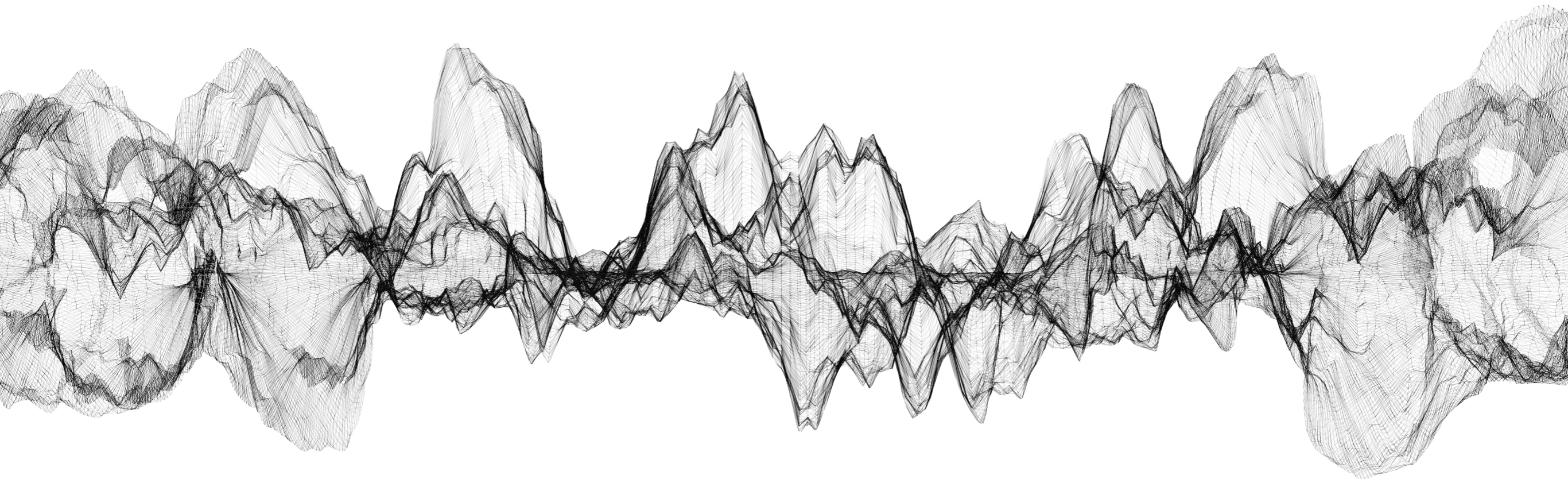




In spoken word recognition, the future predicts the past

Laura Gwilliams

HLP Lab Meeting: 03/11/16



Collaborators



Tal Linzen



David Poeppel



Alec Marantz

Future Influences on Perception

Future Influences on Perception

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

Future Influences on Perception

- Speech is an inherently **noisy and ambiguous** signal
- To fluently derive meaning, listeners must **integrate top-down** contextual information to guide their interpretation

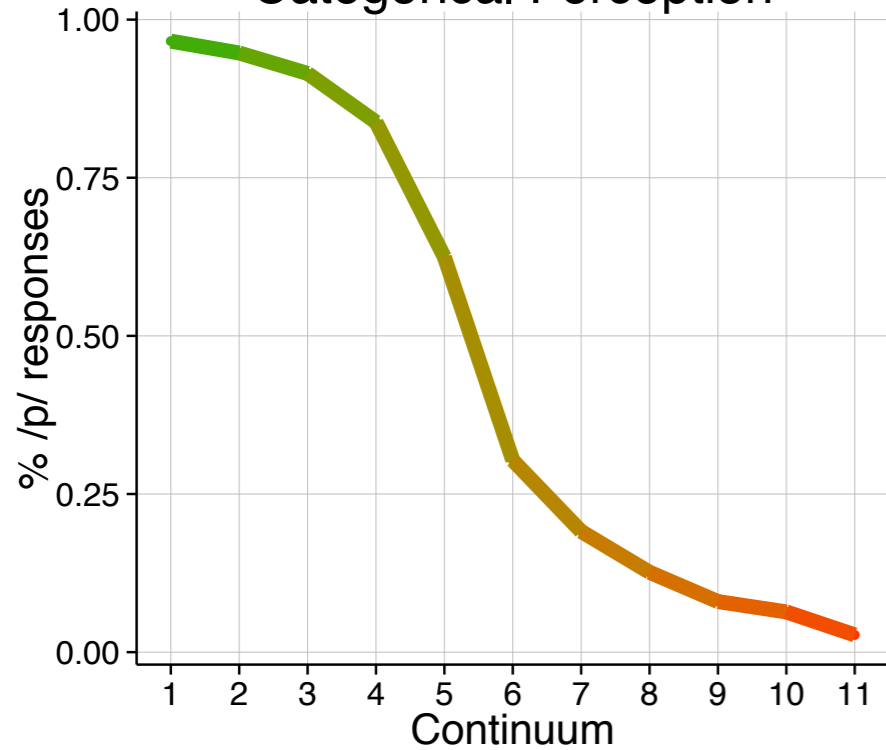
Future Influences on Perception

- 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** (Bicknell et al., submitted; Connine et al., 1991; Samuel, 1981; Szostak & Pitt, 2013; Warren & Sherman, 1974)

