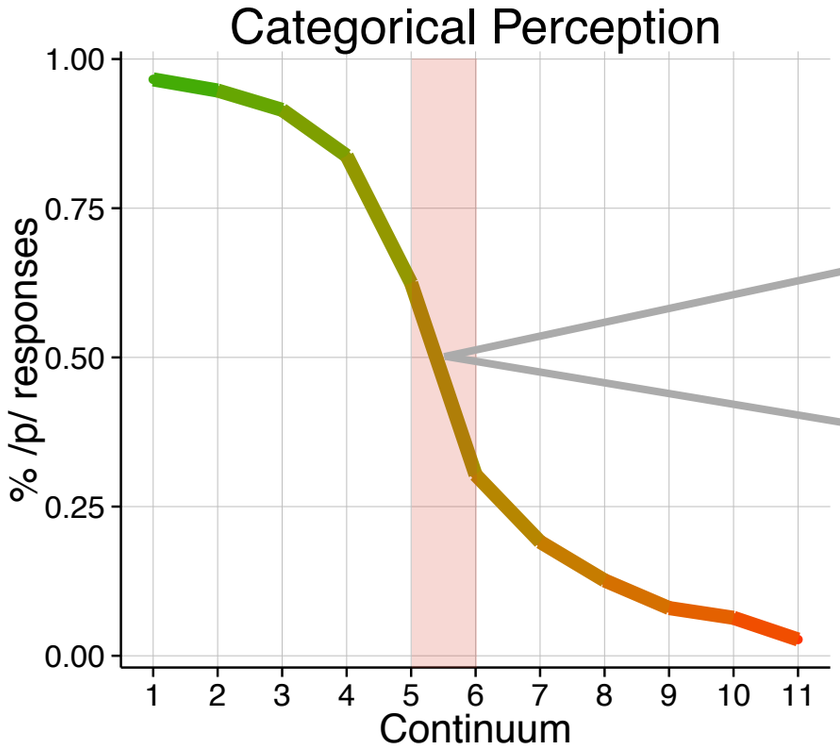
Challenge of Speech Comprehension

- Speech is an inherently **noisy and ambiguous** signal

- To fluently derive meaning, listeners must **integrate top-down** contextual information to guide their interpretation

- Top-down input occurring *after* an acoustic signal can be integrated to **affect the perception of earlier sounds** (Connine et al., 1991; Samuel, 1981; Szostak & Pitt, 2013; Warren & Sherman, 1974)

Challenge of Speech Comprehension



p

b

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(this is a parakeet)

(this is a barricade)

“**P**oint **o**f **D**isambiguation” (POD)

Today's Questions

- How does the auditory system respond to phonological ambiguity?

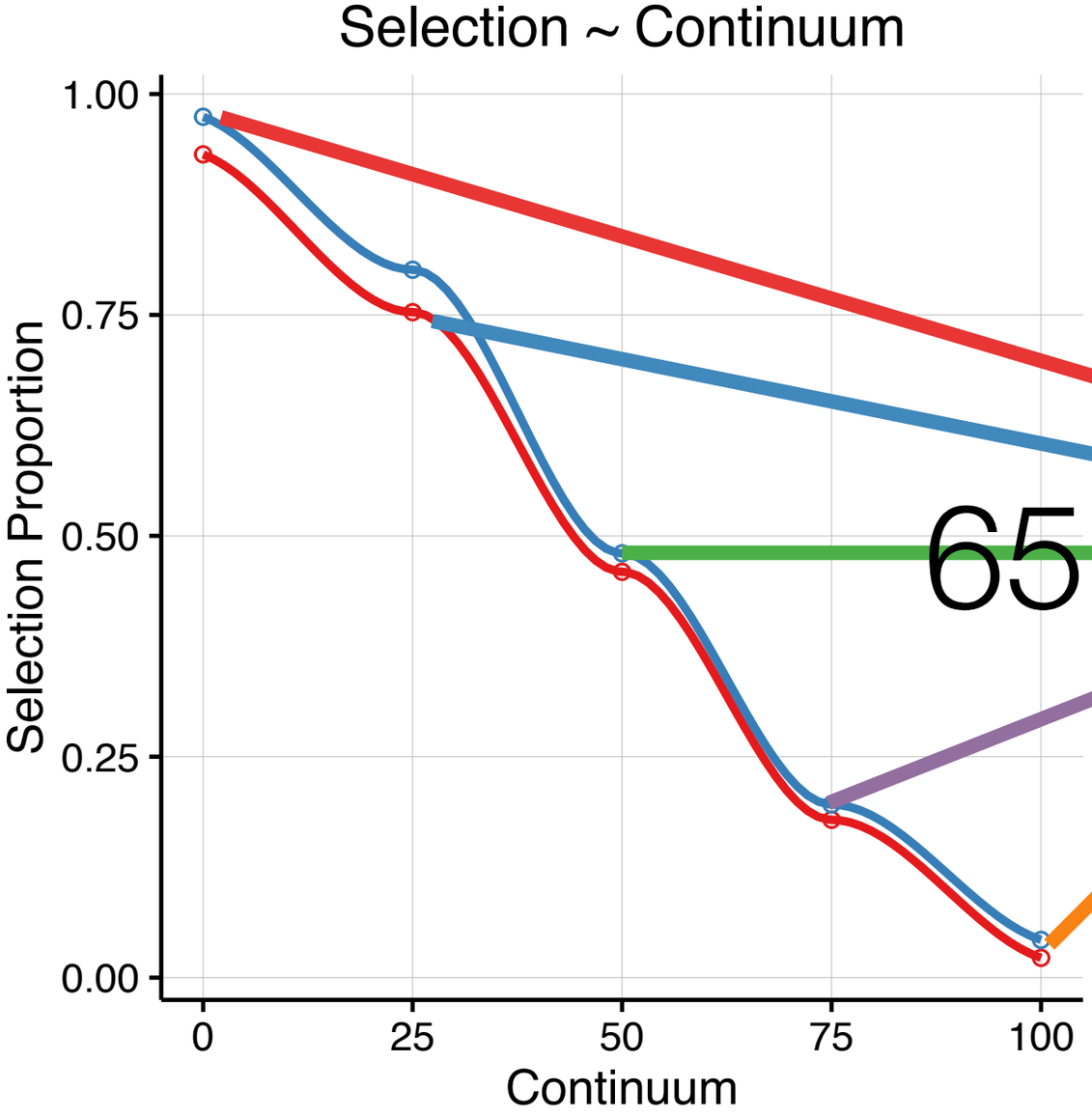
- What mechanism(s) uphold subsequent context integration to resolve bottom-up ambiguity?

- Is there a time-limit on how late subsequent context can be received?

Technique: MEG

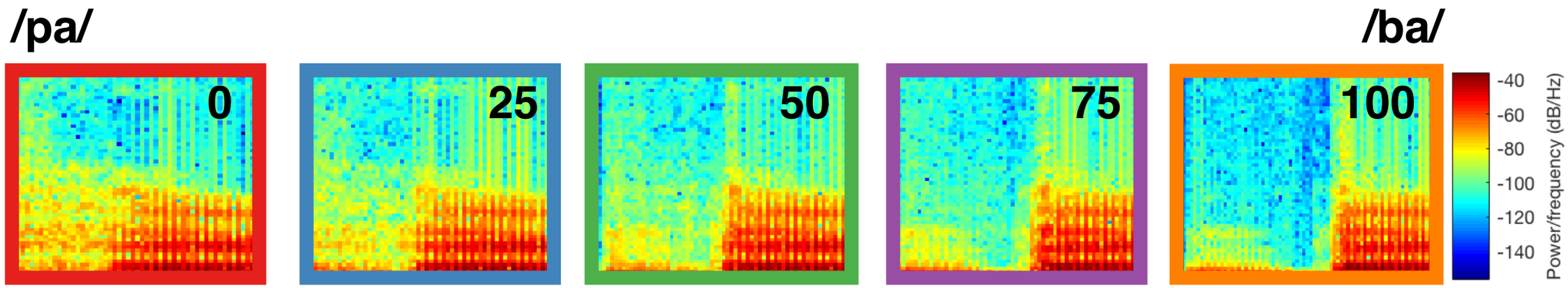
Source gallica.bnf.fr / Bibliothèque nationale de France

Design & Materials



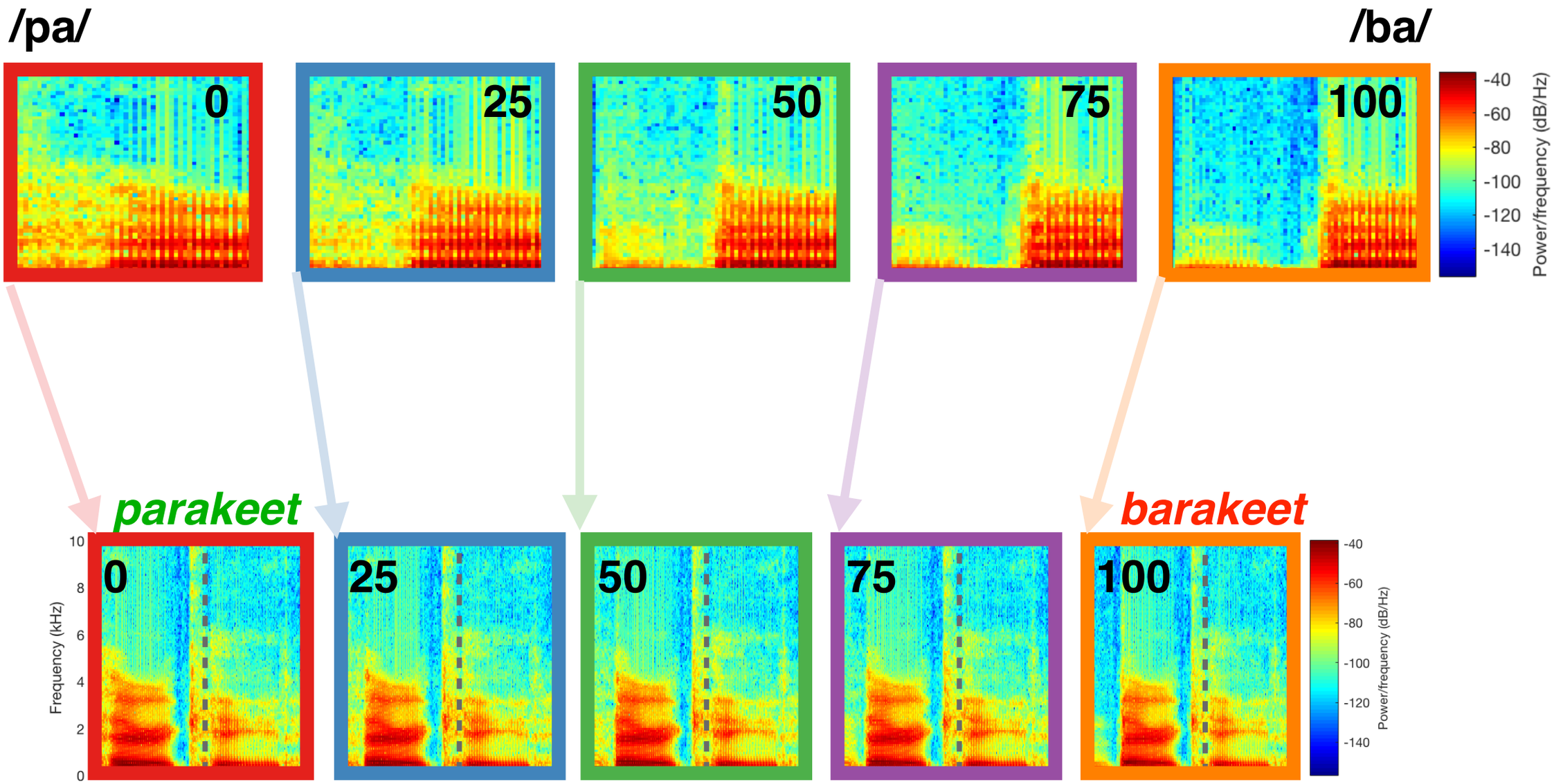
(see also McMurray et al., 2009)