Future Influences on Perception

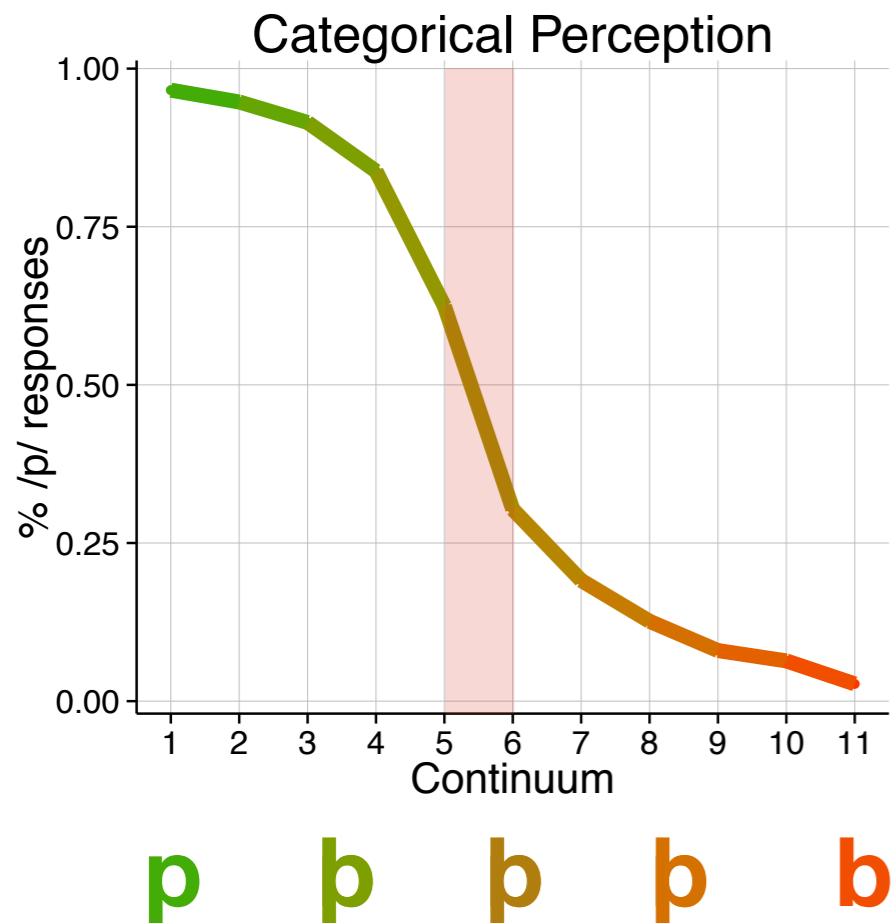
Future Influences on Perception

Categorical Perception

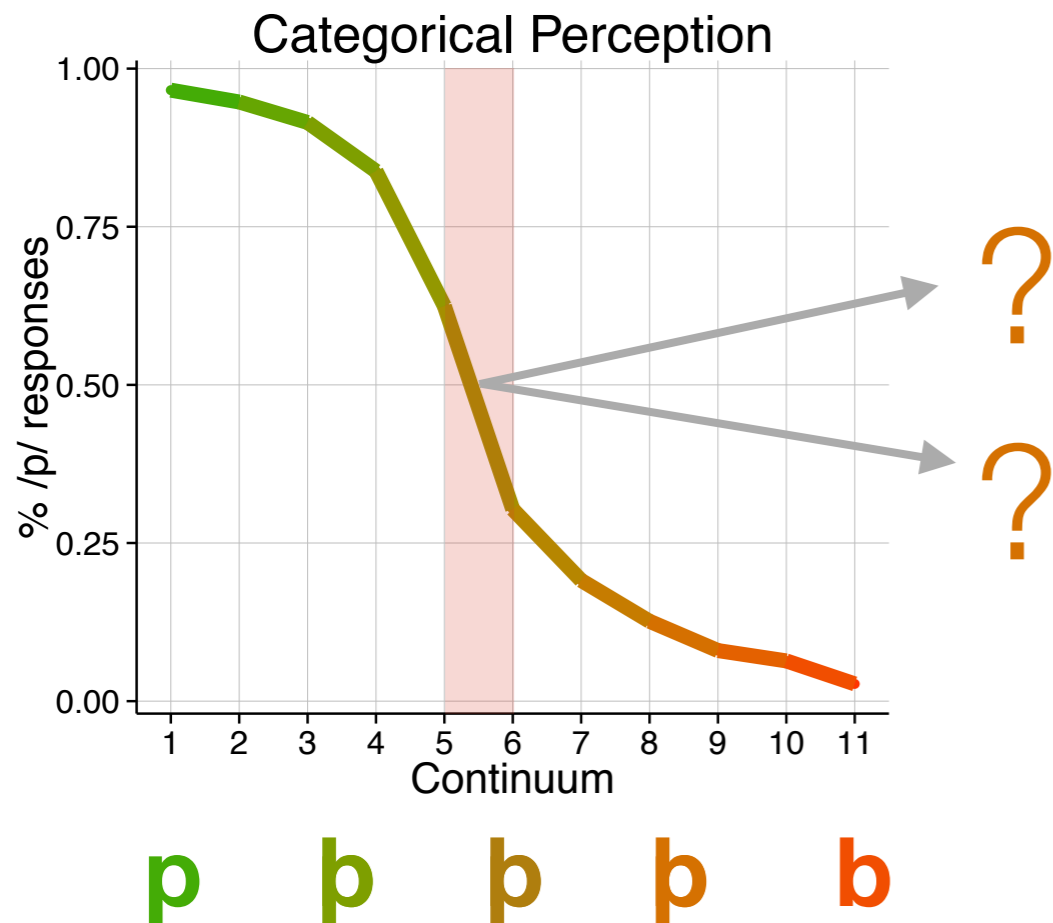


p **p** **p** **p** **b**

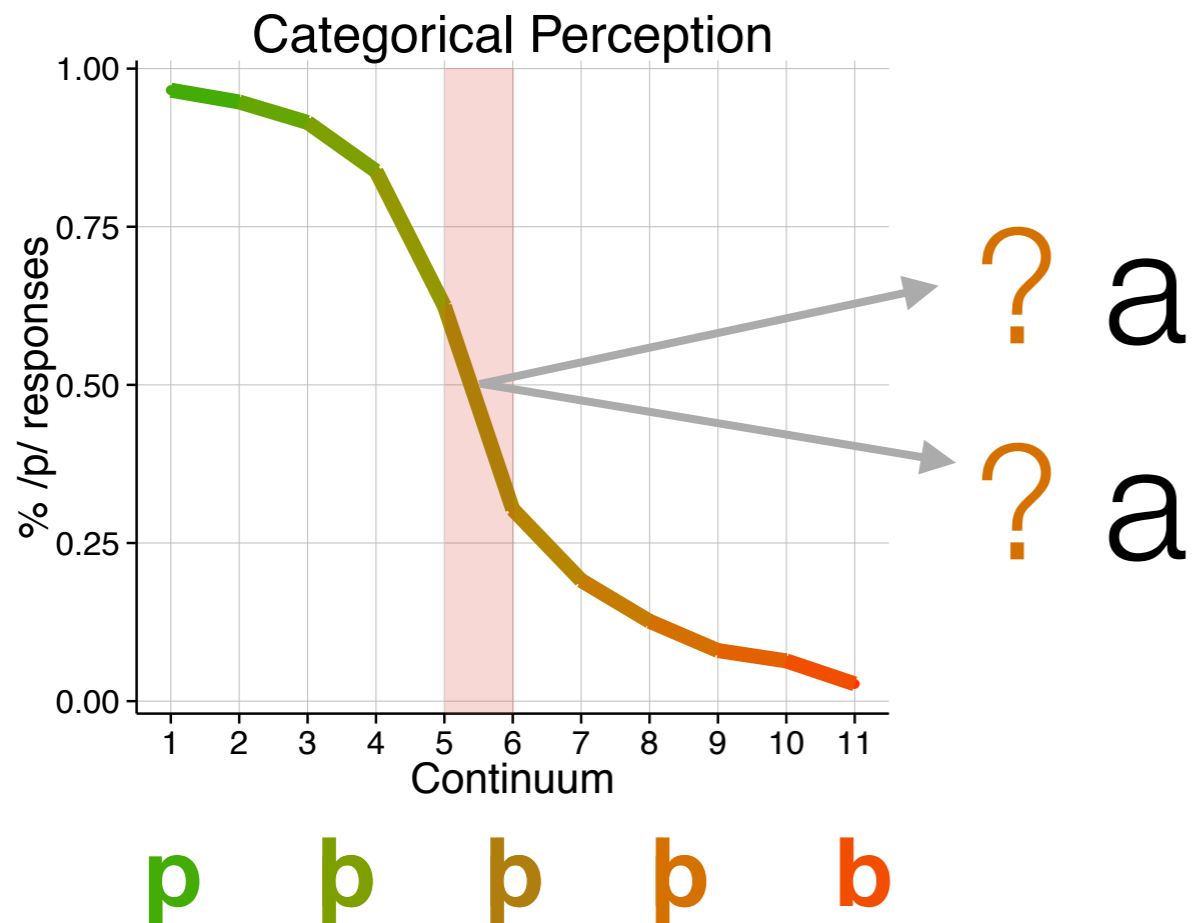
Future Influences on Perception



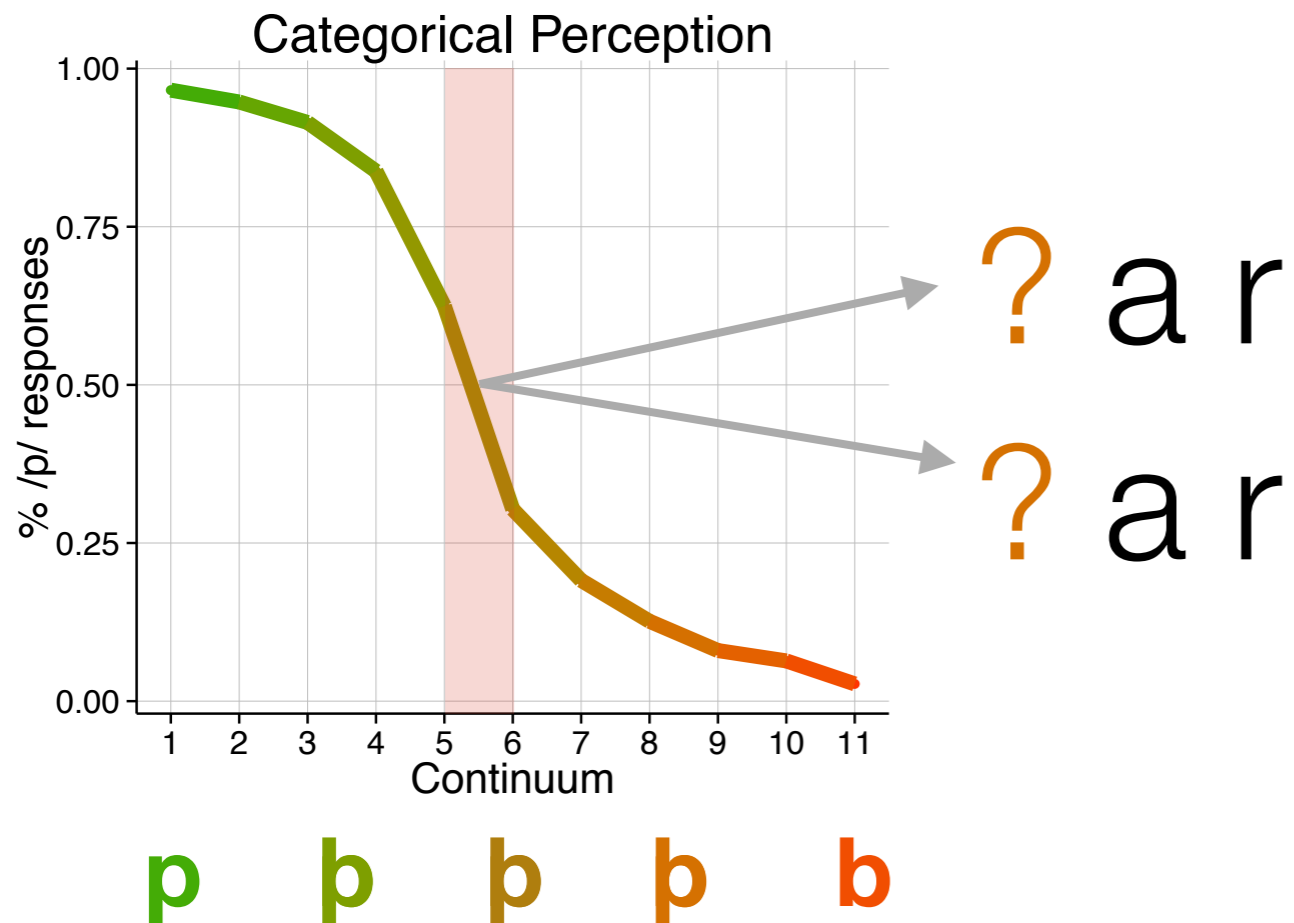
Future Influences on Perception



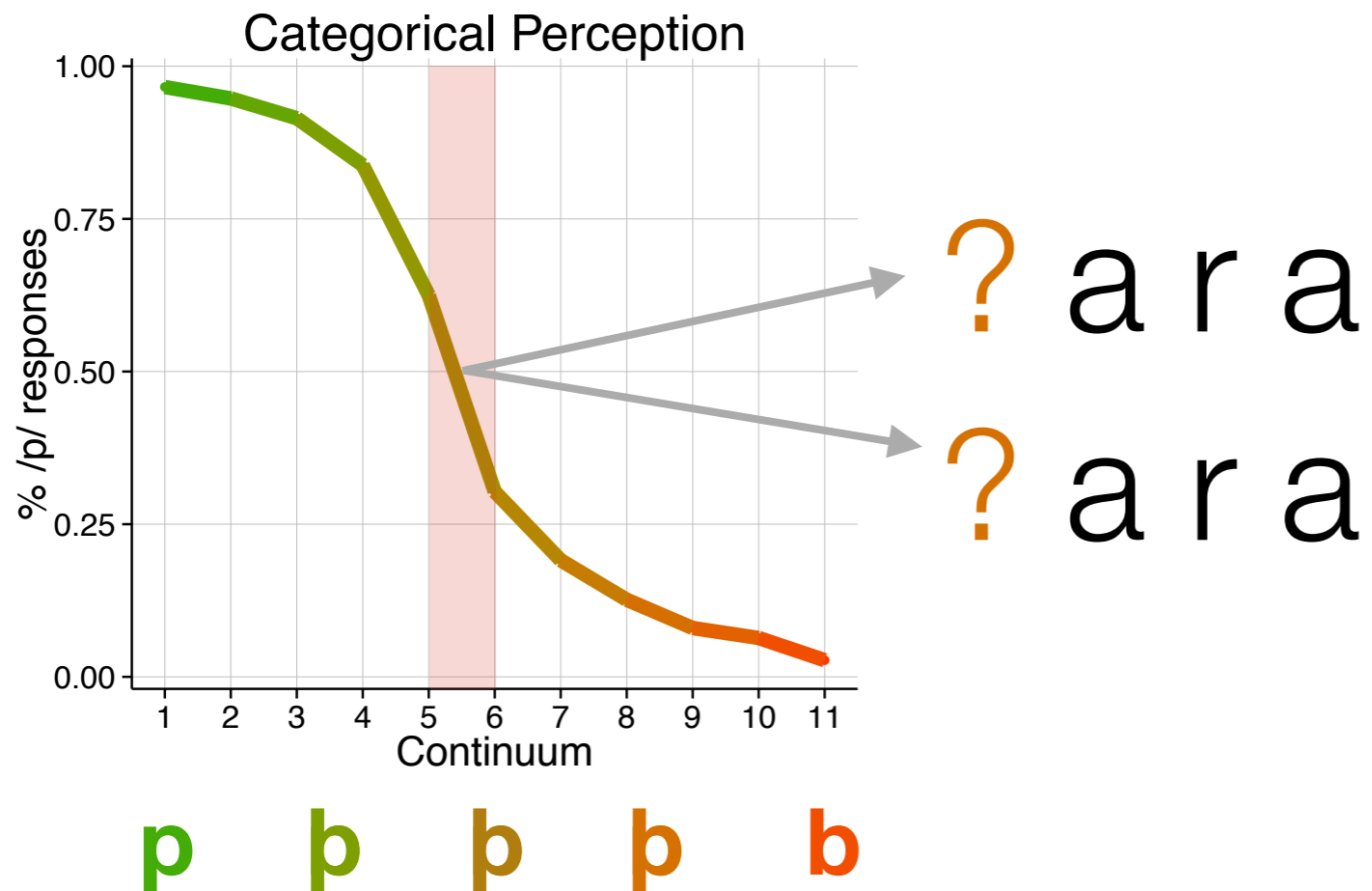
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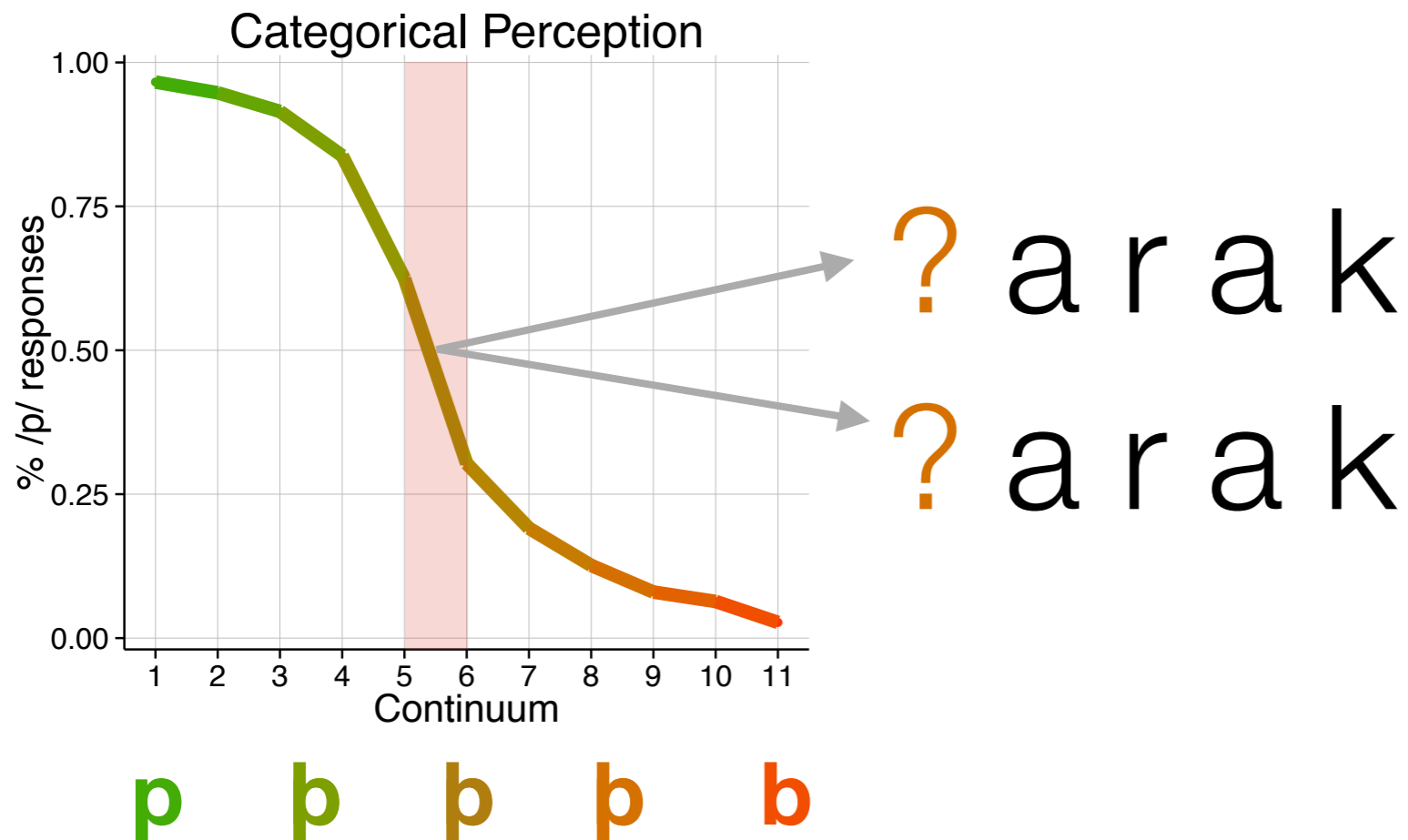
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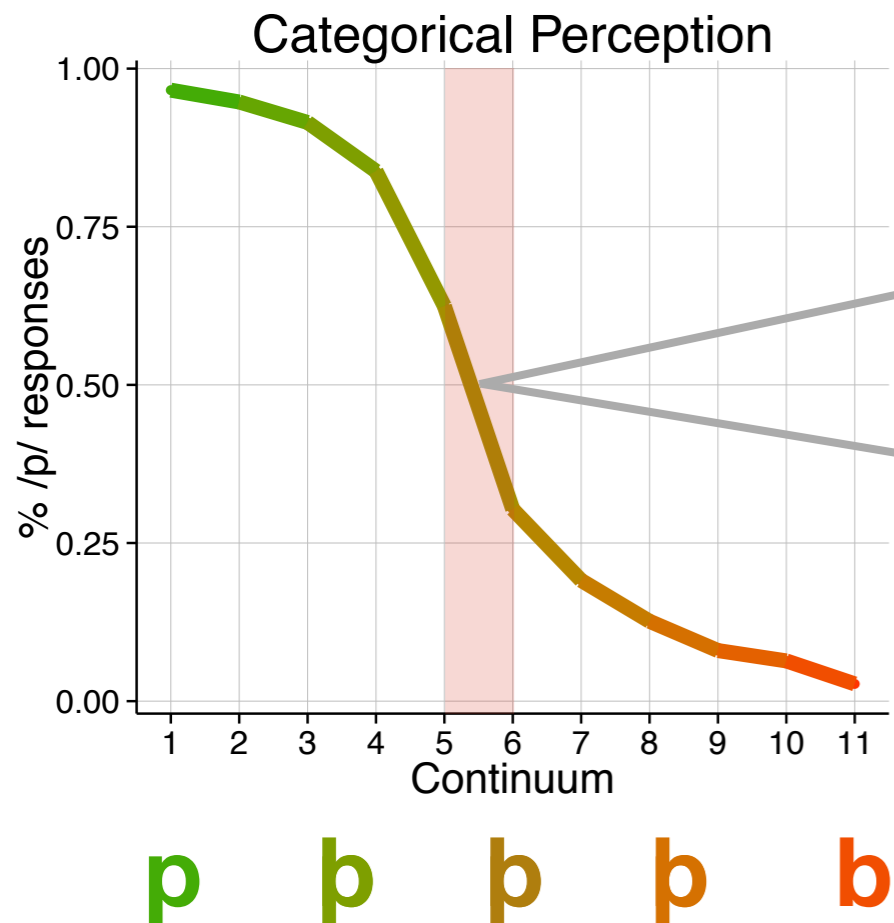
Future Influences on Perception



Future Influences on Perception



Future Influences on Perception

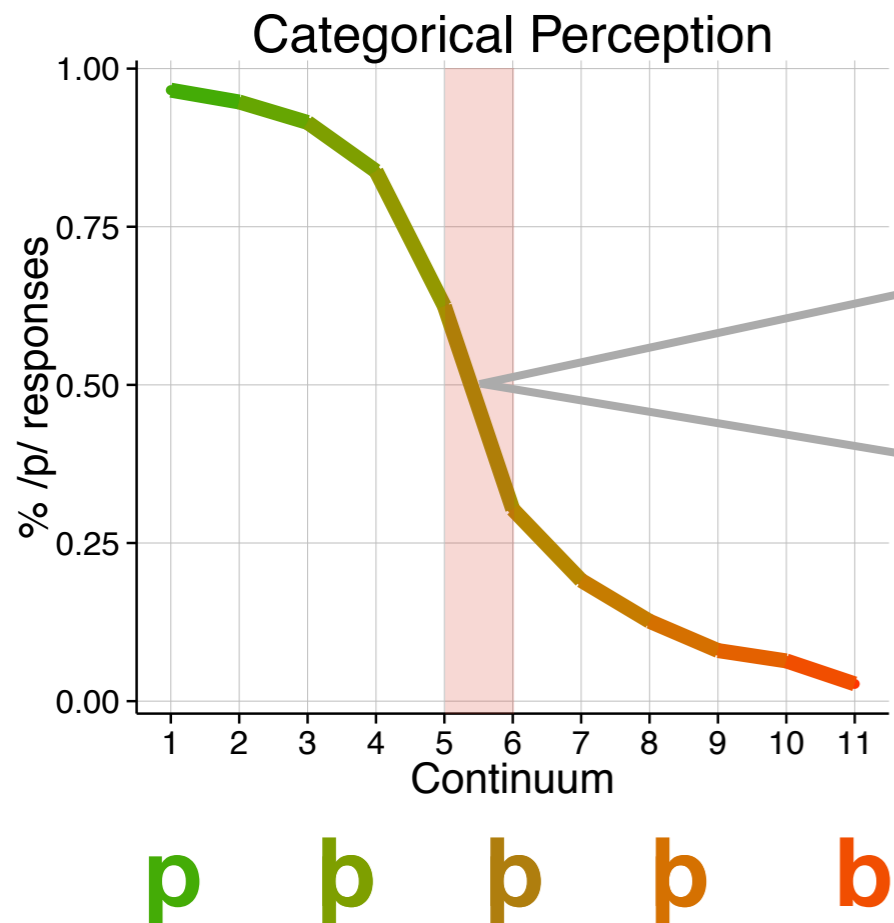


? a r a k **ee** t

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

Future Influences on Perception



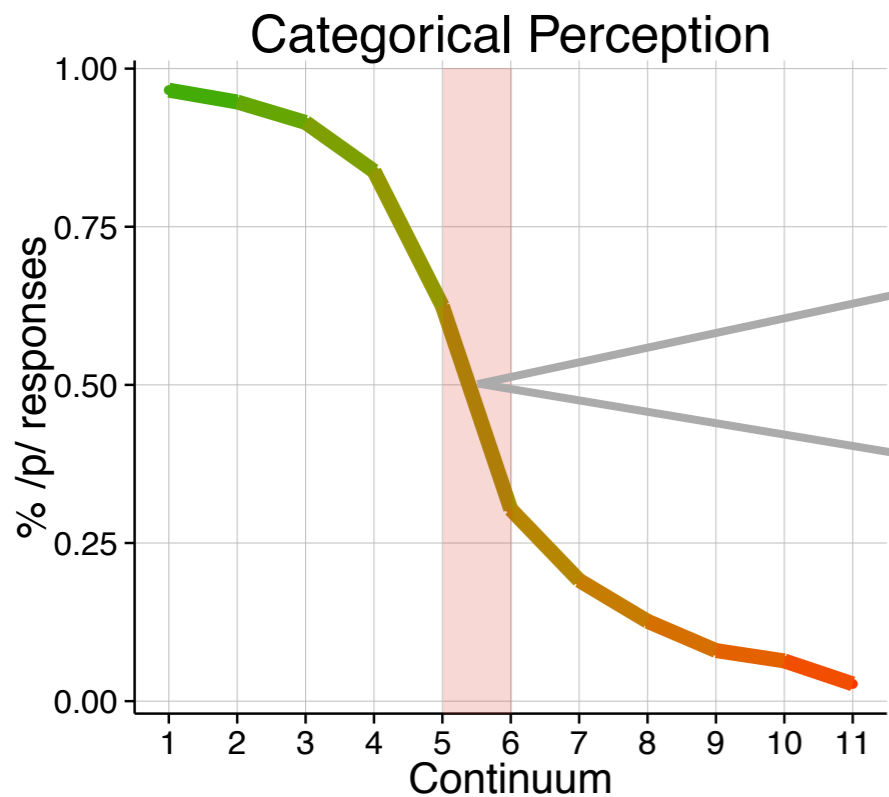
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“**P**oint of **D**isambiguation” (POD)

Future Influences on Perception

(this is a parakeet)



p a r a k e e t
b a r a k a i d

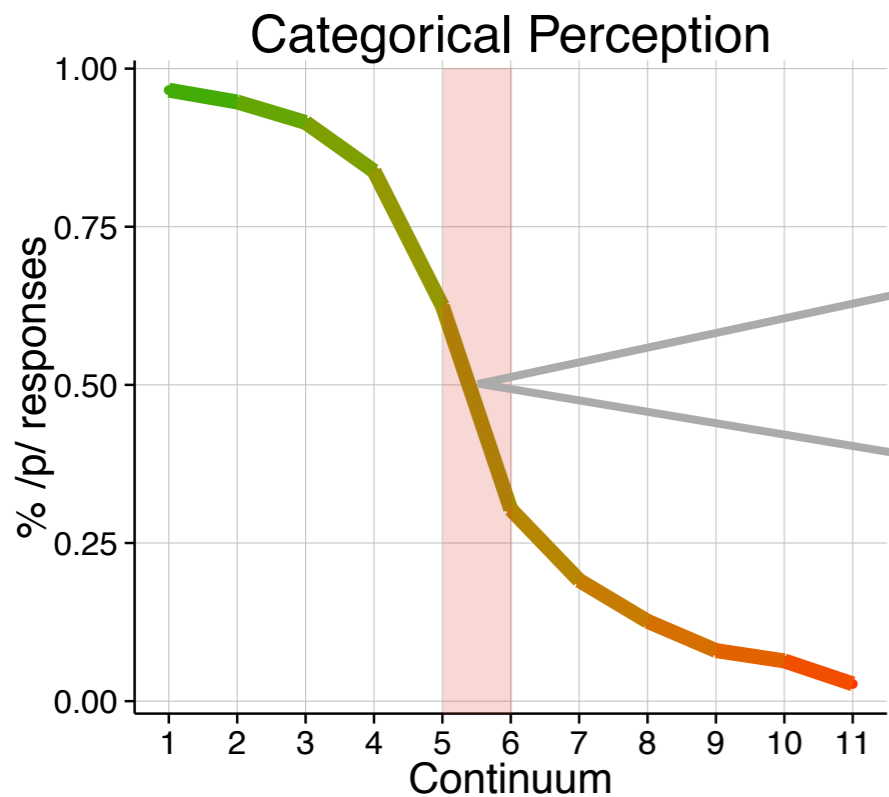


(this is a barricade)

“**P**oint of **D**isambiguation” (POD)

Future Influences on Perception

(this is a parakeet)



p a r a k e e t
b a r a k a i d

p p p p b

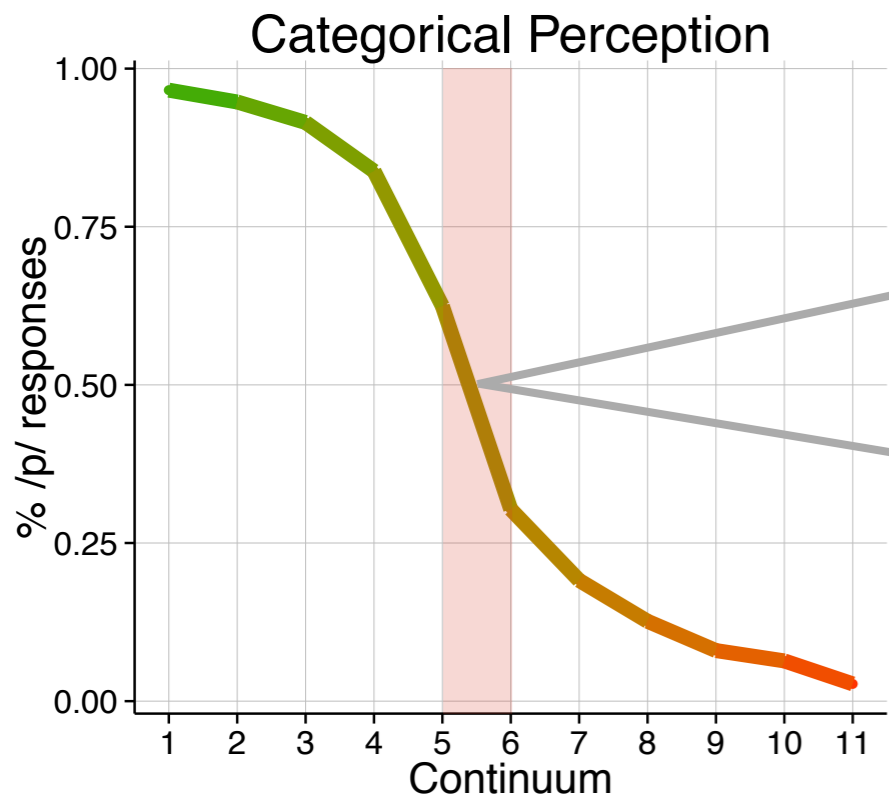


(this is a barricade)

“**P**oint of **D**isambiguation” (POD)

Future Influences on Perception

(this is a parakeet)



p a r a k e e t
b a r a k a i d

(this is a barricade)



“**P**oint of **D**isambiguation” (POD)

p p p p b

Today's Questions

p a r a k e e t

Today's Questions

How does the auditory cortex **respond** to phonological ambiguity?

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Today's Questions

How does the auditory cortex **respond** to phonological ambiguity?

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What are the neural signatures of ambiguity **resolution**?

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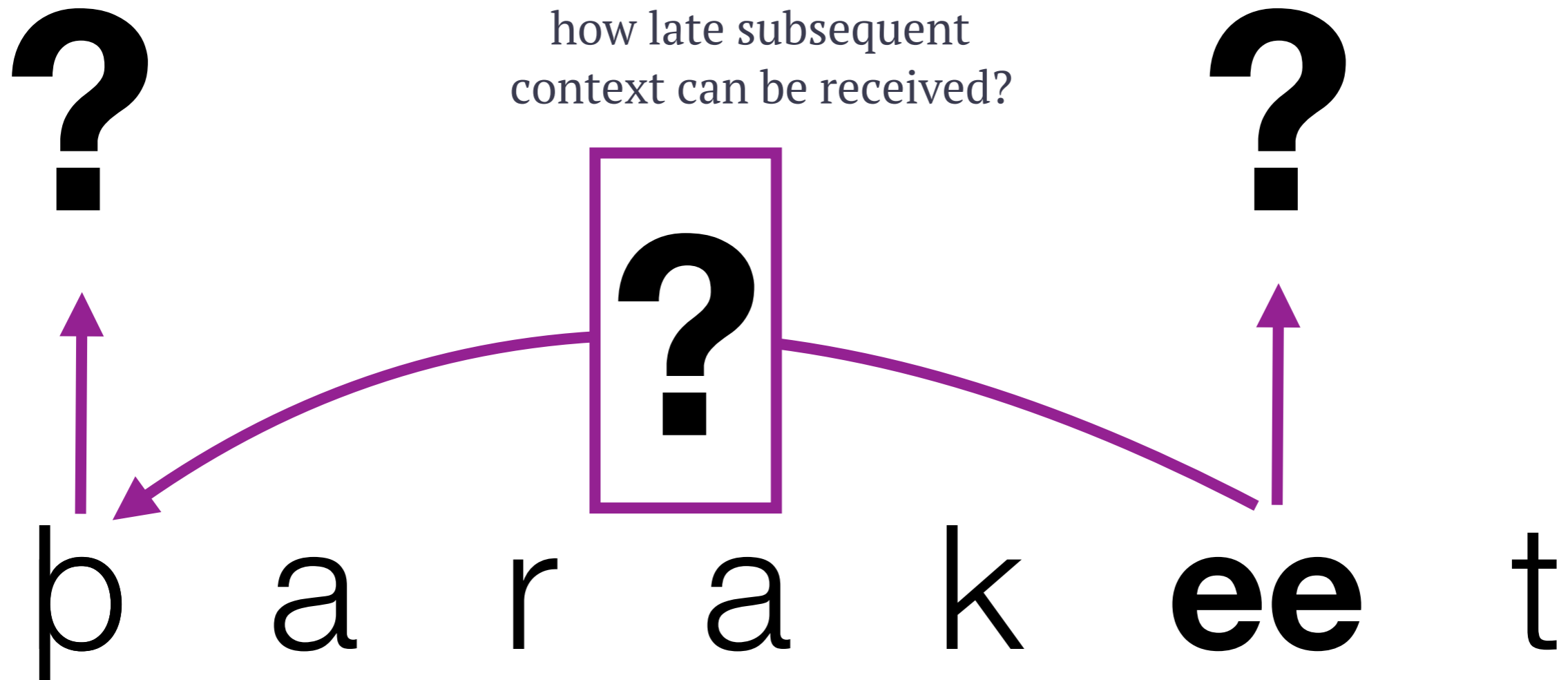
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Today's Questions

How does the auditory cortex **respond** to phonological ambiguity?

What are the neural signatures of ambiguity **resolution**?

What is the **time-limit** on how late subsequent context can be received?



Design & Materials



65 x

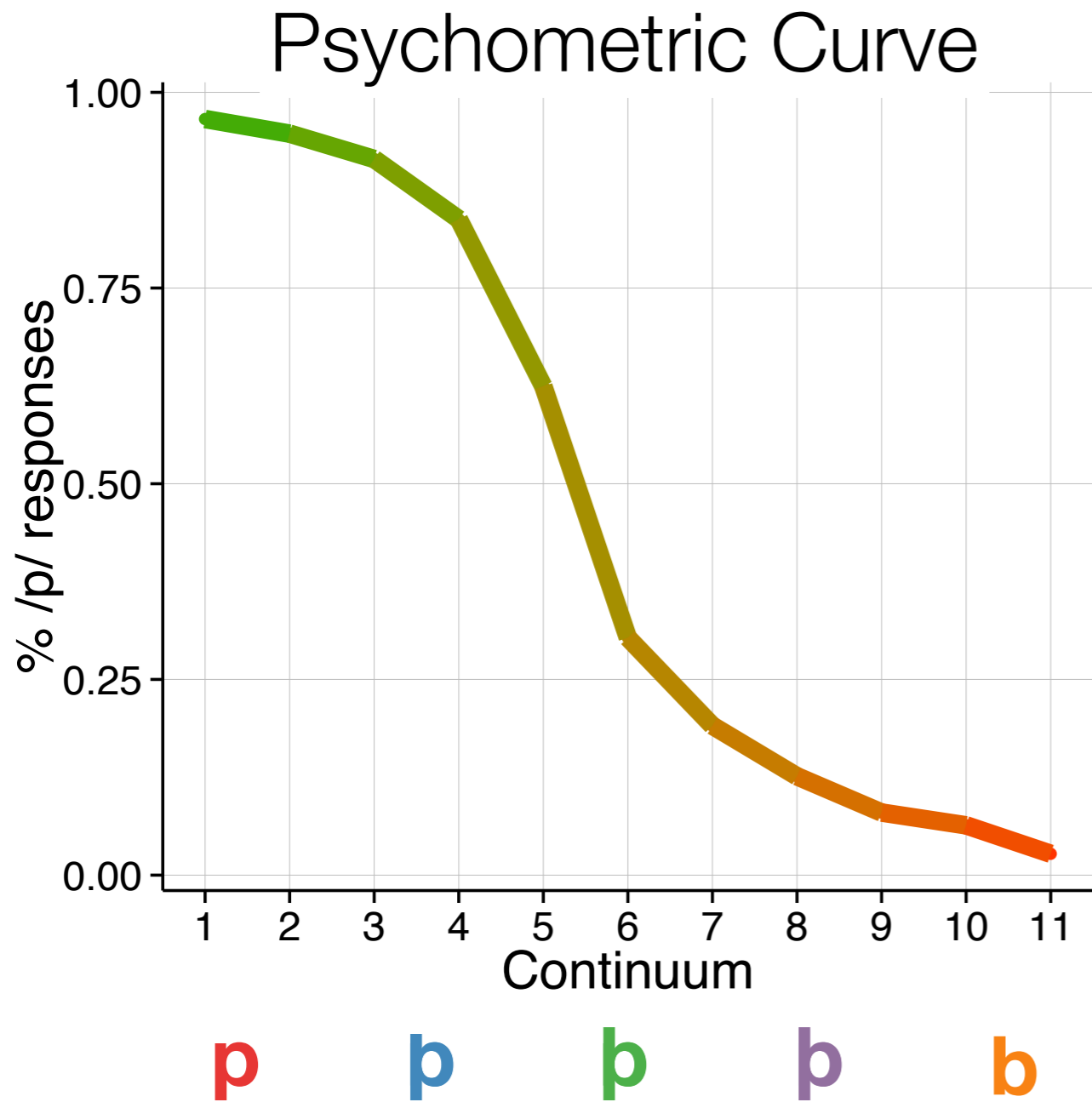
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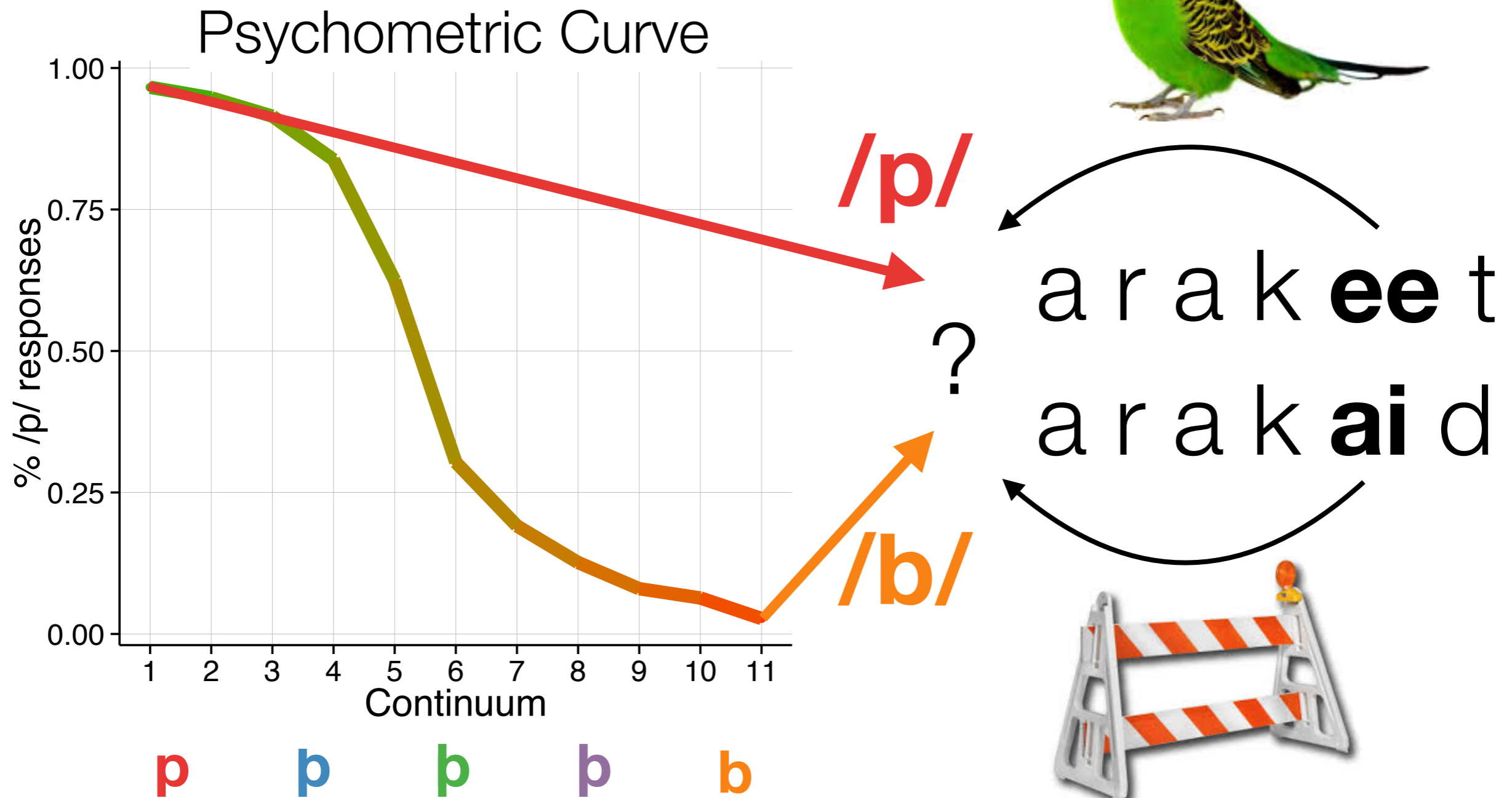
Design & Materials