Experiment 1: Design & Materials

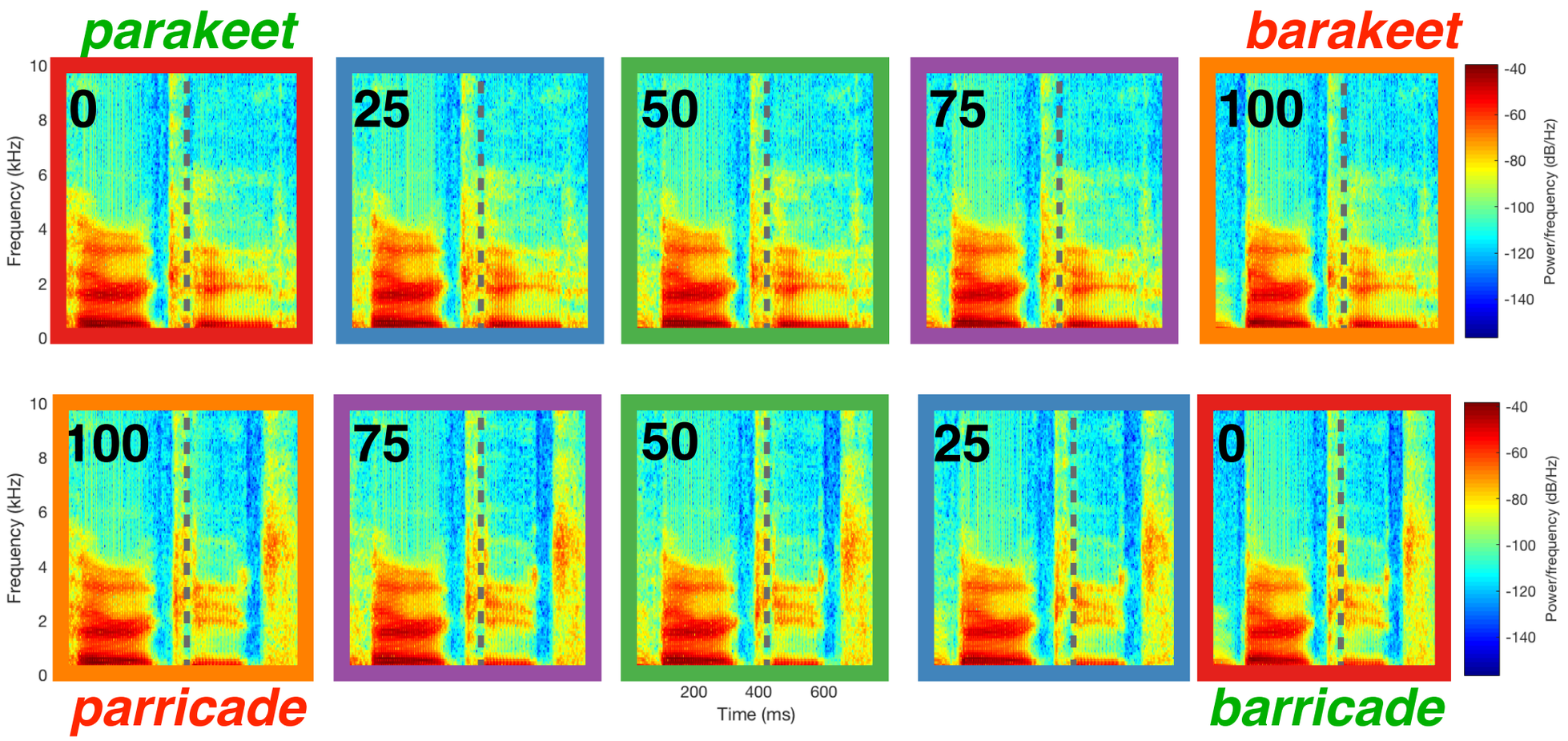


- VOT (31 pairs) {p-b, t-d, k-g} and PoA (22 pairs) {t-k, p-t}

Experiment 2: Design & Materials



Experiment 2: Design & Materials



- Point of Disambiguation (PoD) ranged 3-8 phonemes / 150-750 ms

Procedure & Analysis

Data Collection & Preprocessing

- 25 native English participants in each experiment
- Low pass filter online at 200 Hz
- *MNE-Python* used for preprocessing and source localisation

Analysis

- Multiple regression spatio-temporal cluster test (*Eelbrain*)
  - (for more information see Gwilliams, Lewis & Marantz, 2016 - NeuroImage)
- Corrected for multiple comparisons (Maris & Oostenveld, 2007)

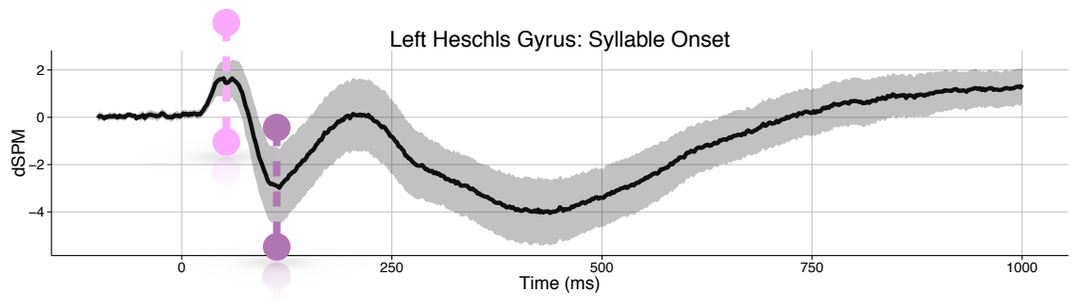
Today's Questions

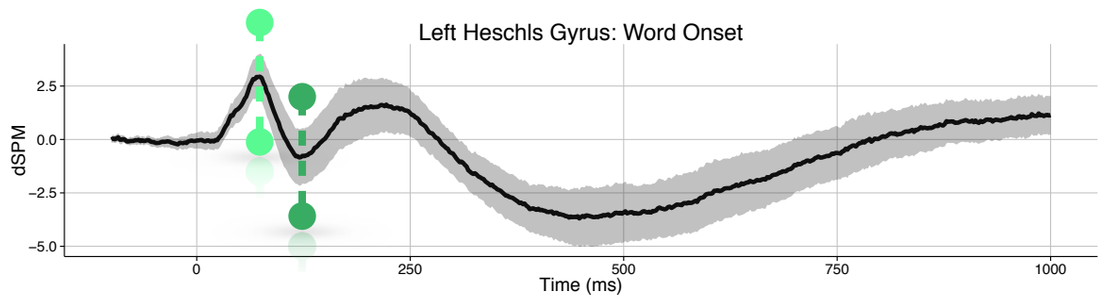
How does the auditory system respond to phonological ambiguity?

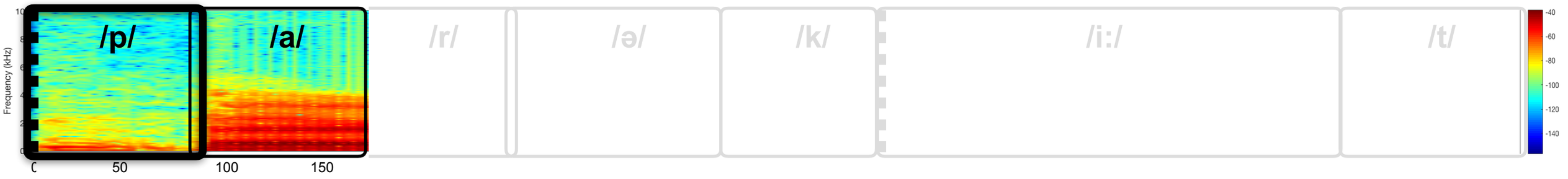
Ambiguity at Onset

Experiment 1: Syllables **Experiment 2: Words**

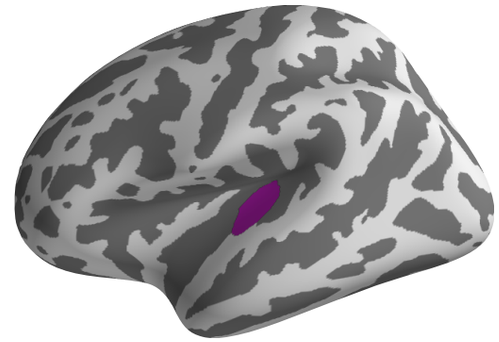
- Time-window: 0-200 ms after syllable/word onset
- Region: Heschl's Gyrus and superior temporal gyrus bilaterally