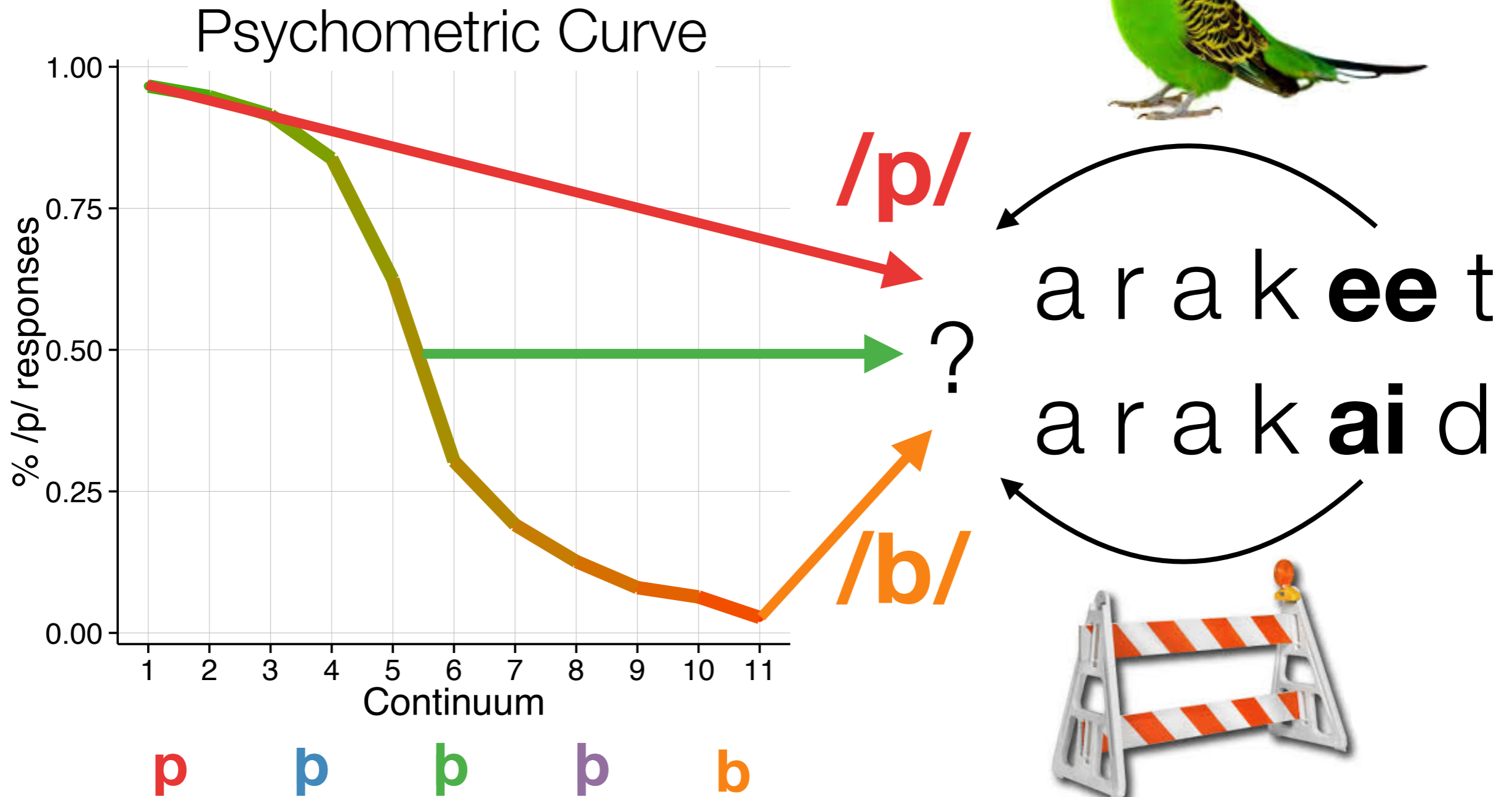
? a r a k **ee** t
a r a k **ai** d



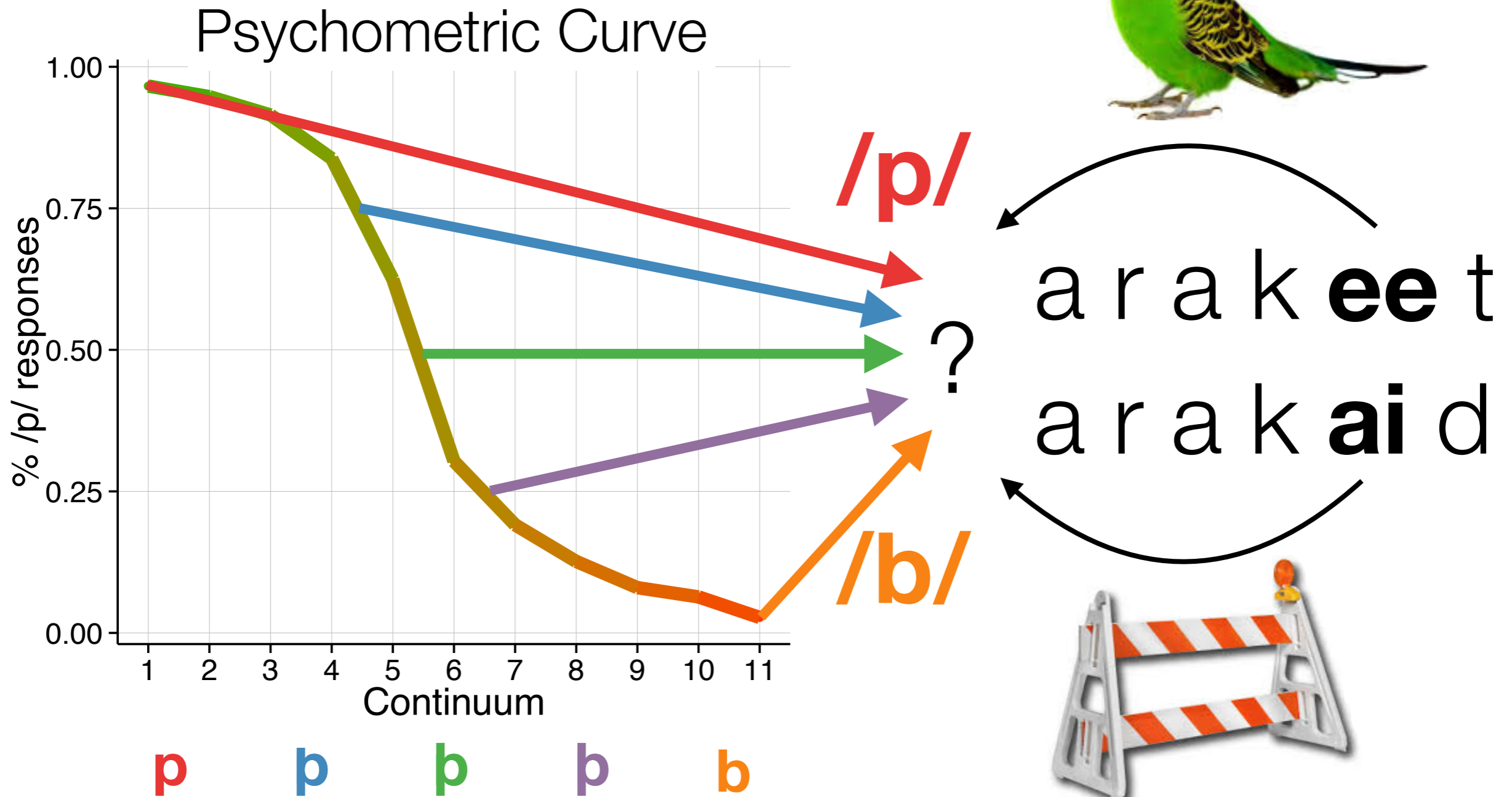
Design & Materials



Design & Materials

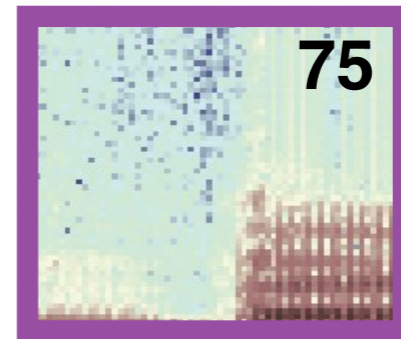
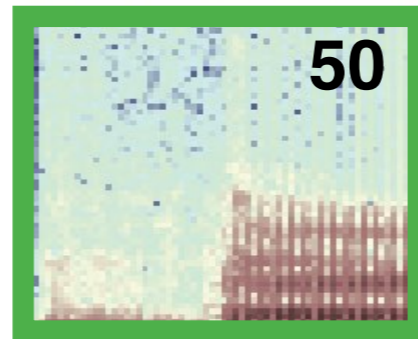
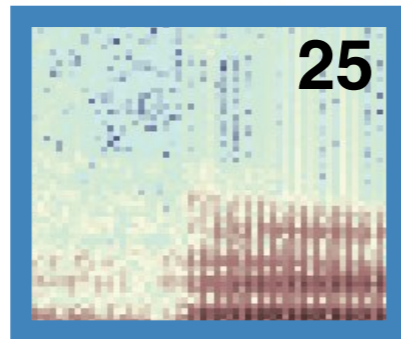
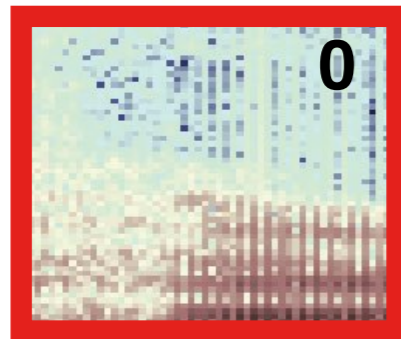


Design & Materials

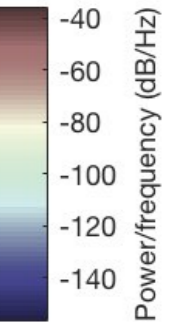
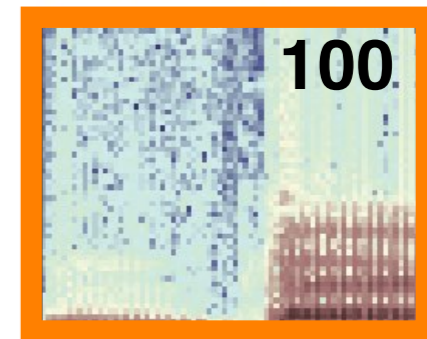


Experiment 1: Design & Materials

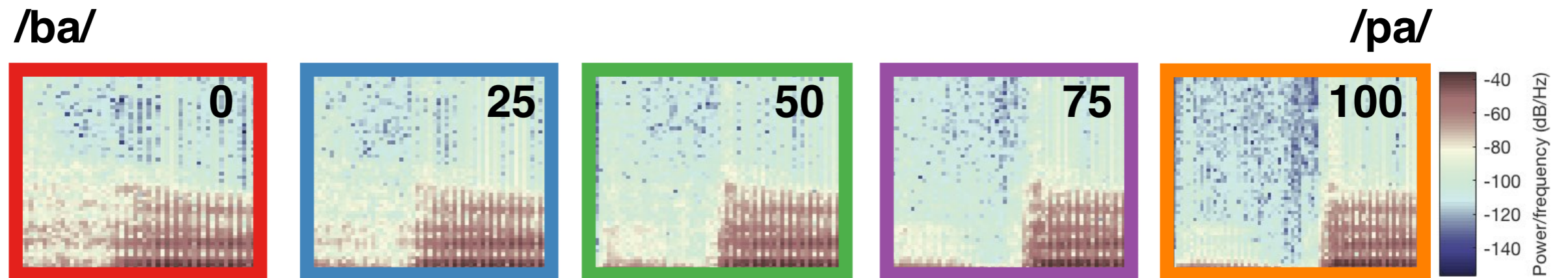
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/pa/

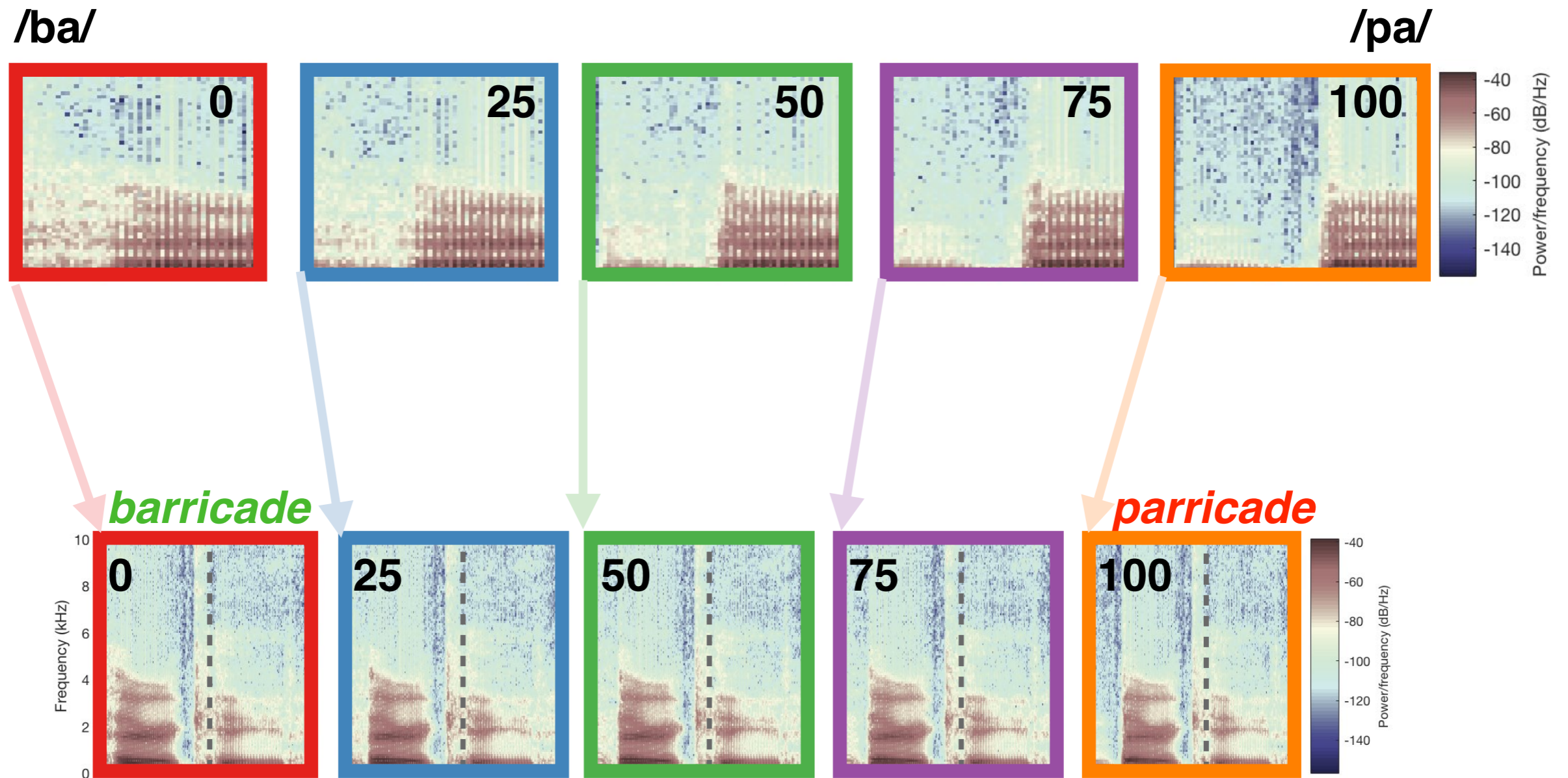


Experiment 1: Design & Materials

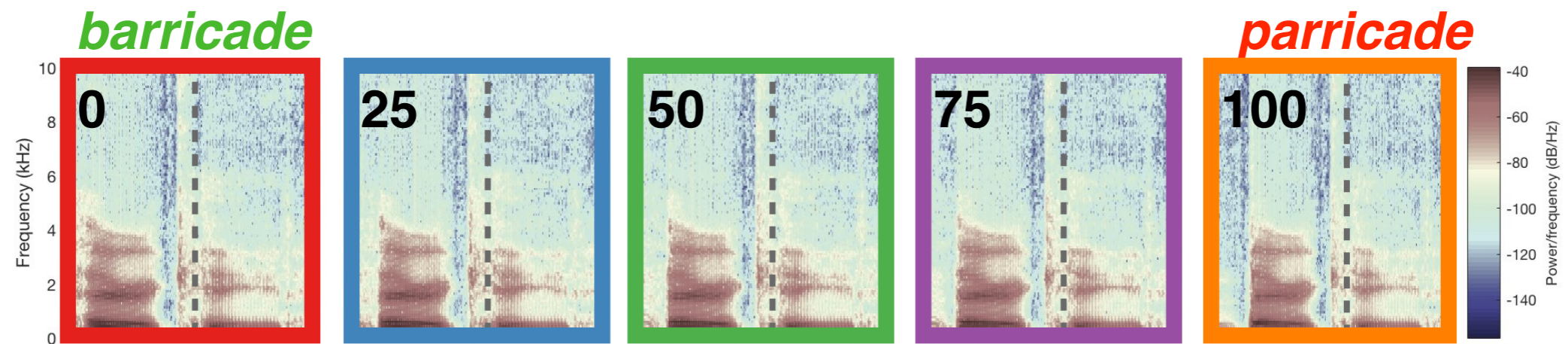


- VOT (31 pairs) {p-b, t-d, k-g} and PoA (22 pairs) {t-k, p-t}

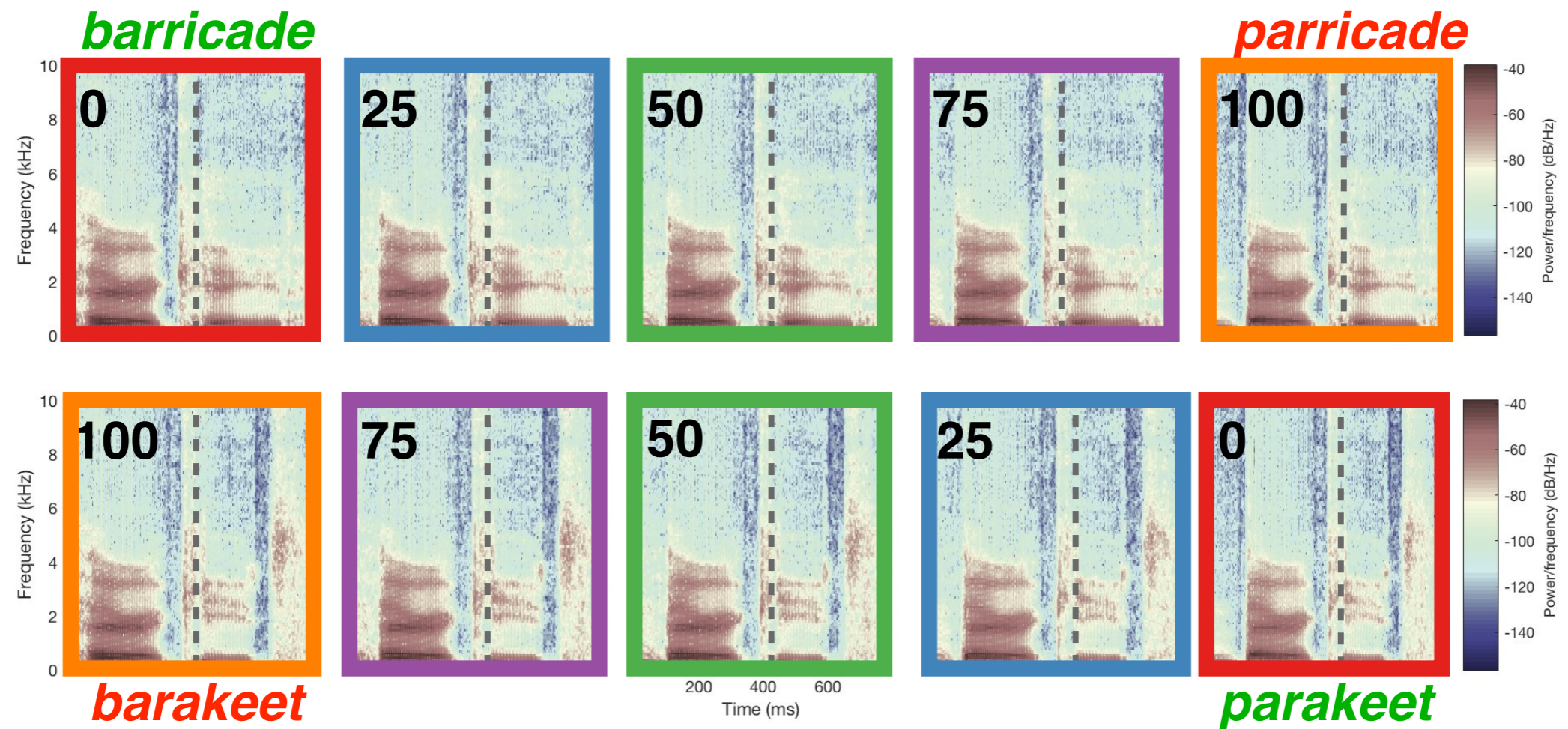
Experiment 2: Design & Materials



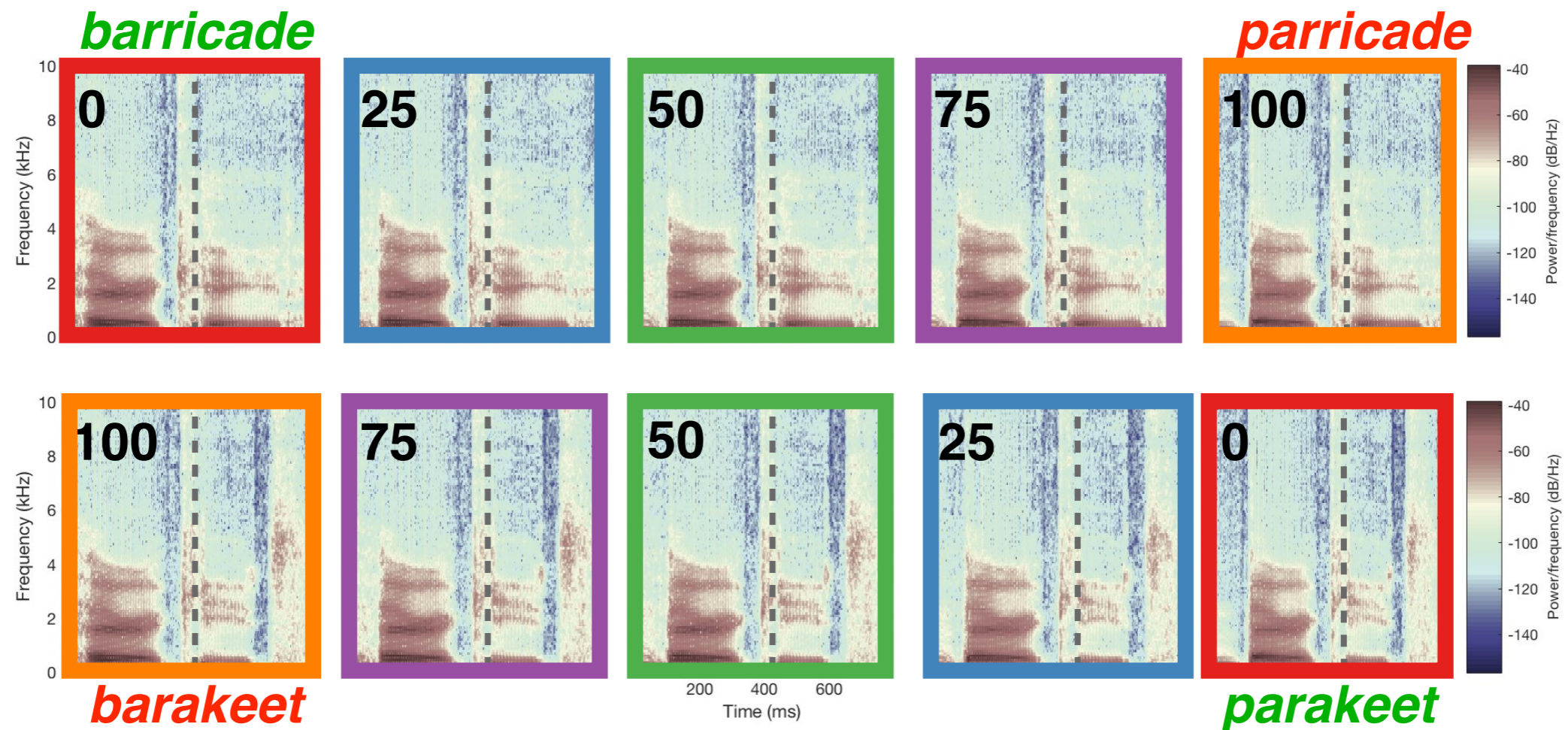
Experiment 2: Design & Materials



Experiment 2: Design & Materials

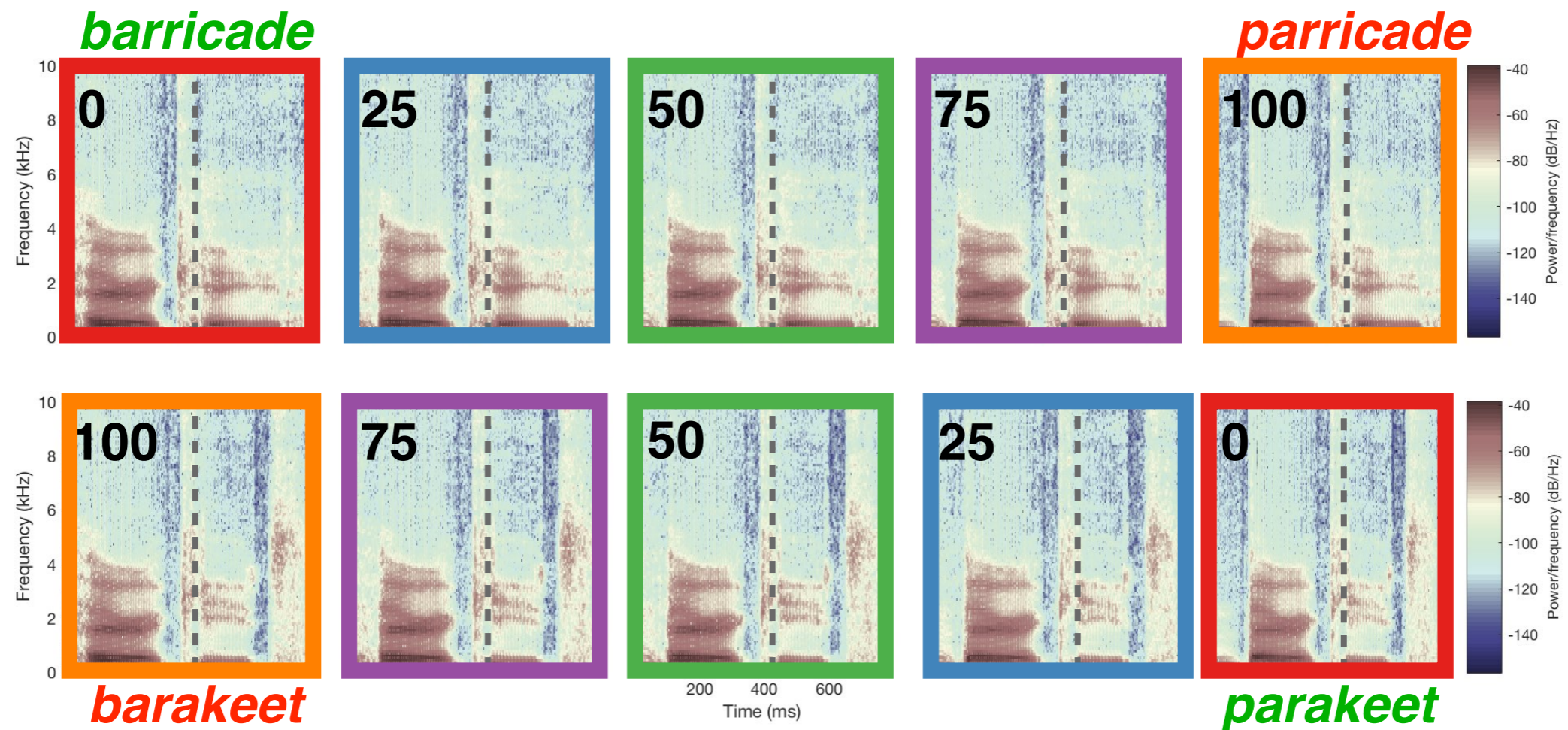


Experiment 2: Design & Materials



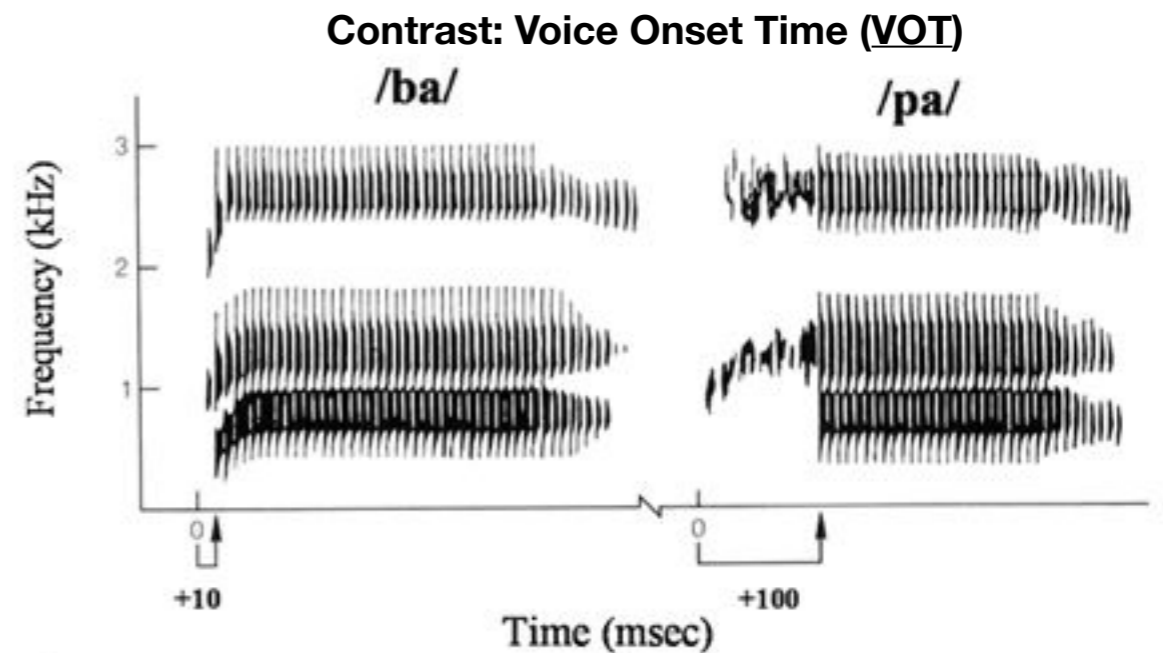
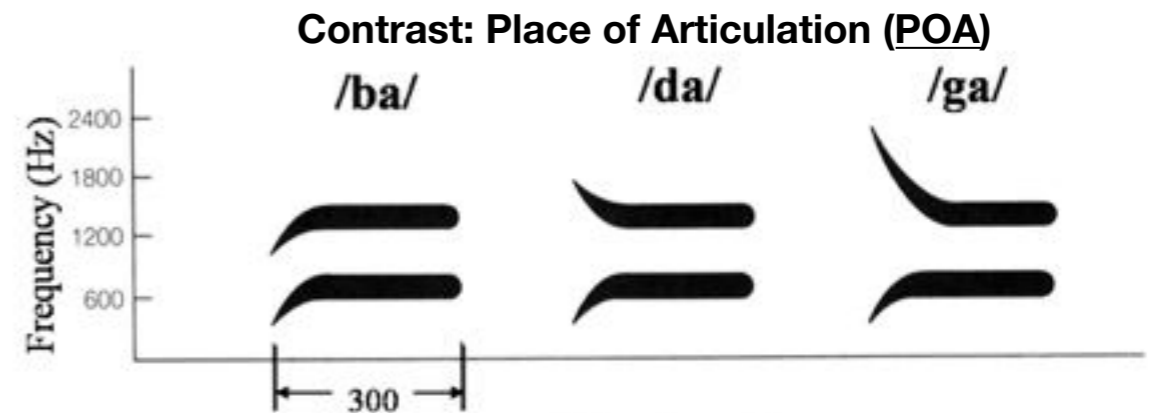
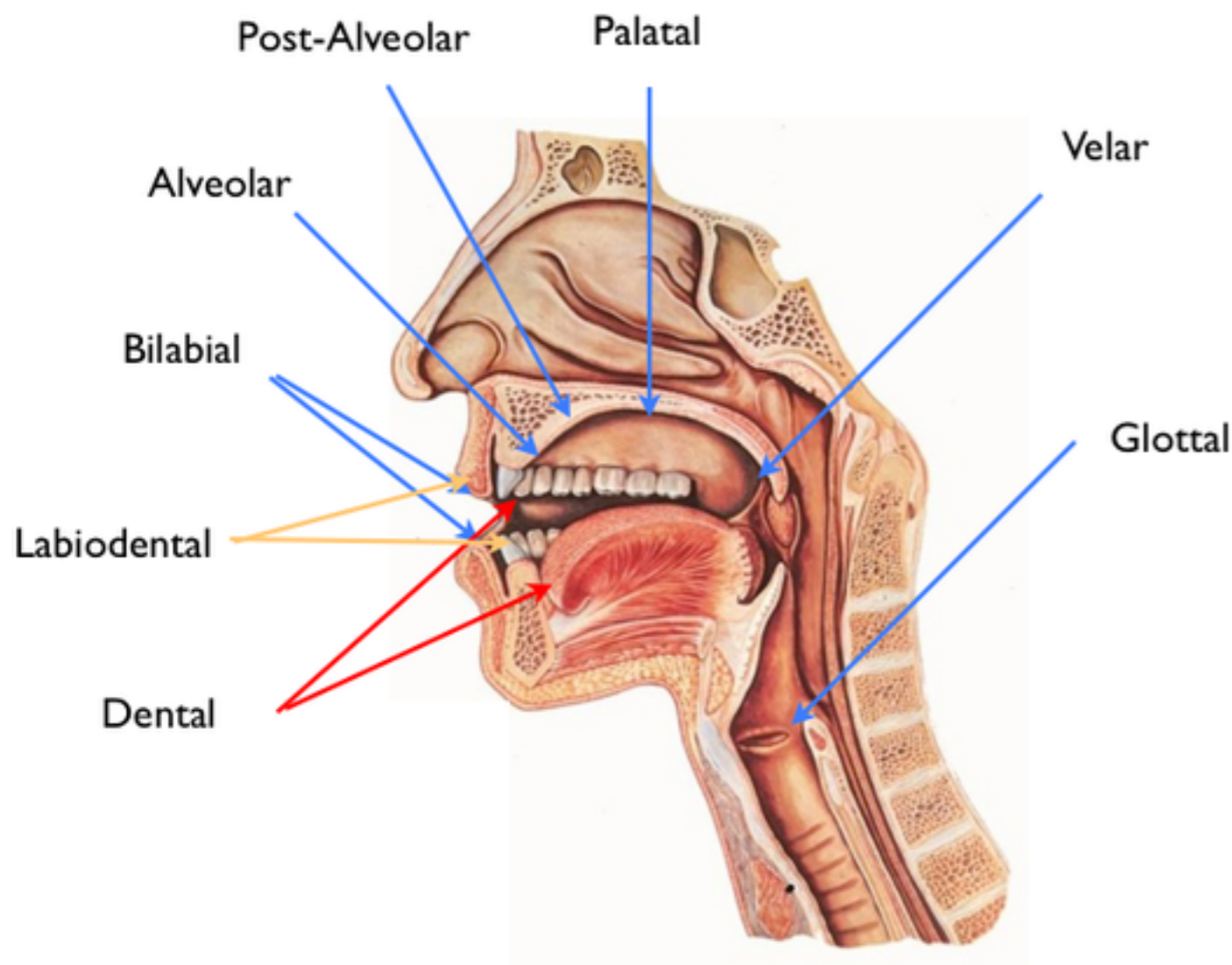
- Point of Disambiguation (POD) ranged 3-8 phonemes / 150-750 ms

Experiment 2: Design & Materials



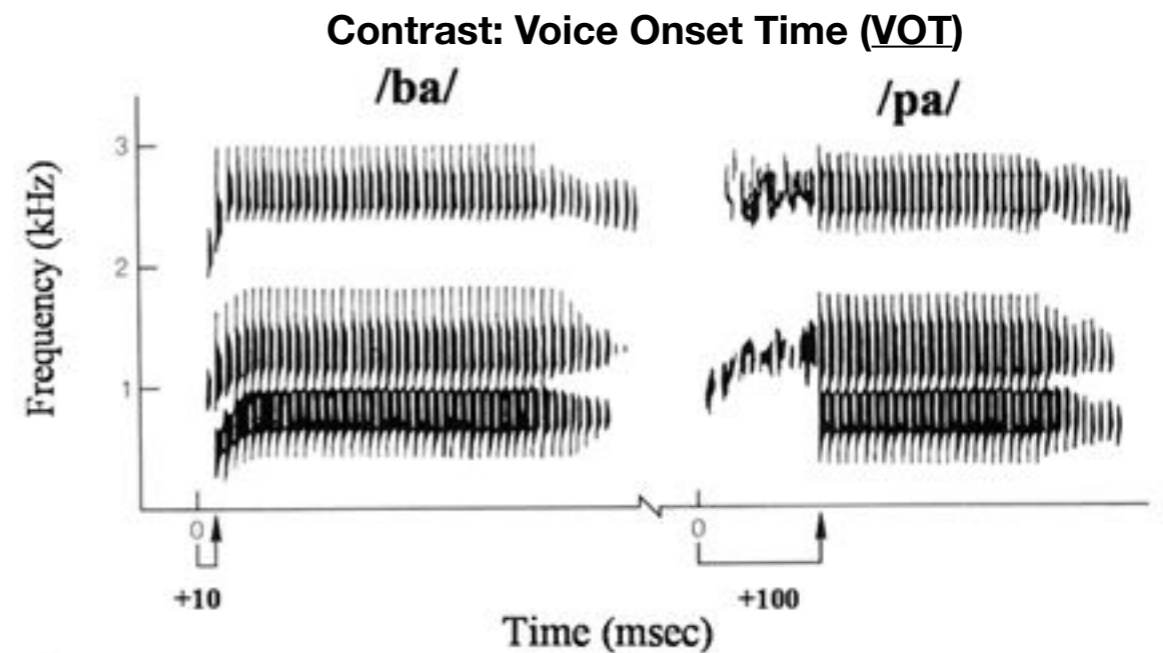
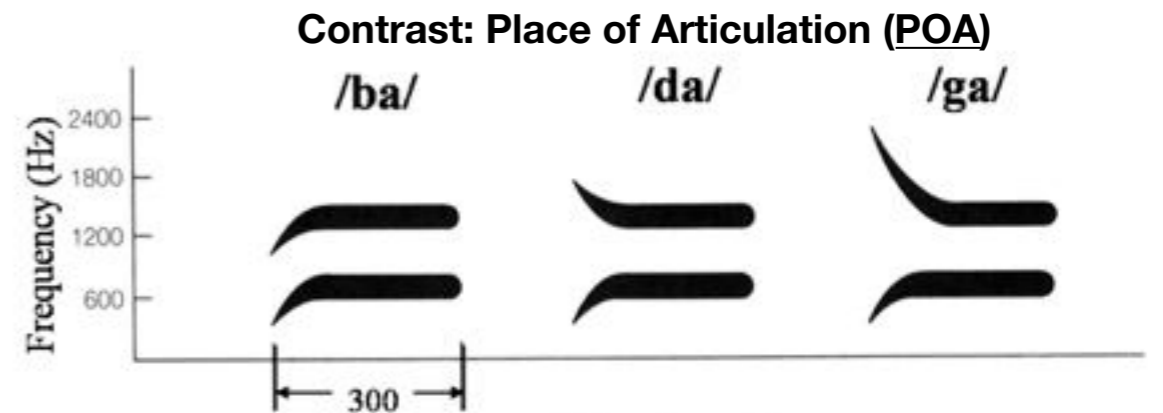
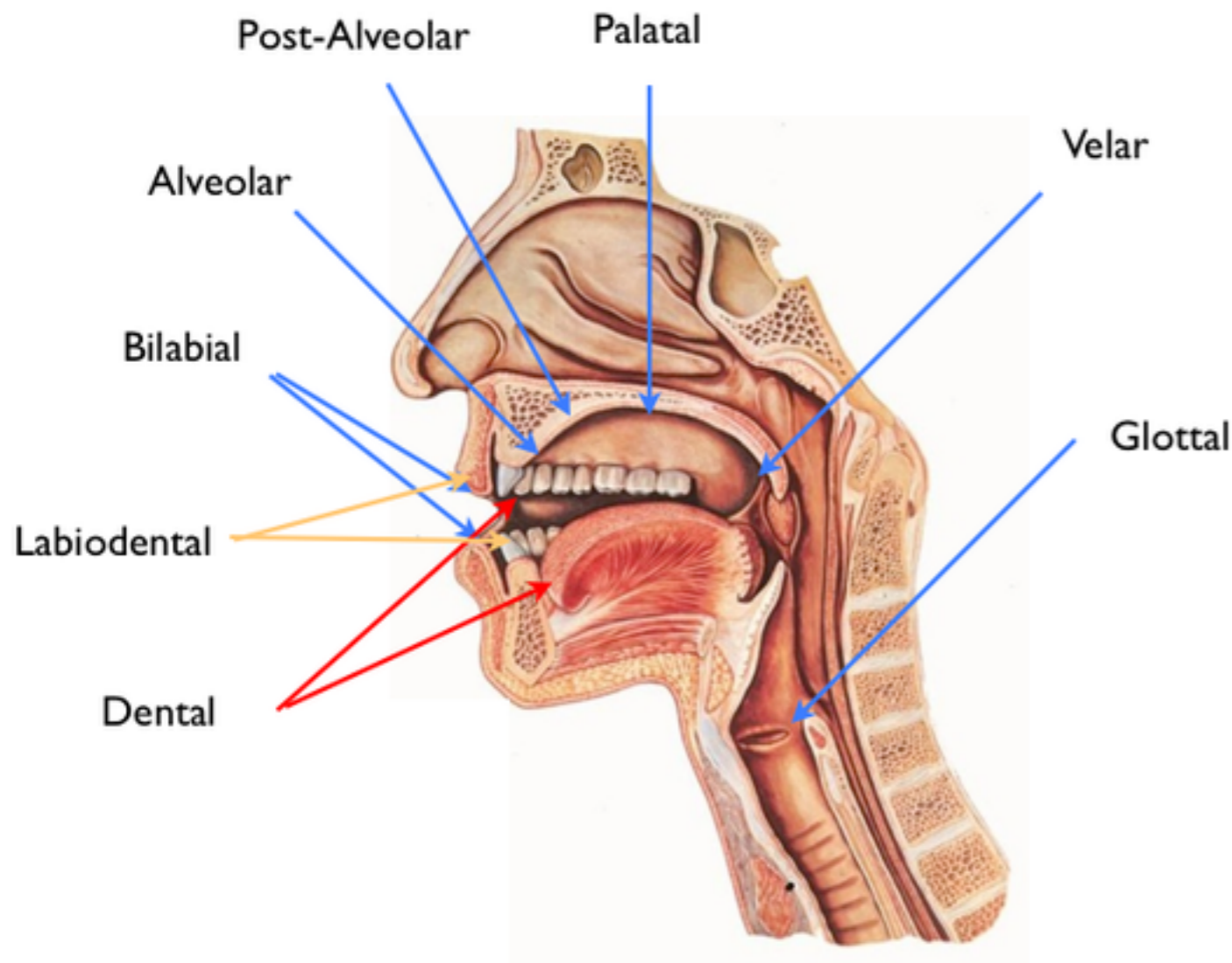
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Design & Materials