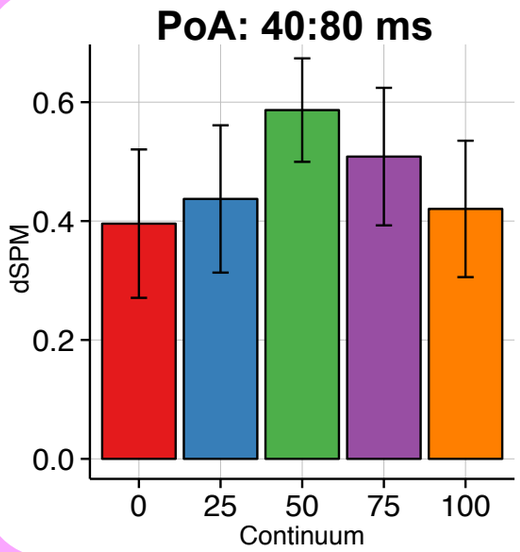


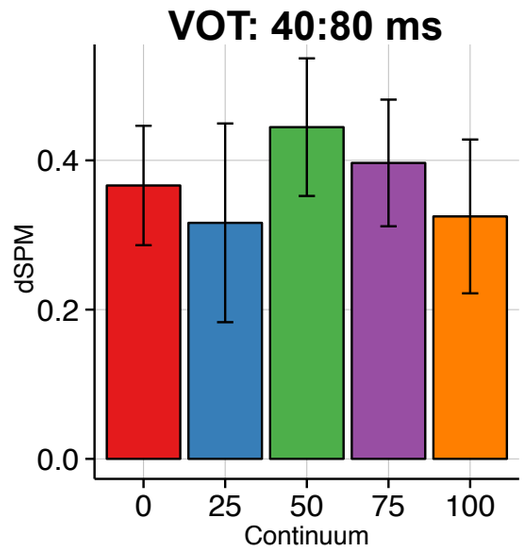


Ambiguity at Onset

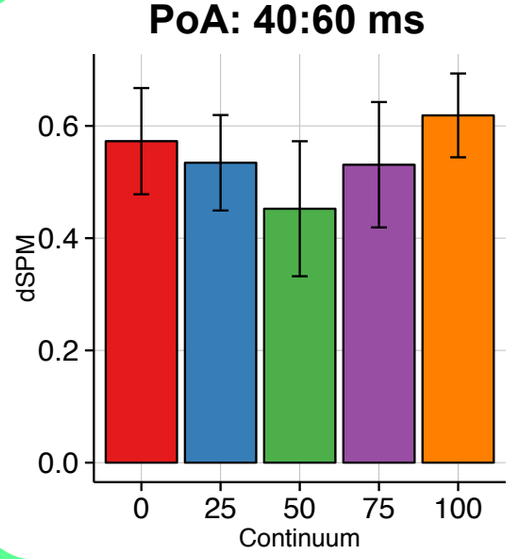


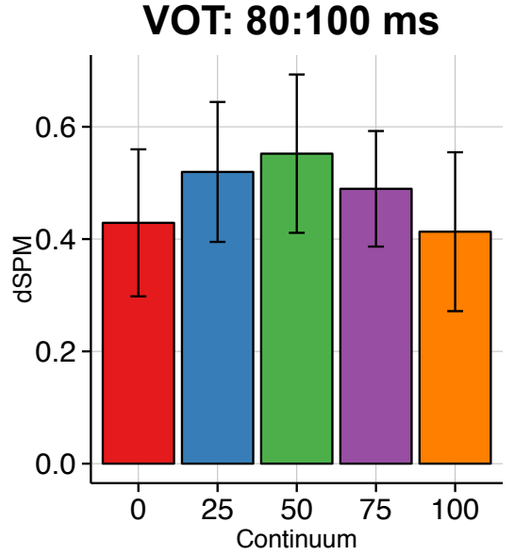
Experiment 1: Syllables

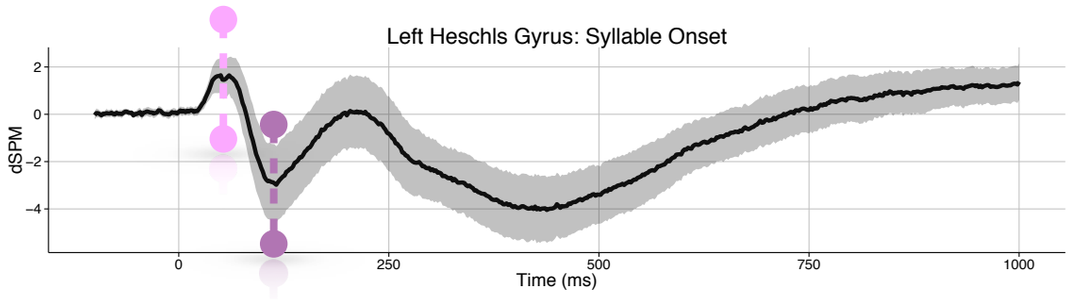


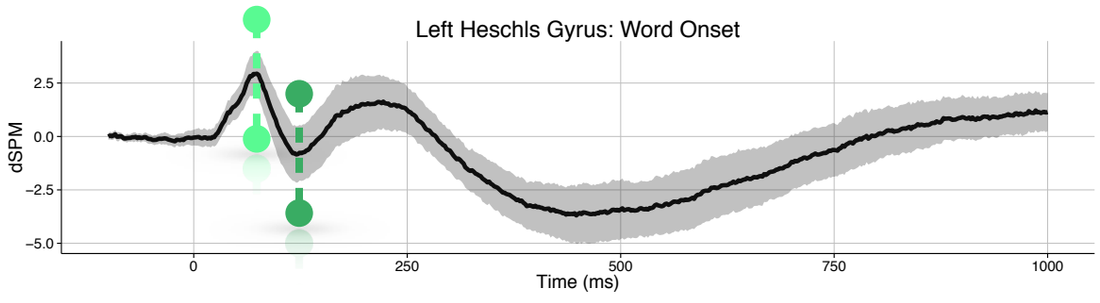


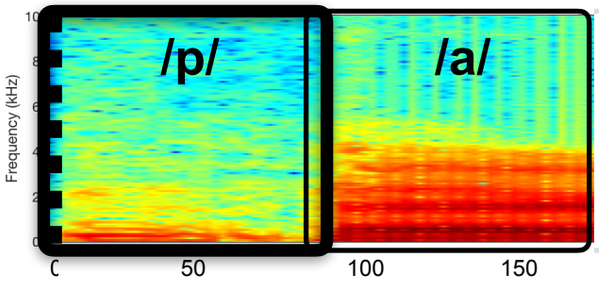
Experiment 2: Words











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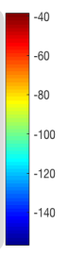

Ambiguity at Onset

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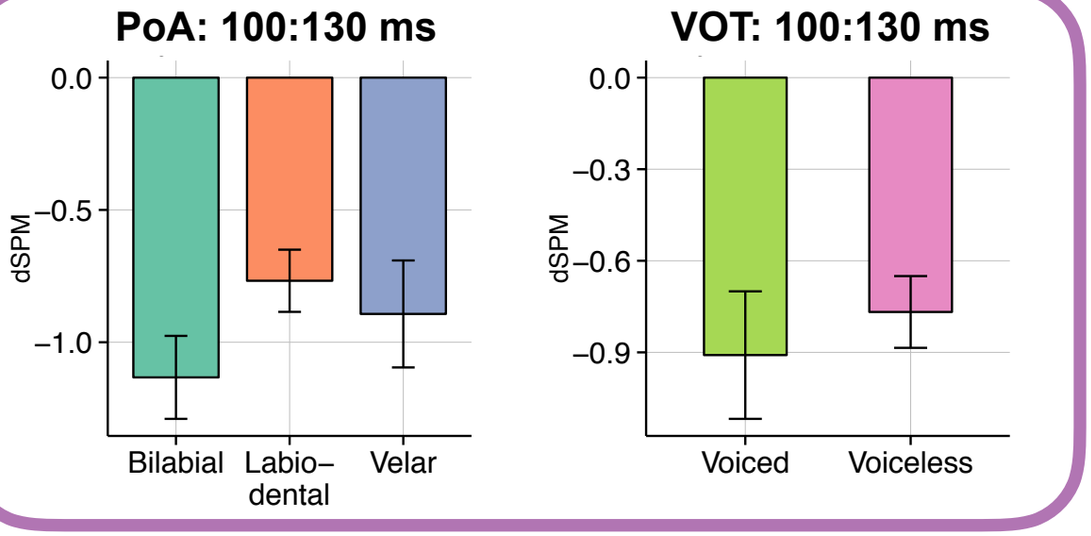
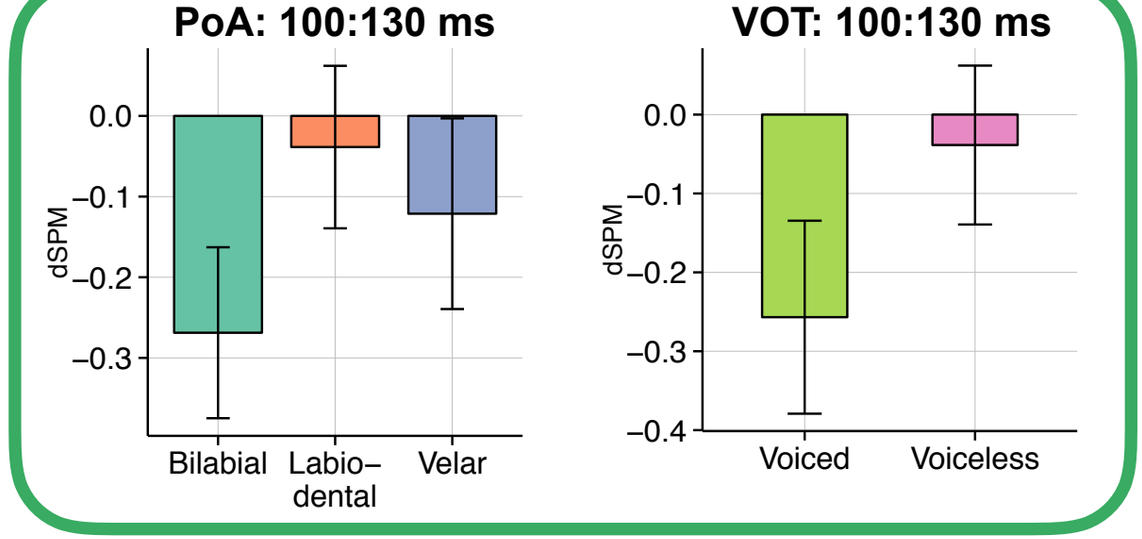
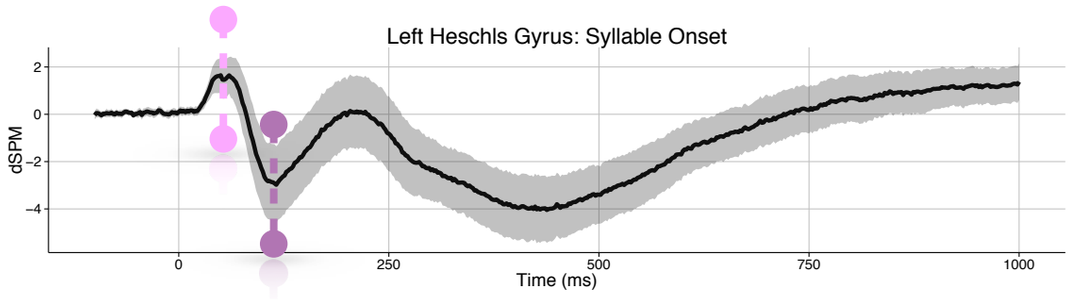
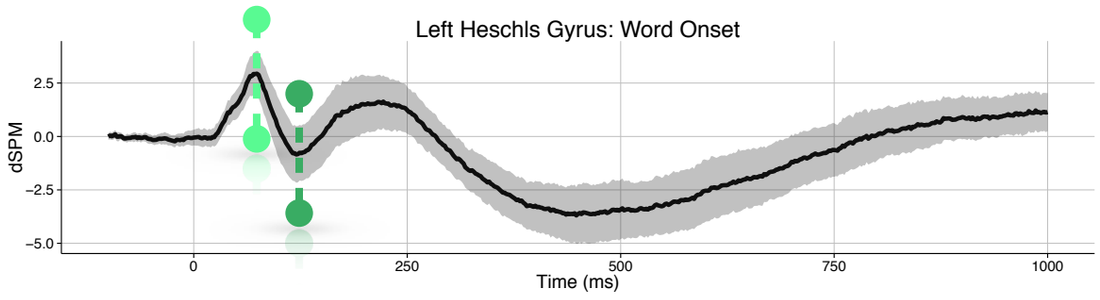
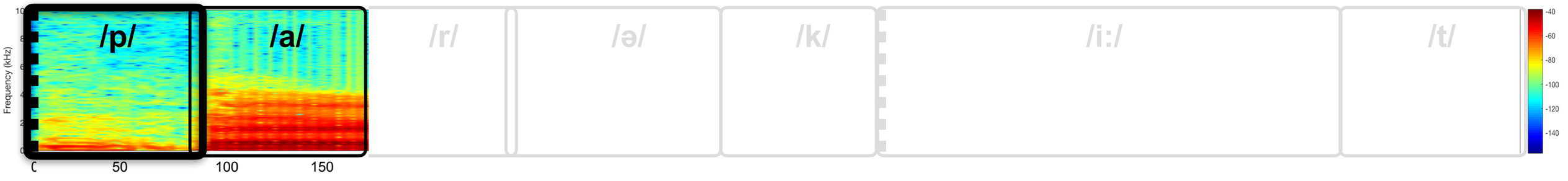


Experiment 2: Words







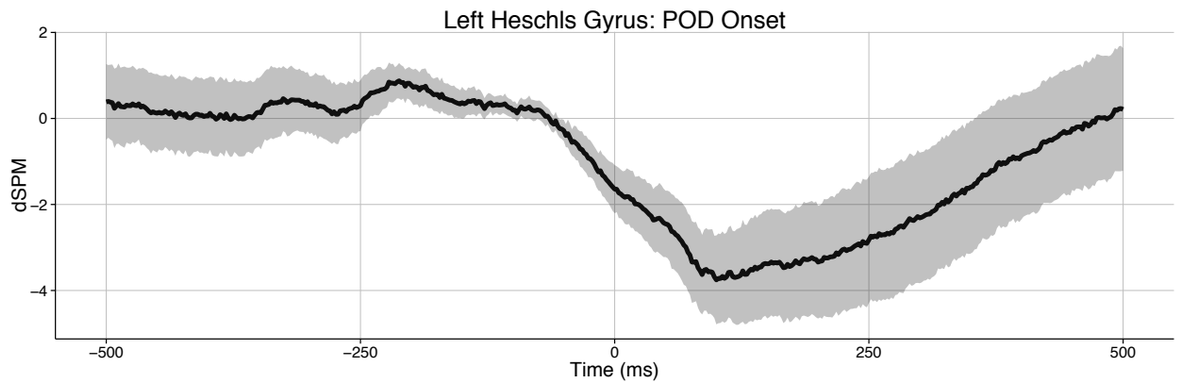


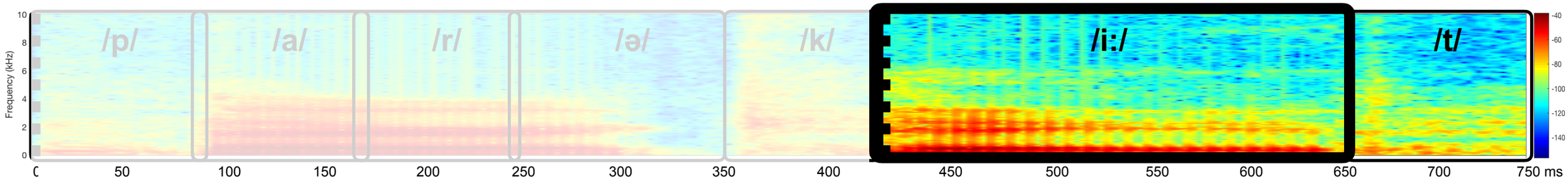
Today's Questions

What mechanism(s) uphold subsequent context integration to resolve bottom-up ambiguity?

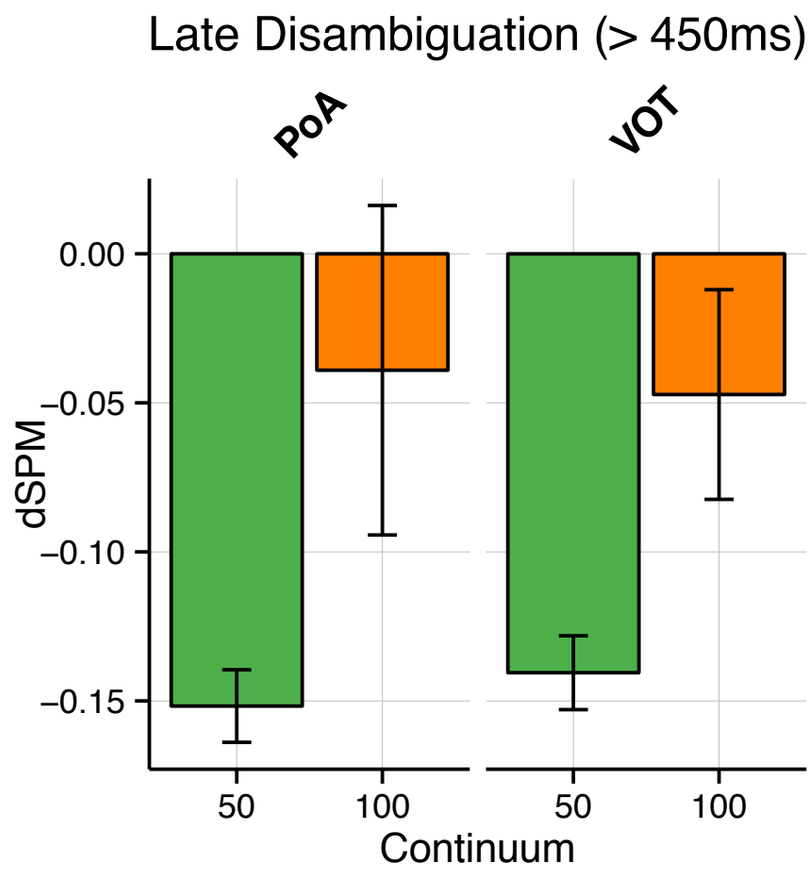
Ambiguity at POD

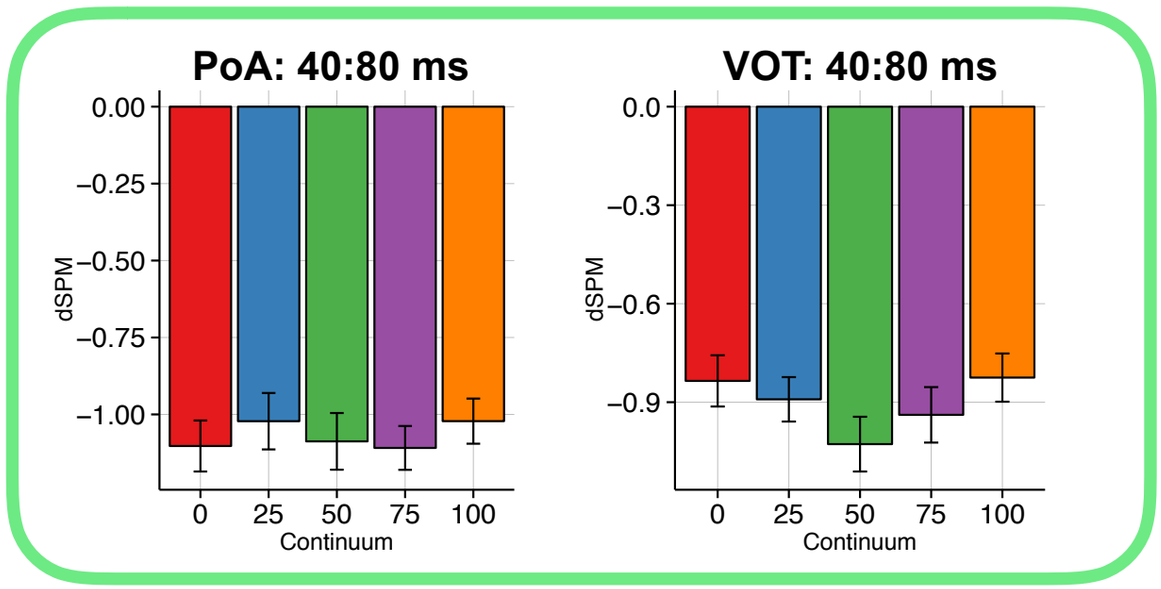
- Time-window: 0-200 ms after POD onset
- Region: Heschl's Gyrus and superior temporal gyrus bilaterally