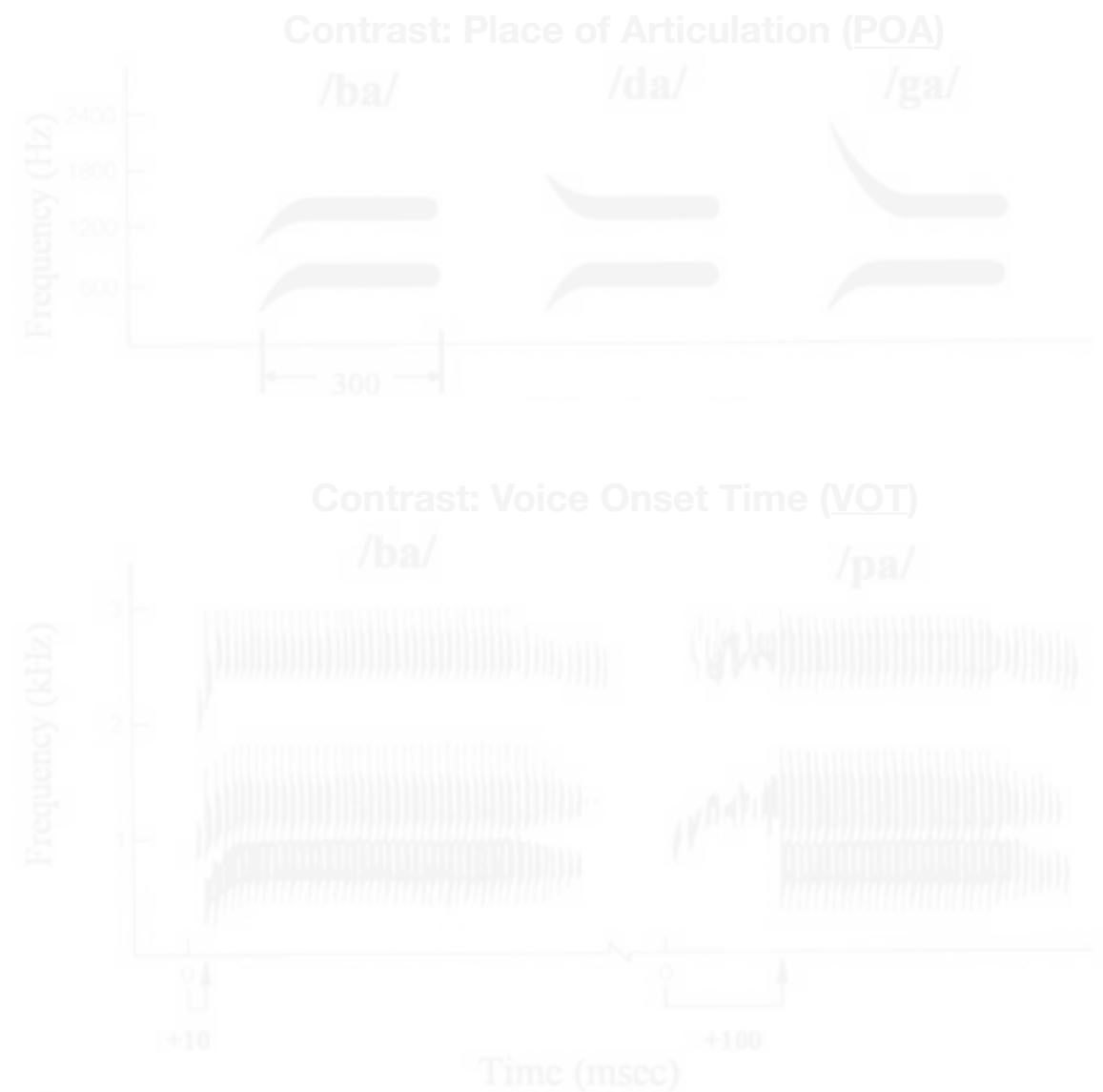
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Procedure & Analysis



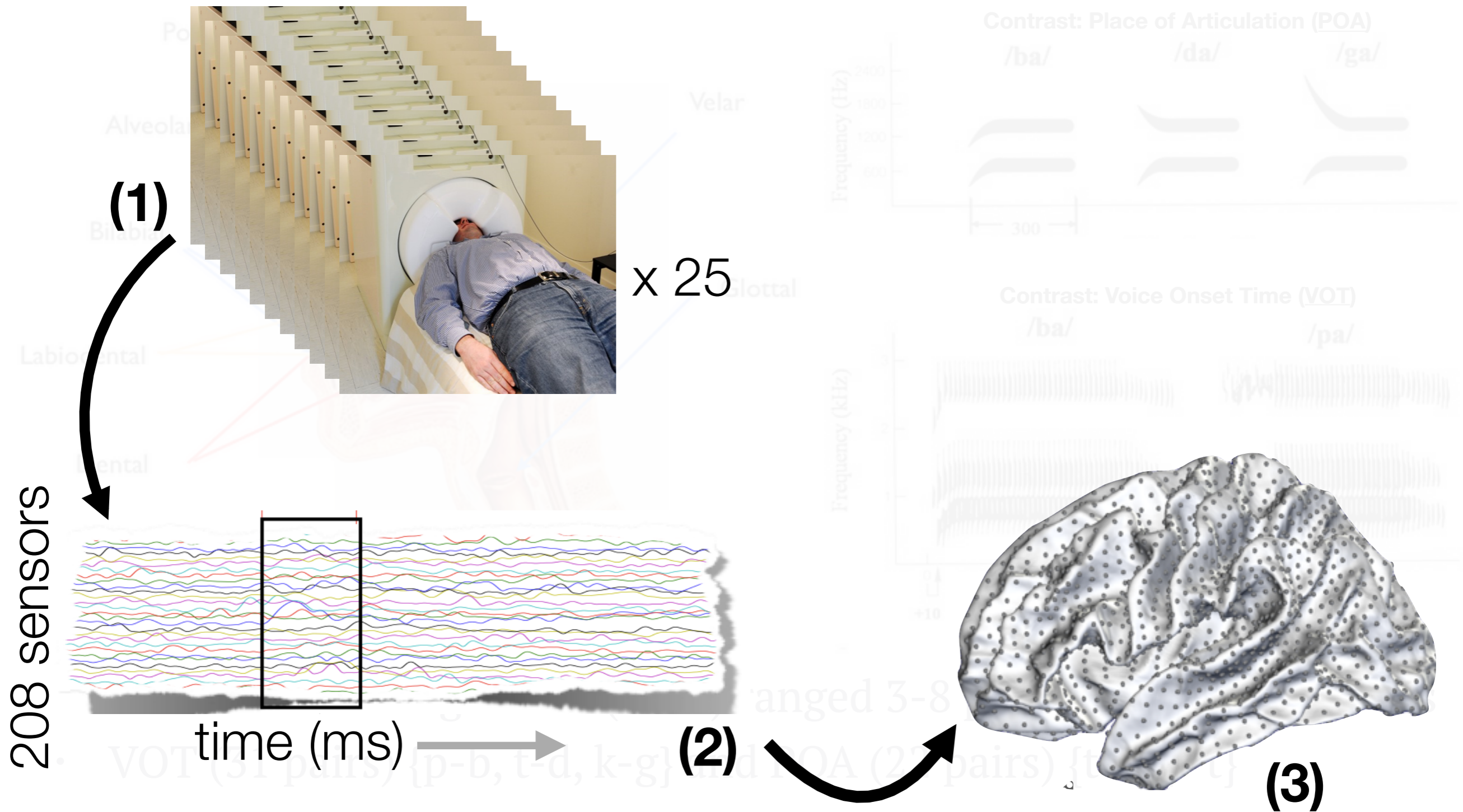
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Procedure & Analysis

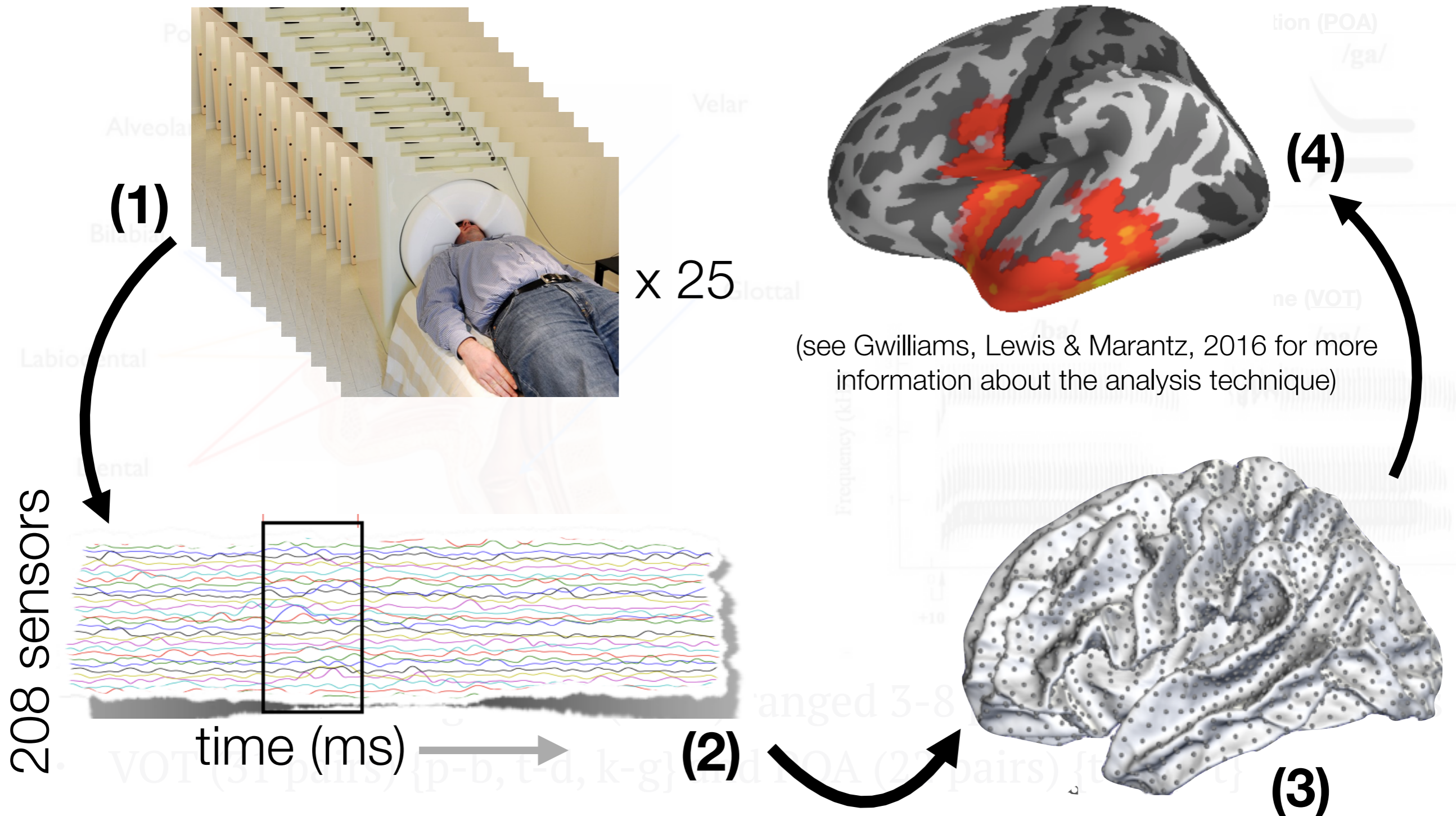


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Procedure & Analysis



Procedure & Analysis



Today's Questions

How does the auditory cortex
respond to phonological ambiguity?

Ambiguity at Onset

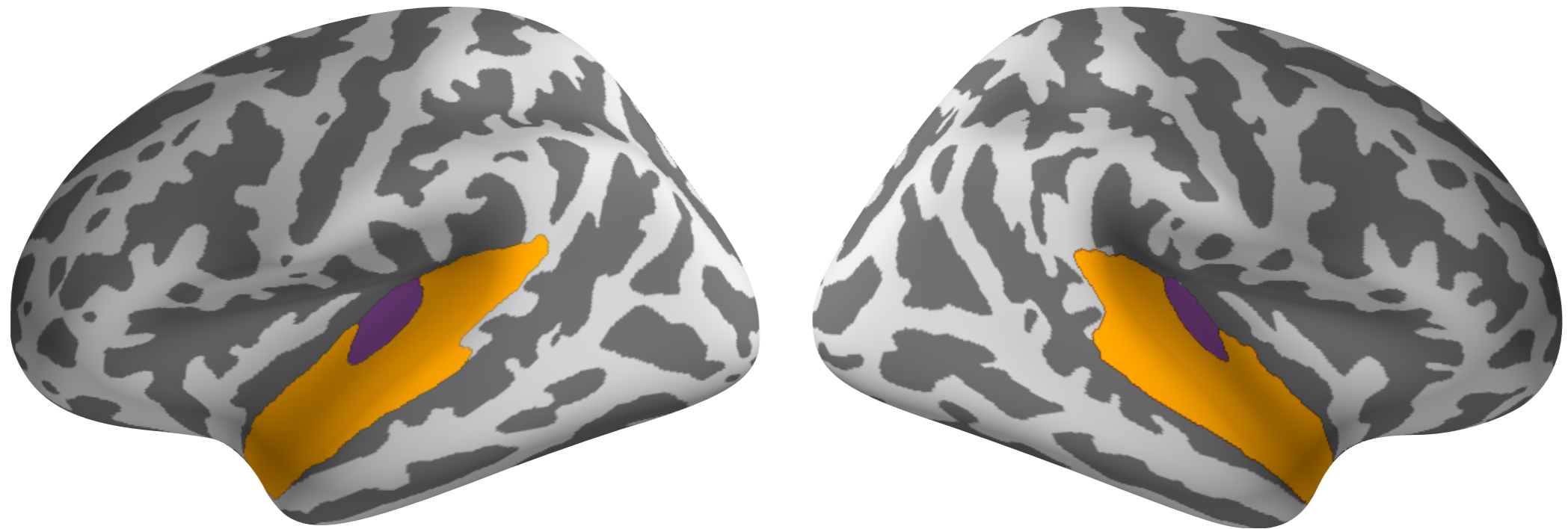
Ambiguity at Onset



Ambiguity at Onset



Ambiguity at Onset



- Time-window: 0-200 ms after word onset
- Region: **Heschl's gyrus** & **superior temporal gyrus** bilaterally



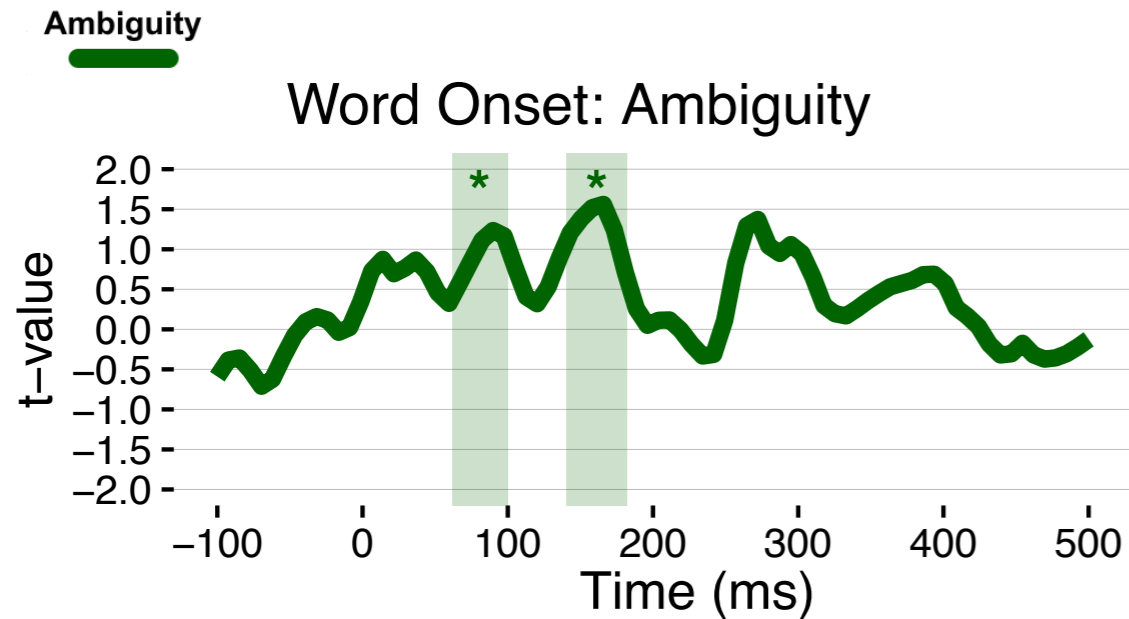
Ambiguity at Onset

Ambiguity

- Time-window: 0-200 ms after word onset
- Region: **Heschl's gyrus** & **superior temporal gyrus** bilaterally