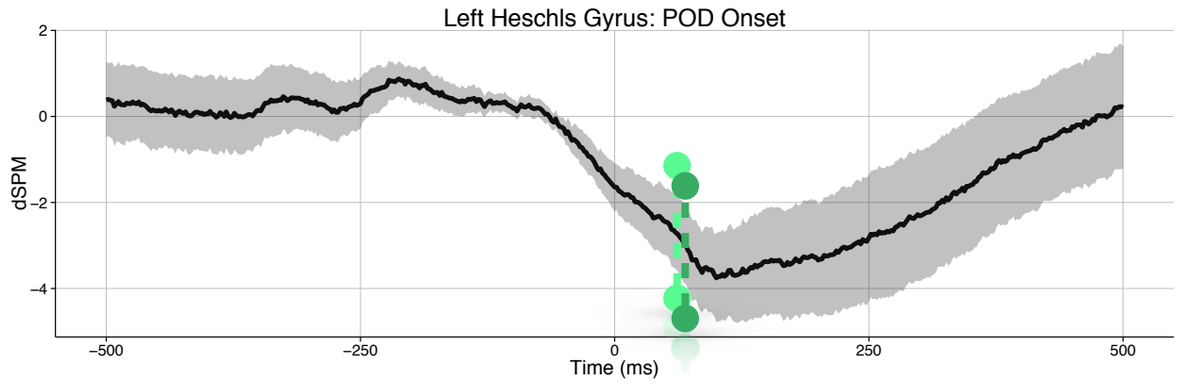


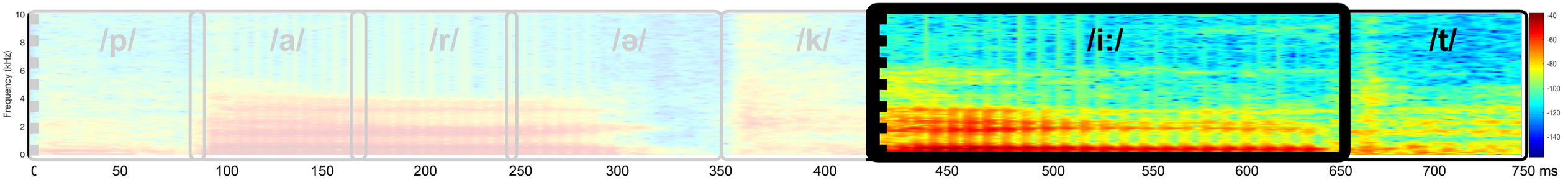


Ambiguity at POD









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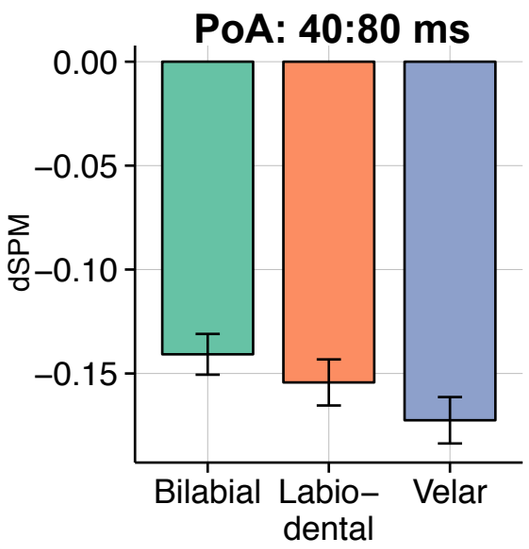
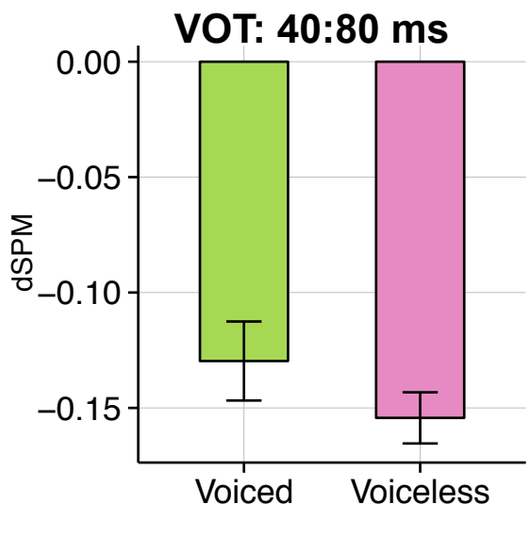
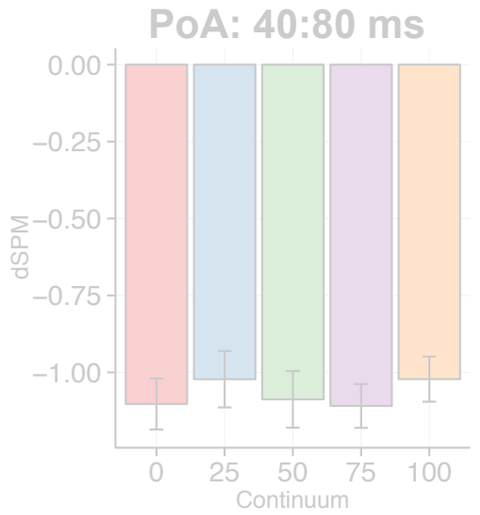
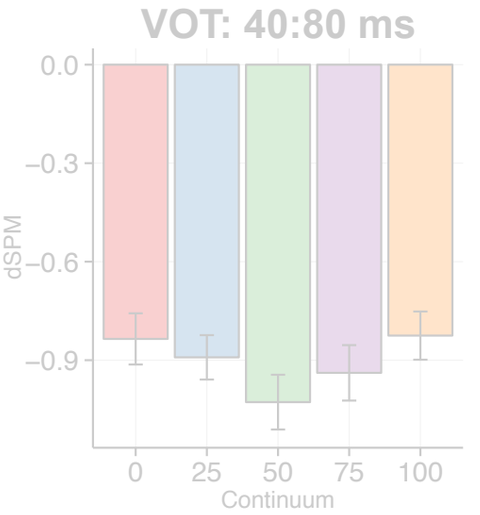
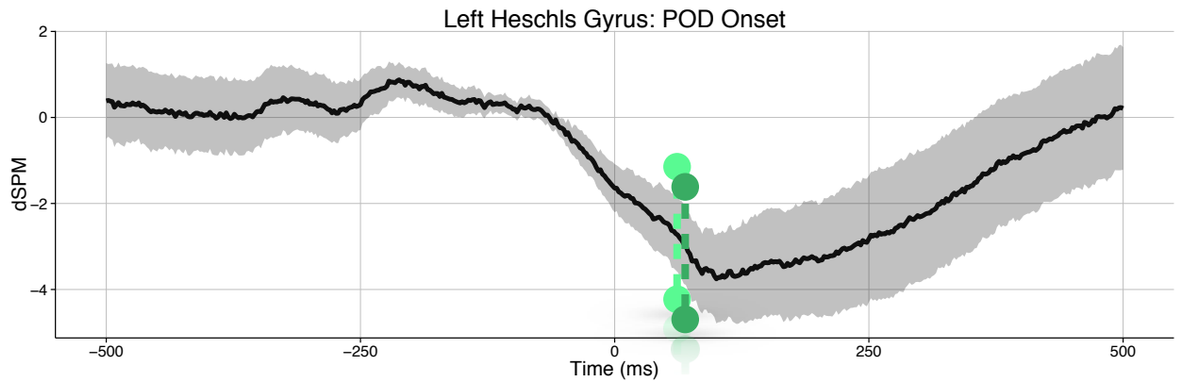


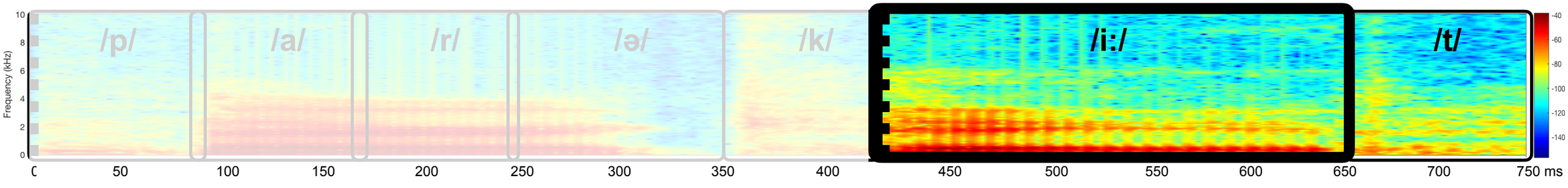






Onset phoneme is “heard again” at disambiguation

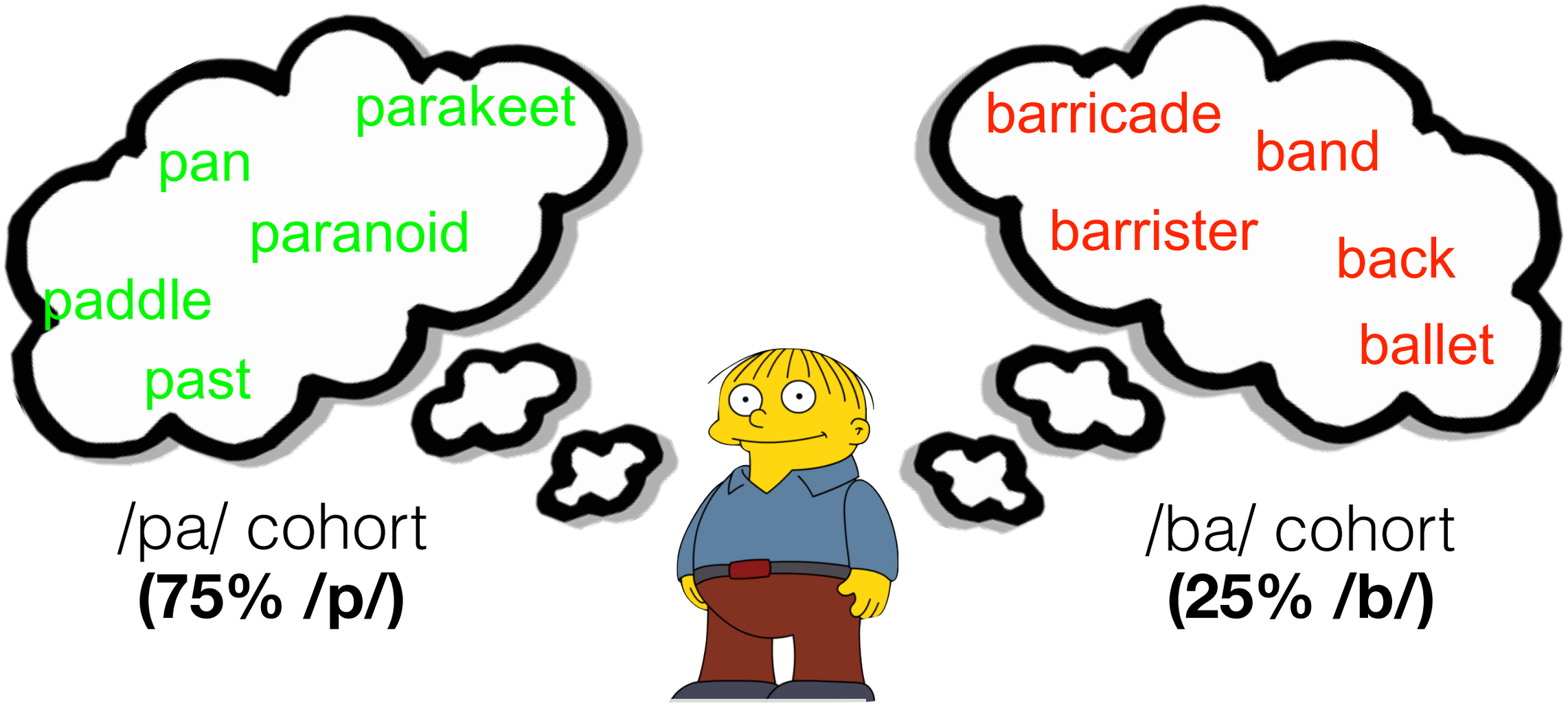




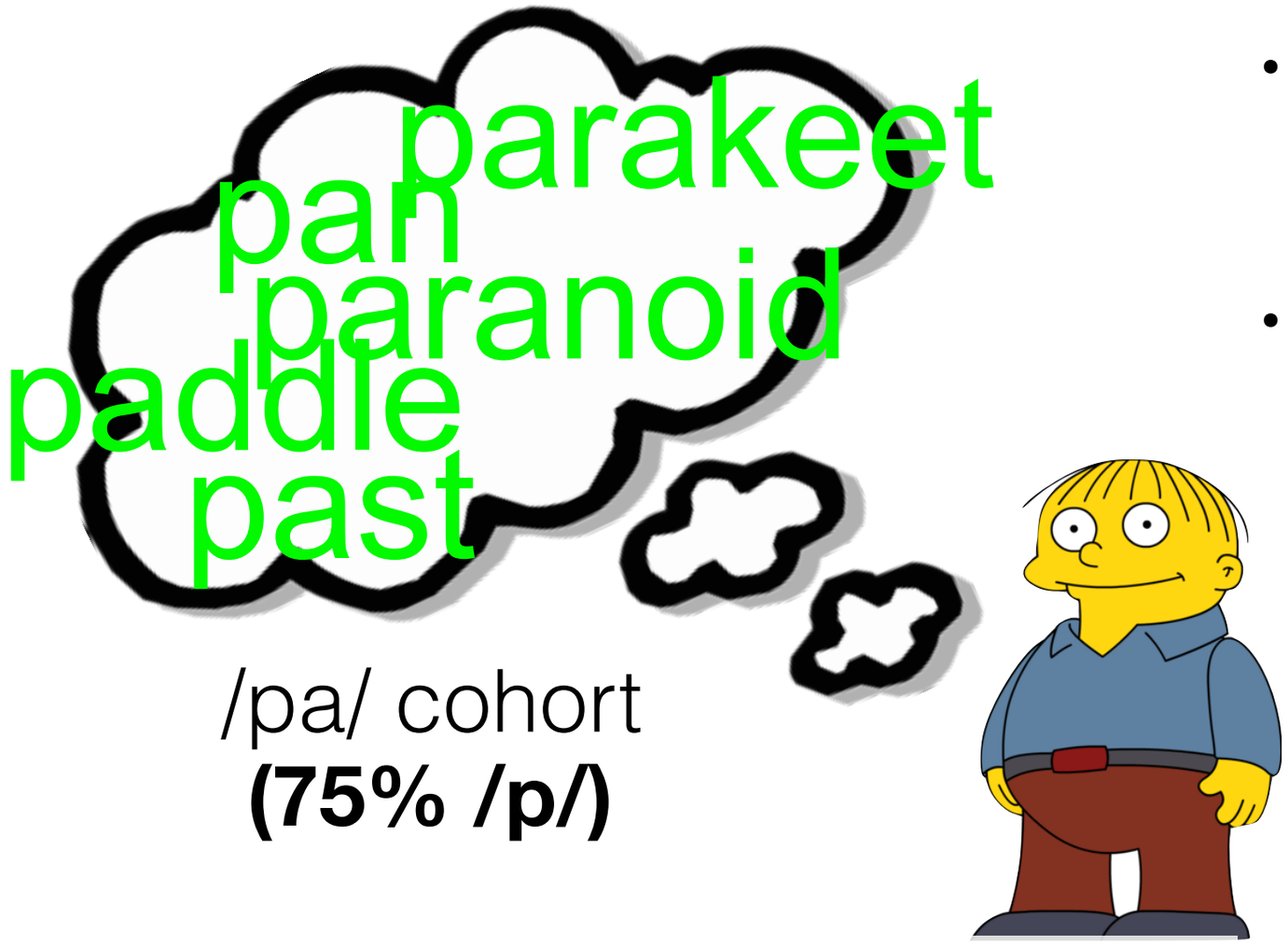
Today's Questions

Is there a time-limit on how late subsequent context can be received?

Commitment Before POD

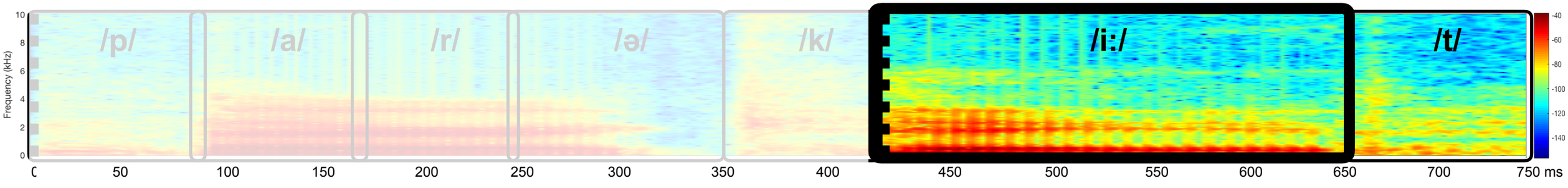


Commitment Before POD

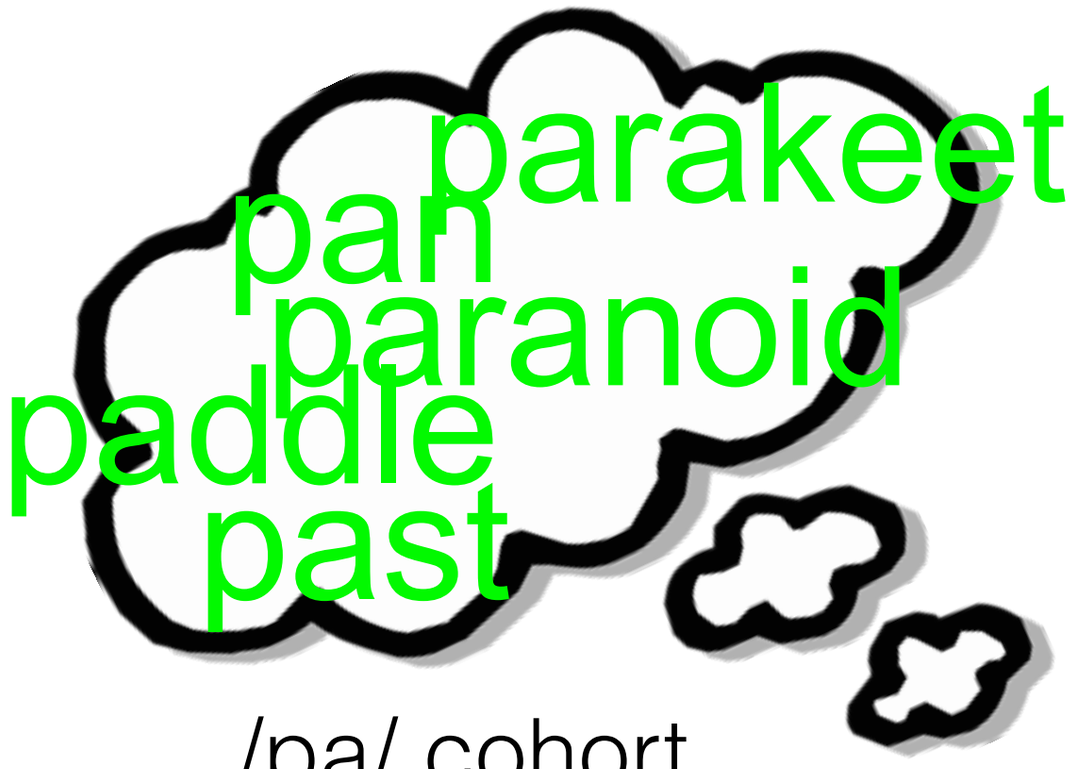


/pa/ cohort
(75% /p/)

- Time-window: 0-400 ms after POD onset
- Region: Heschl's Gyrus, superior and middle temporal gyrus bilaterally



Commitment Before POD



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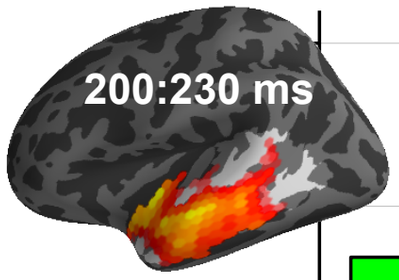
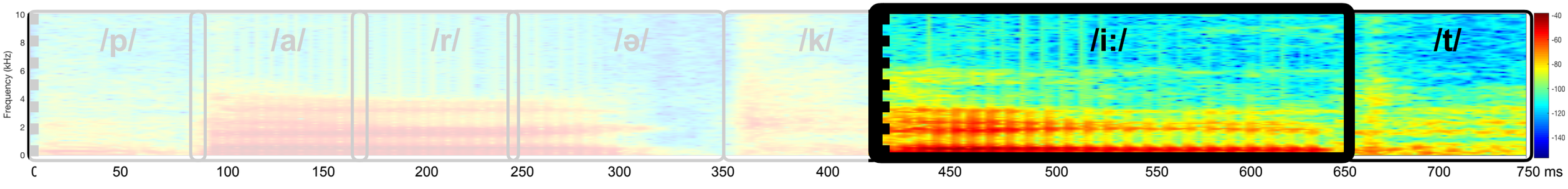
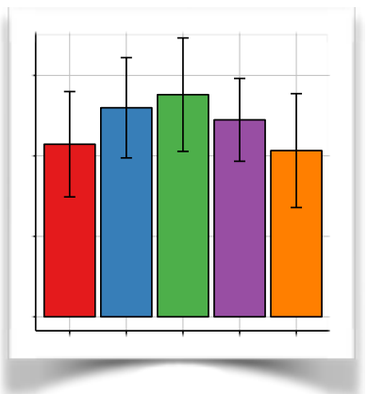


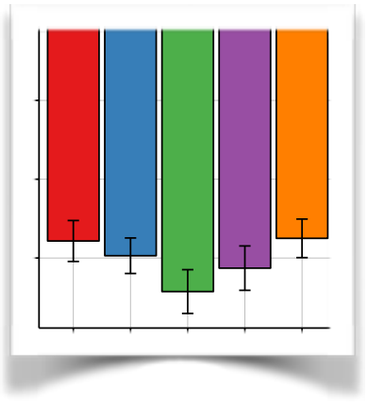


Conclusion

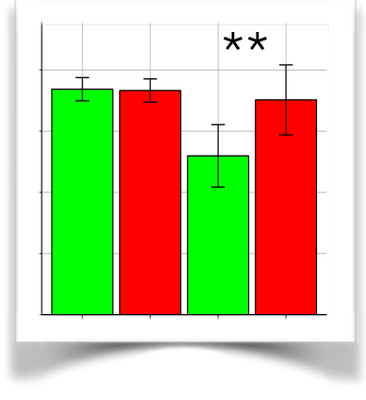
- Sensitivity to phoneme ambiguity ~50 ms after onset in primary auditory cortex



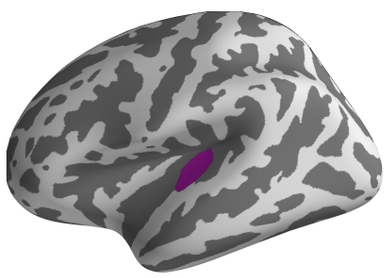
- Subphonemic detail is maintained over long time-scales (+700 ms) and re-evoked at point of disambiguation



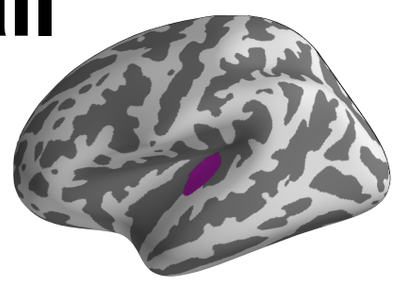
- Phonological commitment resolves ~450 ms after phoneme onset in superior temporal gyrus