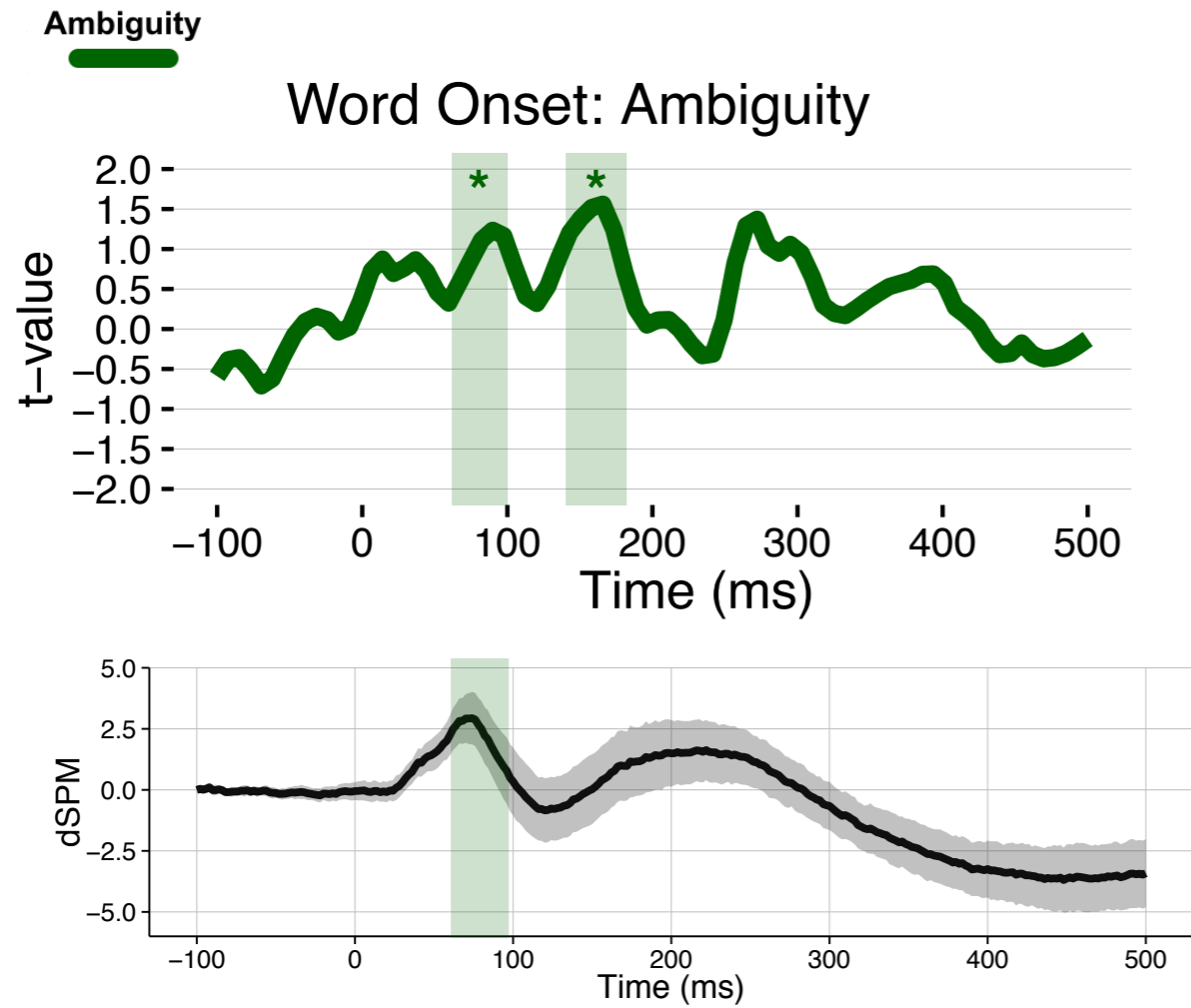
Ambiguity at Onset



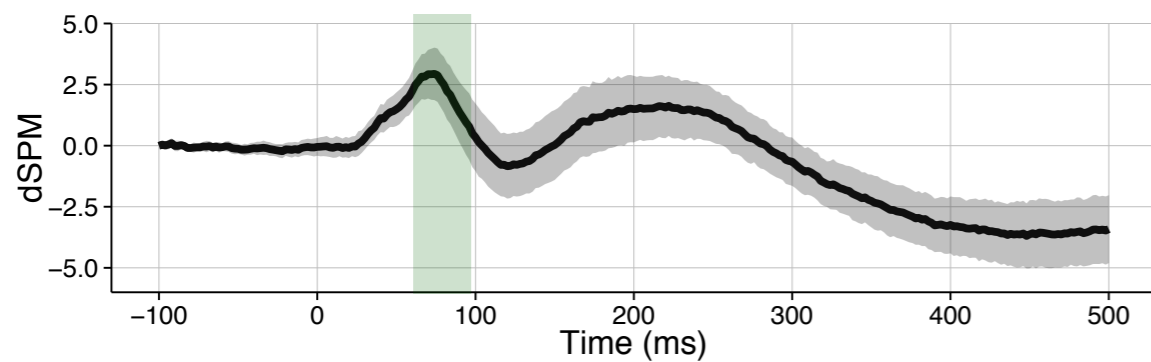
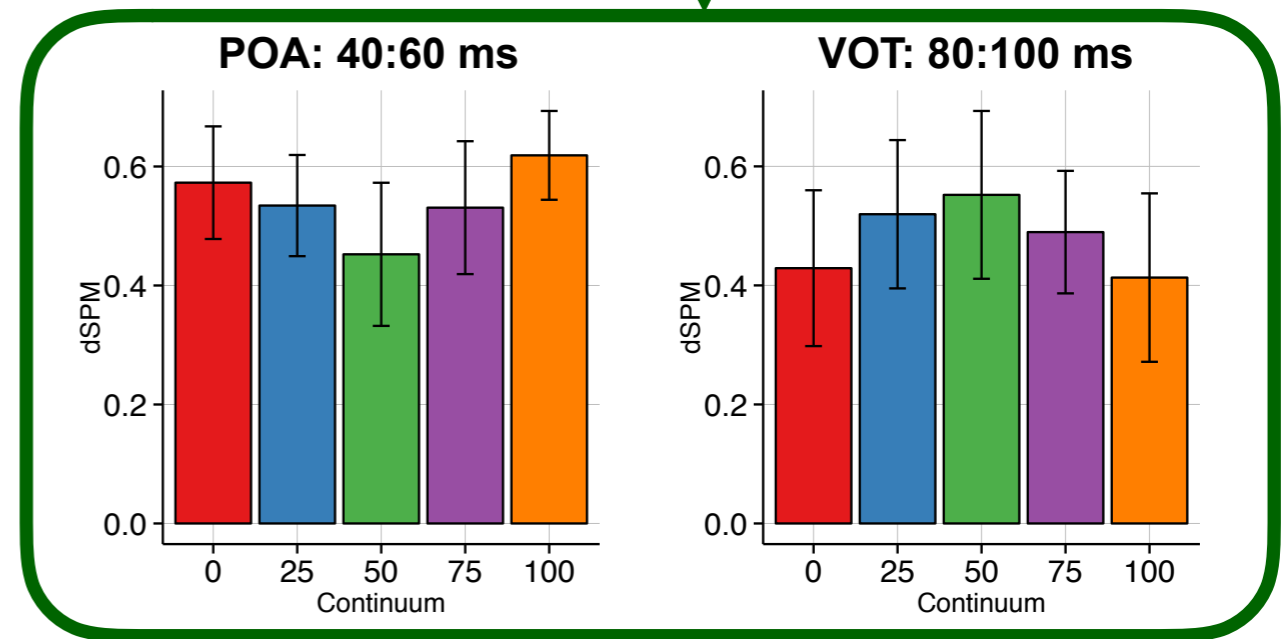
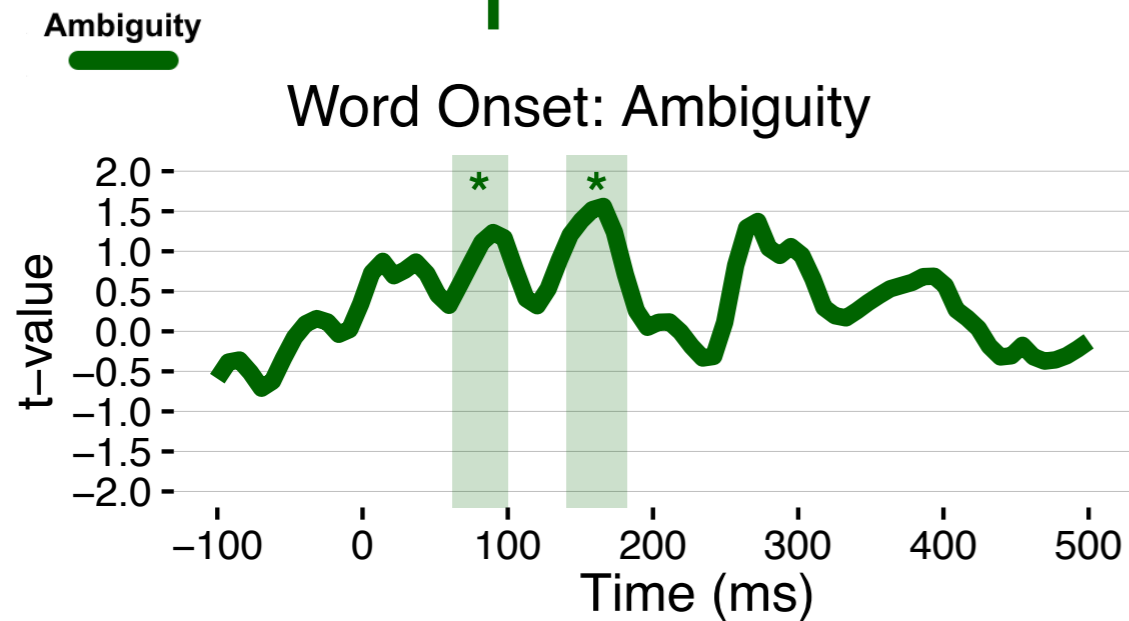
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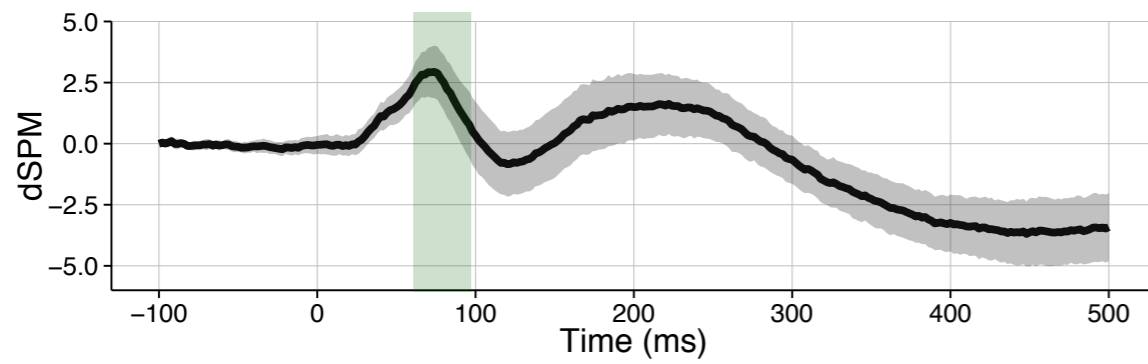
Ambiguity at Onset



Ambiguity at Onset



Ambiguity at Onset

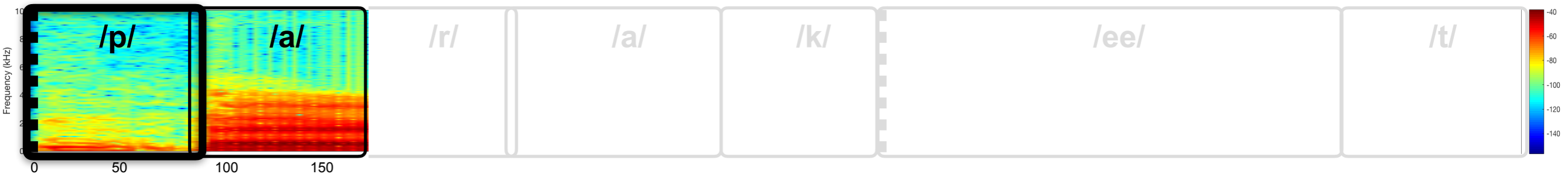
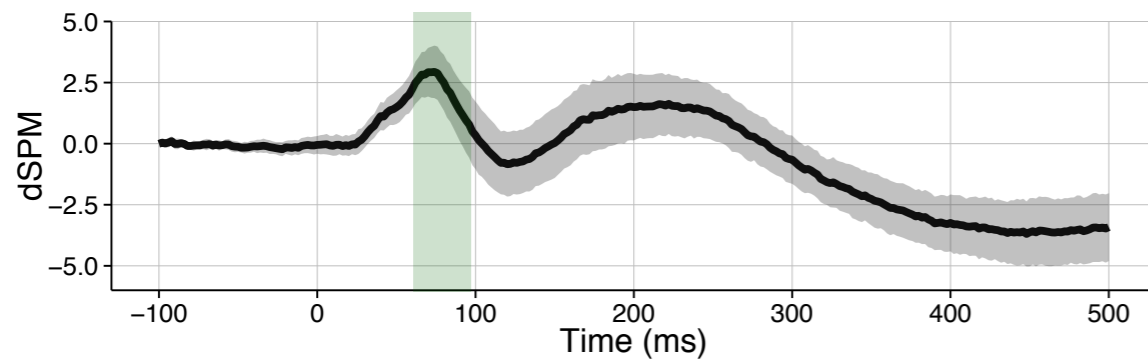


Ambiguity at Onset

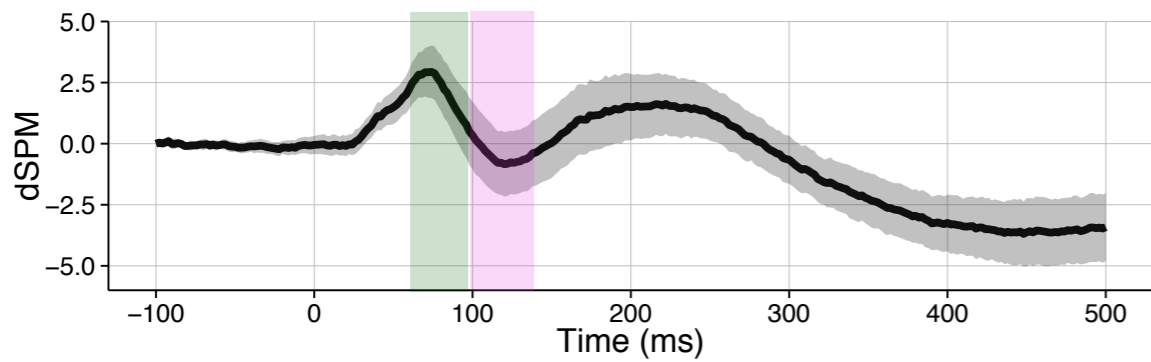
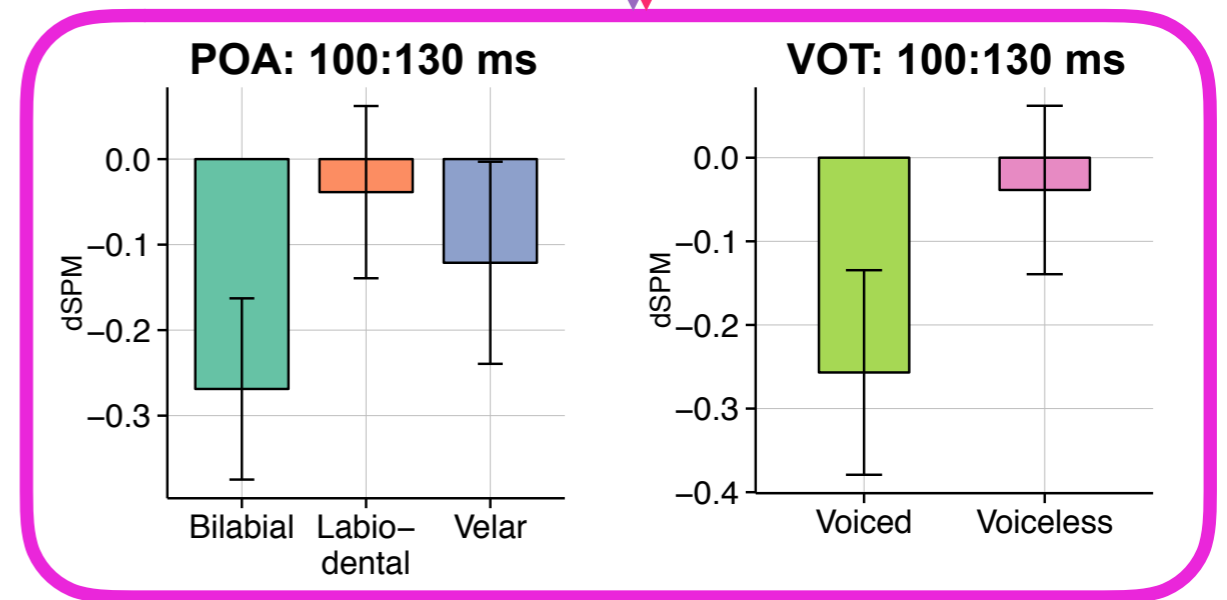
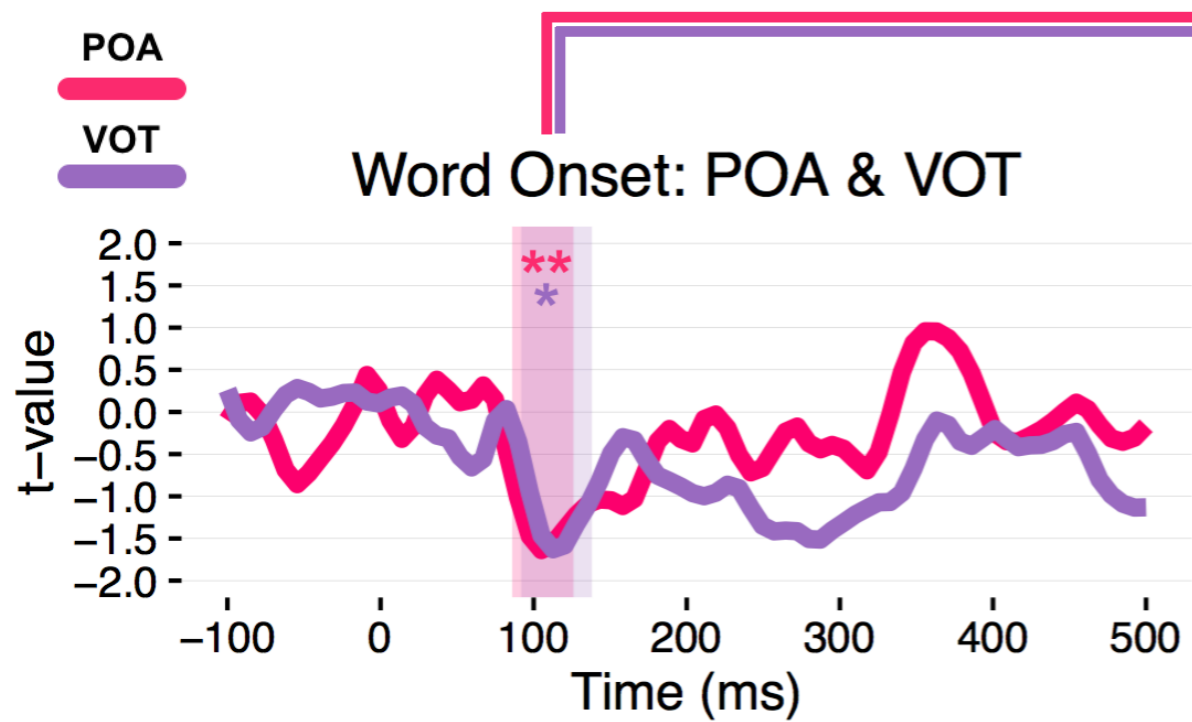
POA