Take Home Message



maintain **subphonemic detail**
across long time-scales



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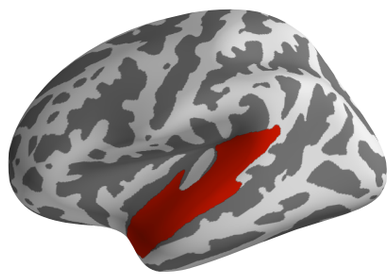
p

commit to most likely **phonological** interpretation ~450 ms



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With big thanks to:

- My supervisors, Alec Marantz & David Poeppel
- Everyone in the Neuroscience of Language Lab and Poeppel Lab

Funding: G1001 Abu Dhabi Institute

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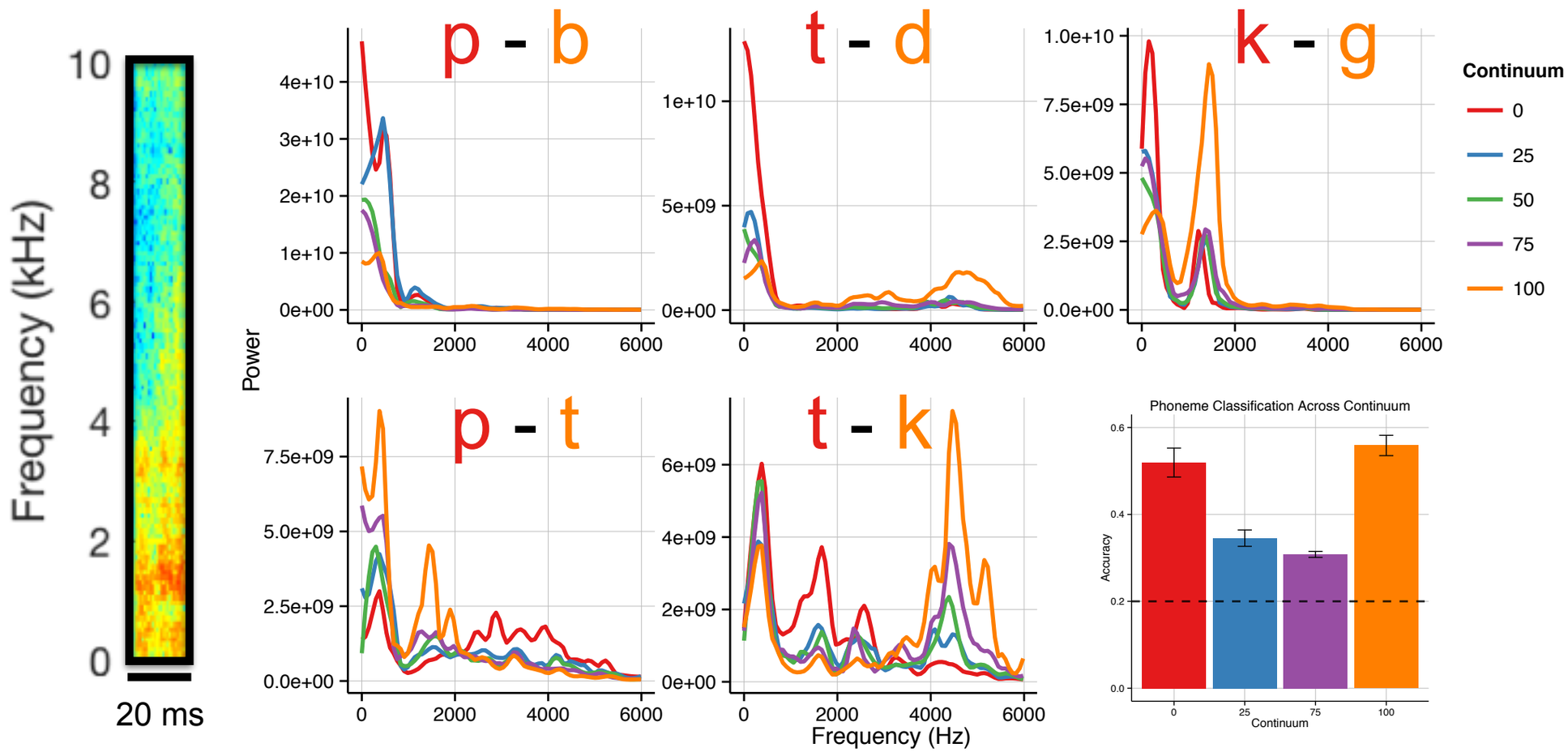
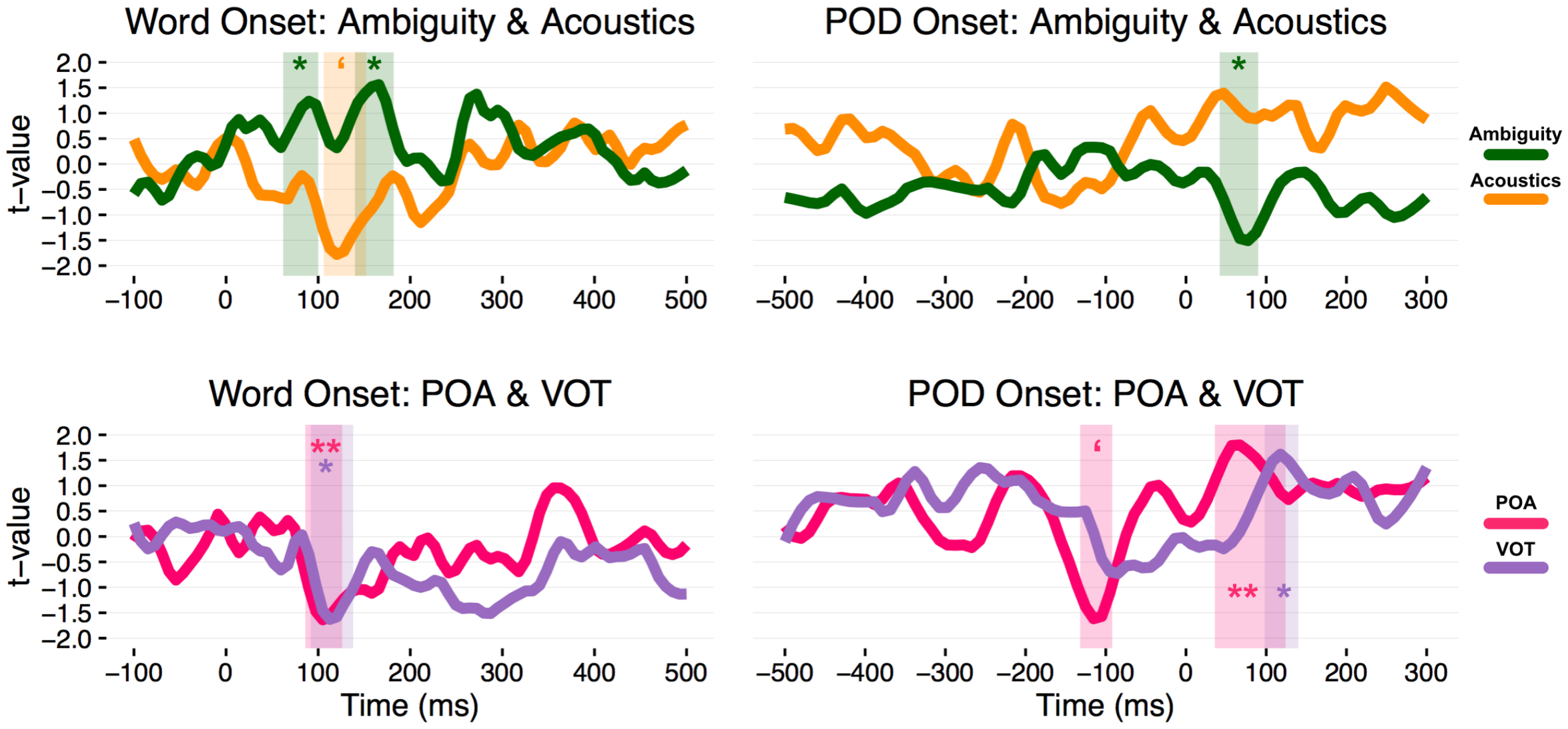
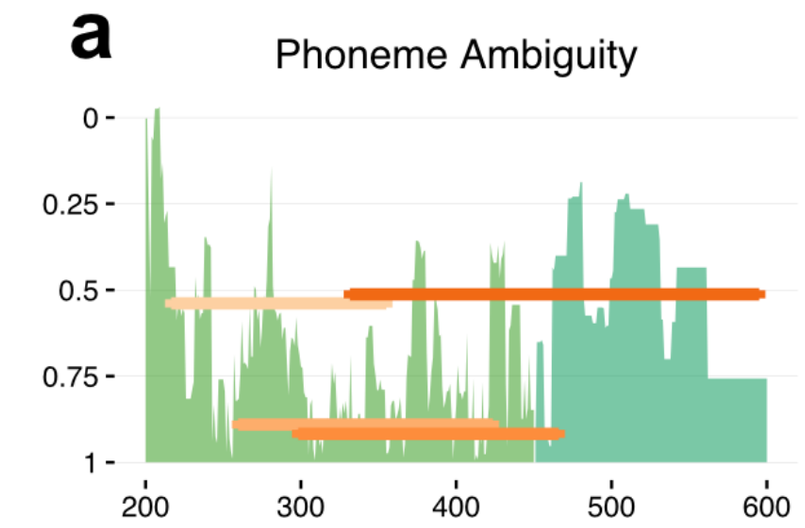
Eskerrik Asko!

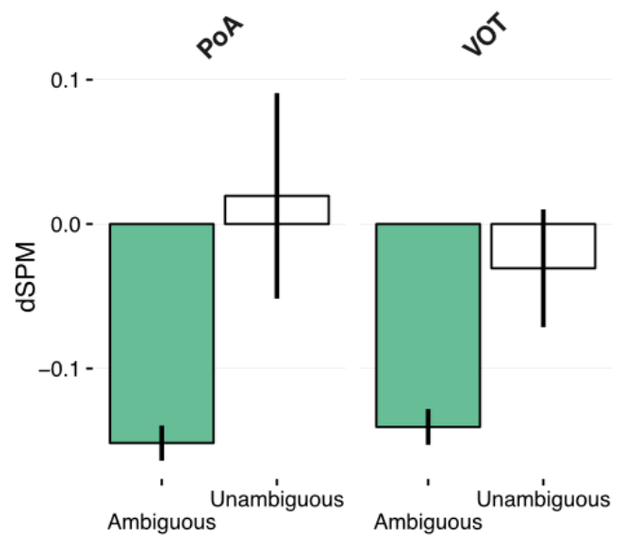
Discussion

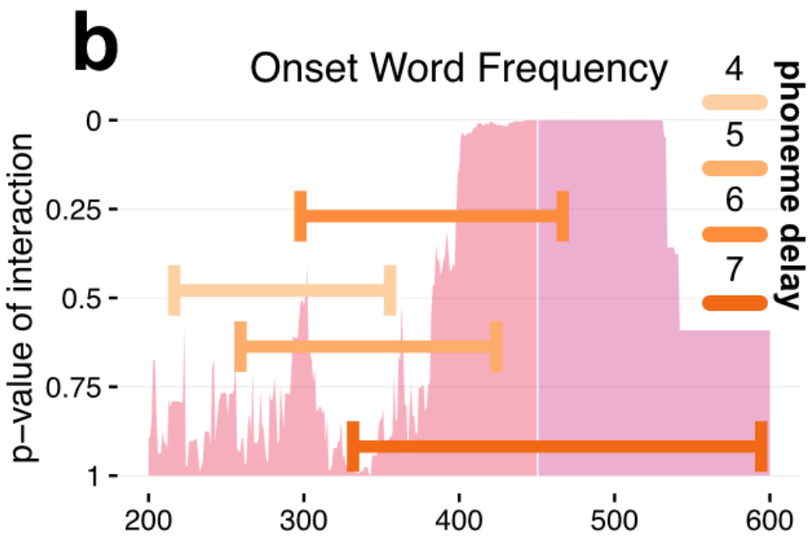
- 50 ms is **very** early — what information is present in the input that could determine phonological category?

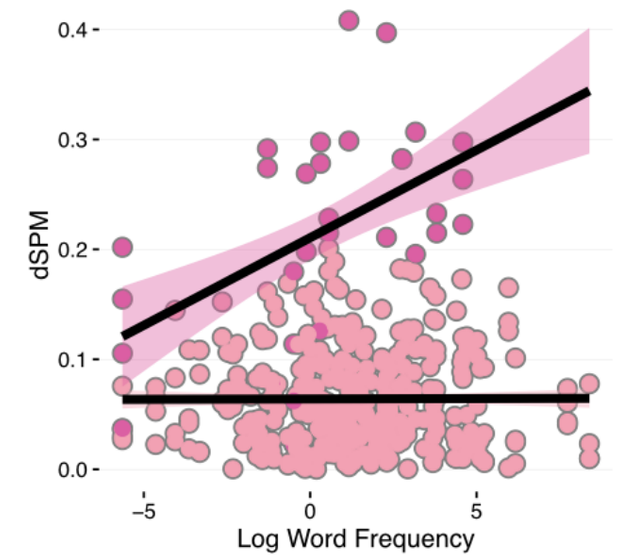


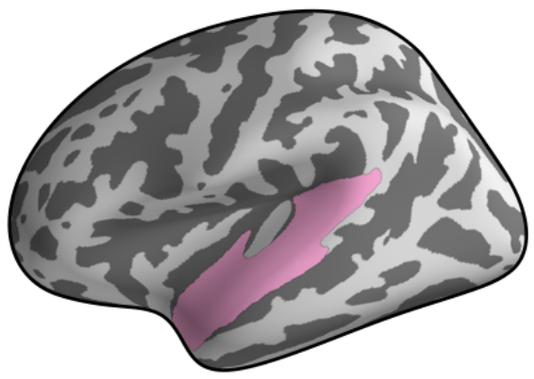

Word Onset: Ambiguity & Acoustics
POD Onset: Ambiguity & Acoustics
t–value
2.0
1.5
1.0
0.5
0.0
–0.5
–1.0
–1.5
–2.0
–100
0
100
200
300
400
500
–500
–400
–300
–200
–100
0
100
200
300
Ambiguity
Acoustics
Word Onset: POA & VOT
POD Onset: POA & VOT
t–value
Time (ms)
Time (ms)
POA
VOT

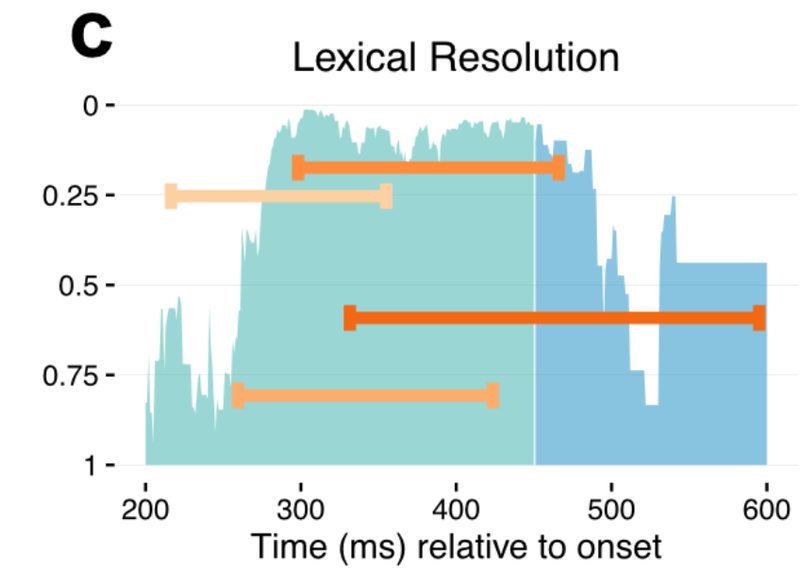

a
Phoneme Ambiguity
0
0.25
0.5
0.75
1
200
300
400
500
600

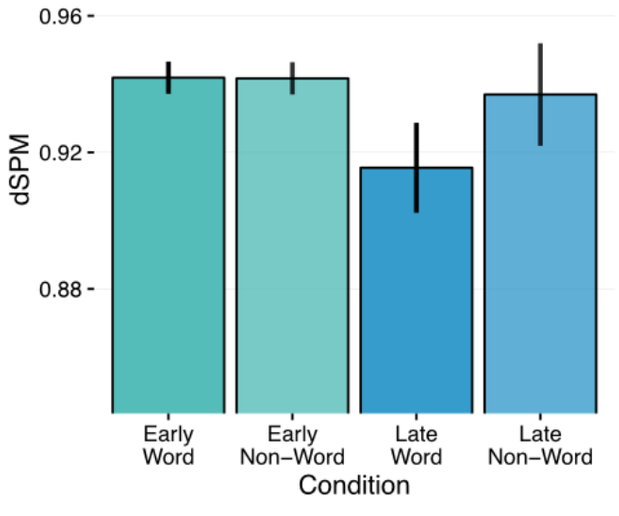

PoA
VOT
0.1
0.0
−0.1
dSPM
Ambiguous
Unambiguous
Ambiguous
Unambiguous

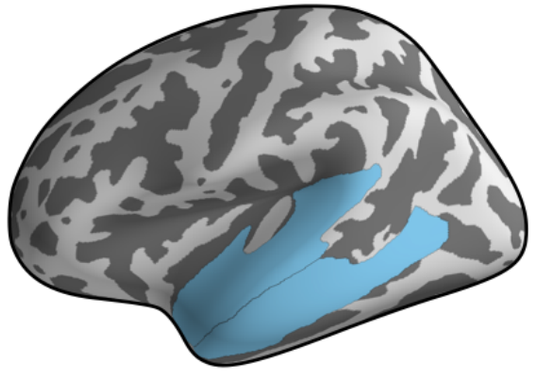

b
Onset Word Frequency
4
5
6
7
phoneme delay
p−value of interaction
0
0.25
0.5
0.75
1
200
300
400
500
600


0.4
0.3
0.2
0.1
0.0
dSPM
−5
0
5
Log Word Frequency



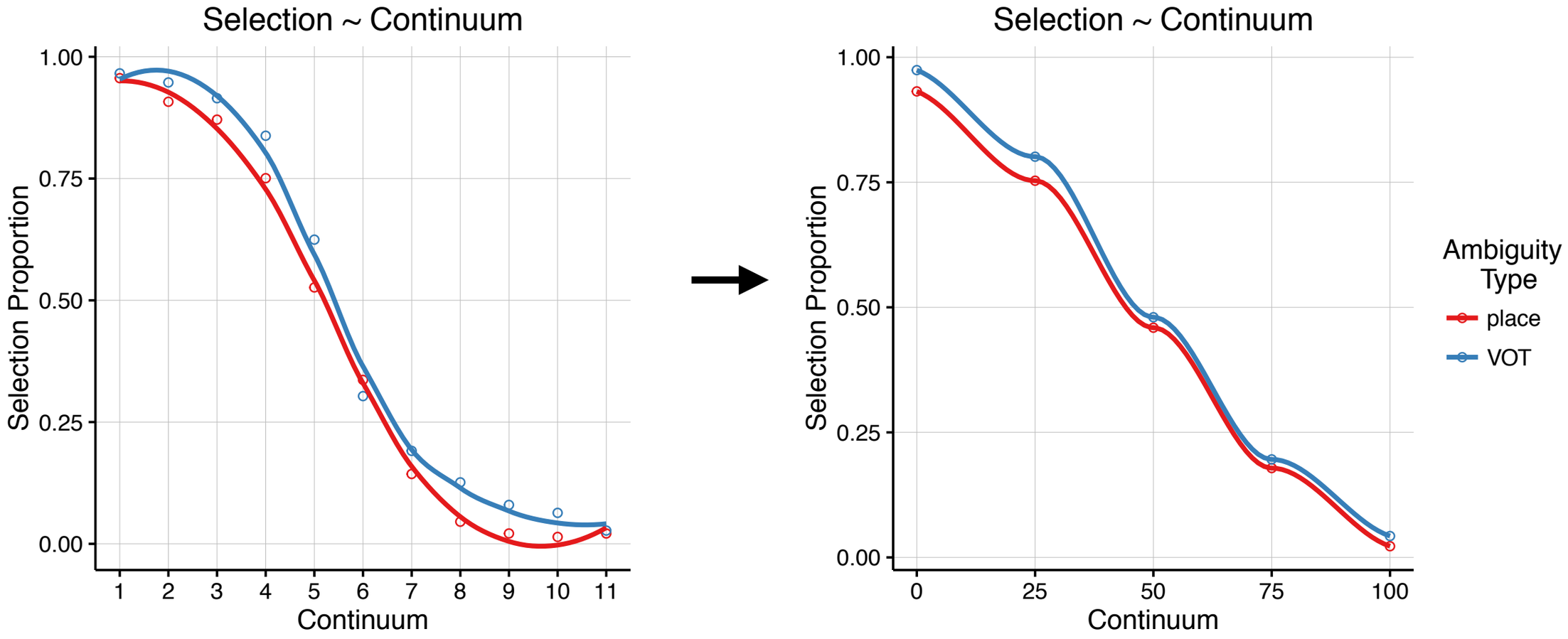

c
Lexical Resolution
0
0.25
0.5
0.75
1
200
300
400
500
600
Time (ms) relative to onset


0.96
0.92
0.88
dSPM
Early Word
Early Non−Word
Late Word
Late Non−Word
Condition



Experiment 1: Design & Materials

- Re-sampled the continuum to match perceptual categorisation



No Ambiguity Effect in Right Hemisphere