VOT



Ambiguity at Onset



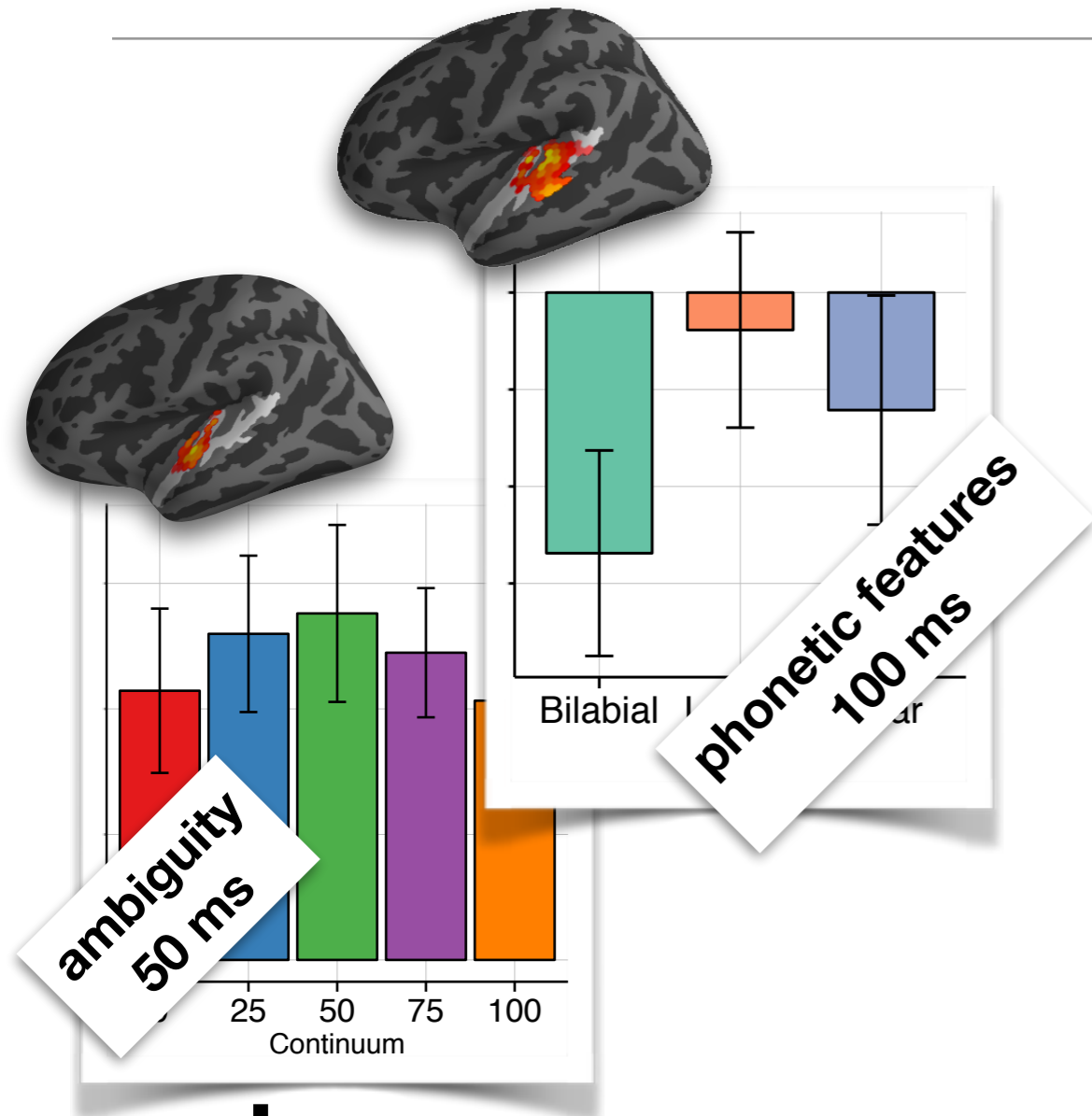
Interim Conclusion

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parakeet

Interim Conclusion

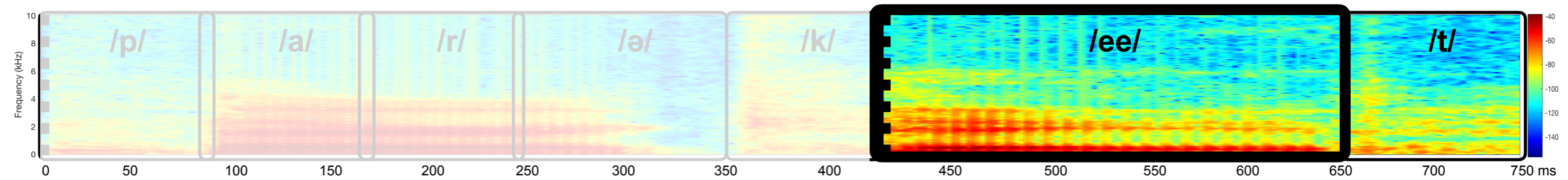


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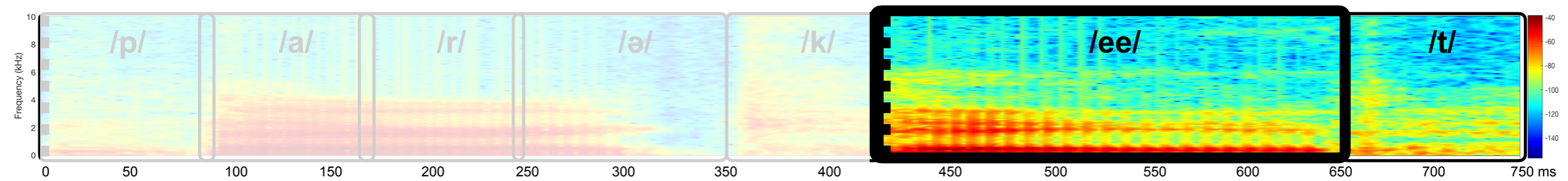
Today's Questions

What are the neural signatures of
ambiguity **resolution**?

Ambiguity at POD

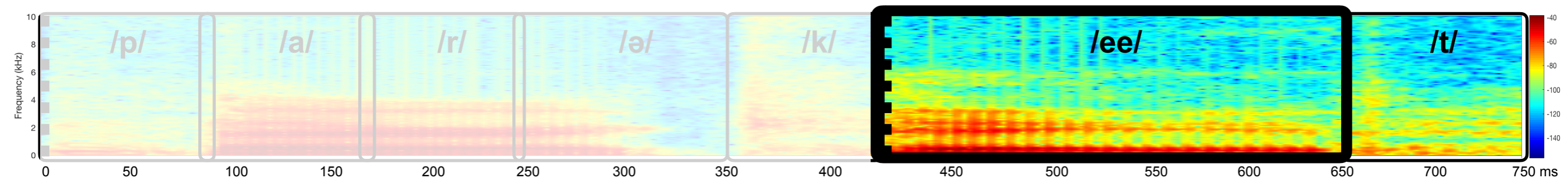


Ambiguity at POD



Ambiguity at POD

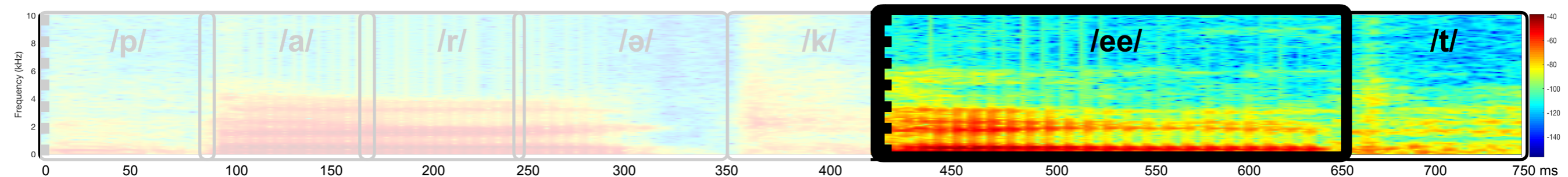
- Time-window: 0-200 ms after POD onset
- Region: **Heschl's gyrus** & **superior temporal gyrus** bilaterally



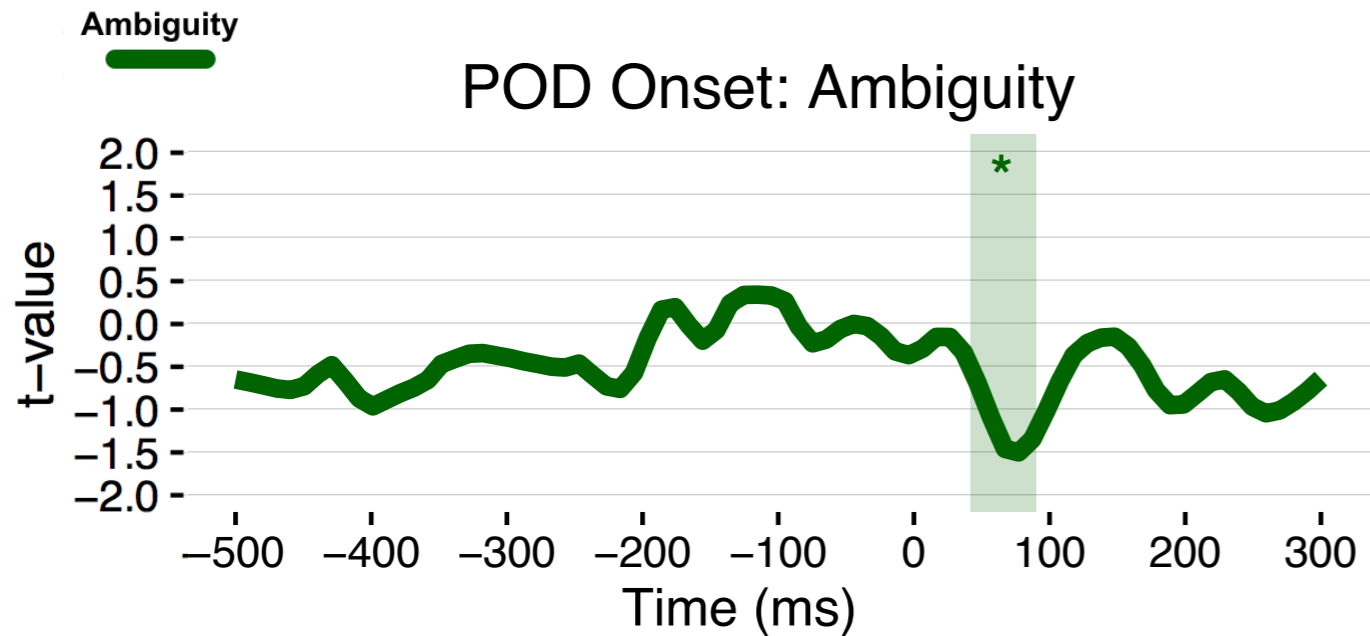
Ambiguity at POD

Ambiguity

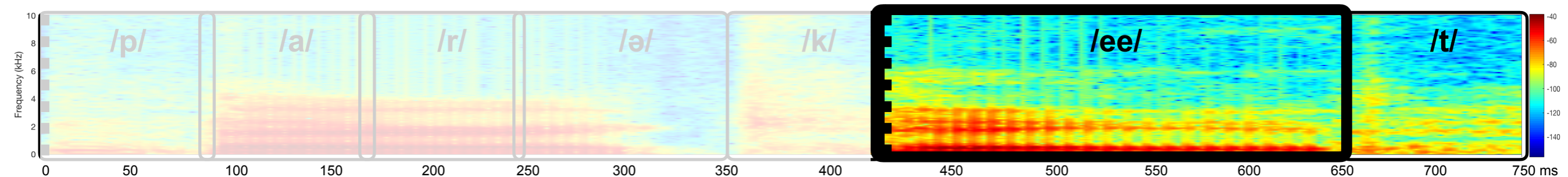
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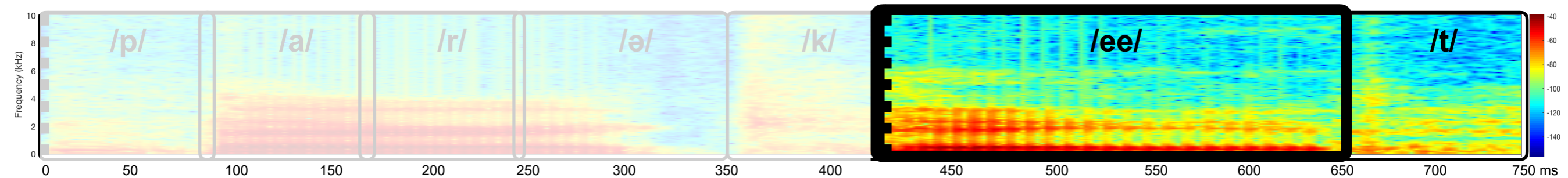
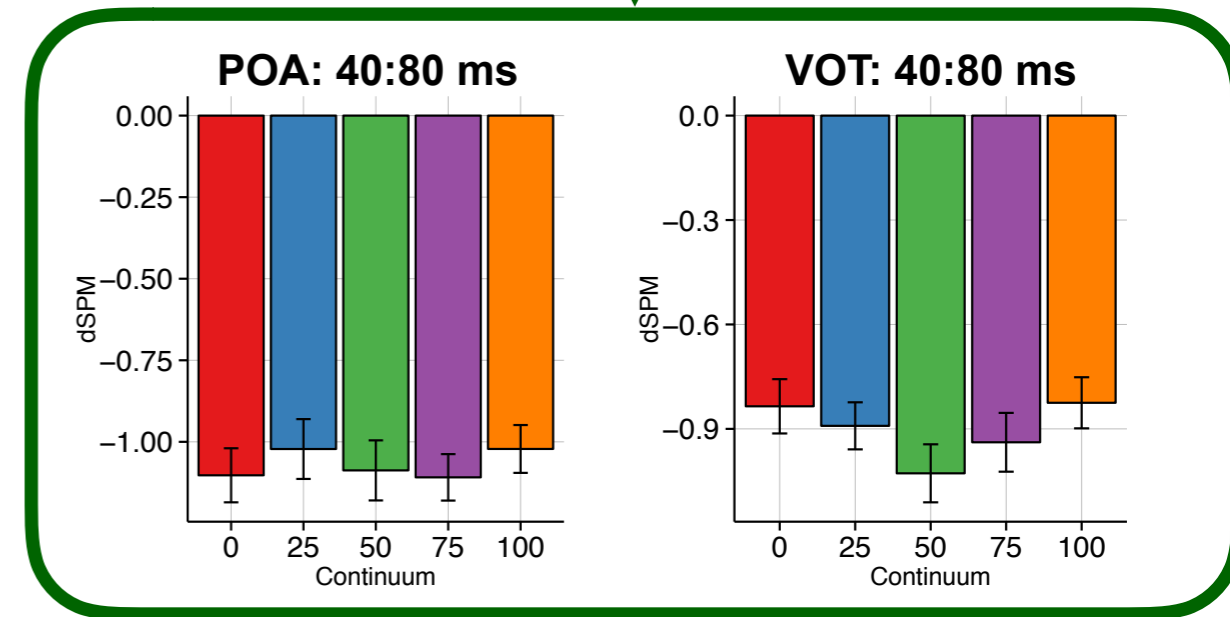
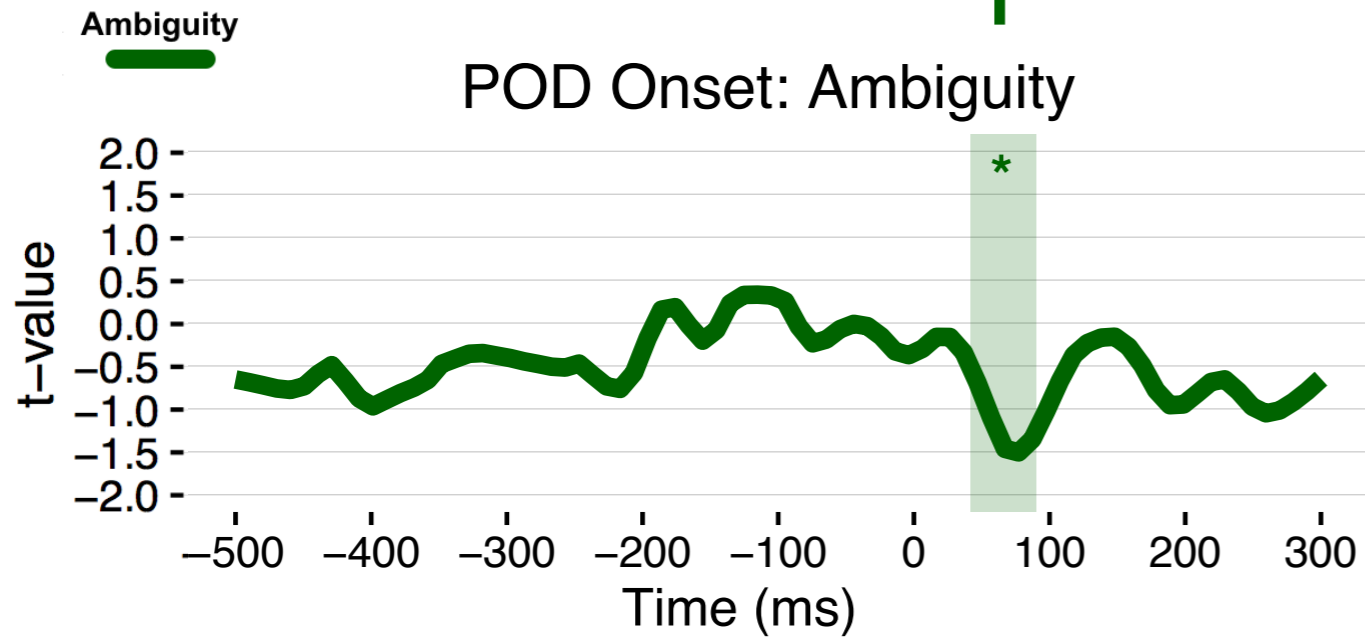
Ambiguity at POD



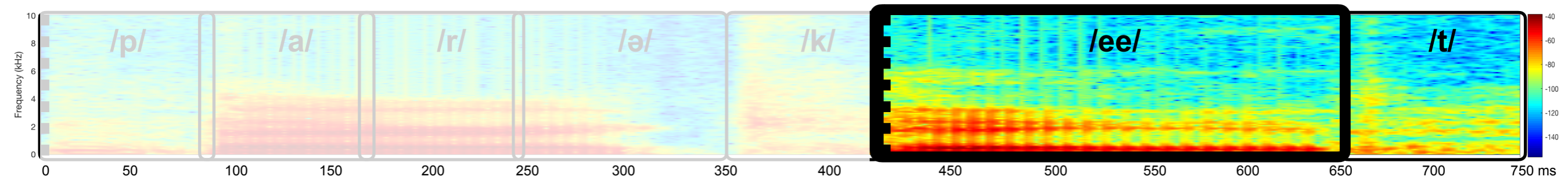
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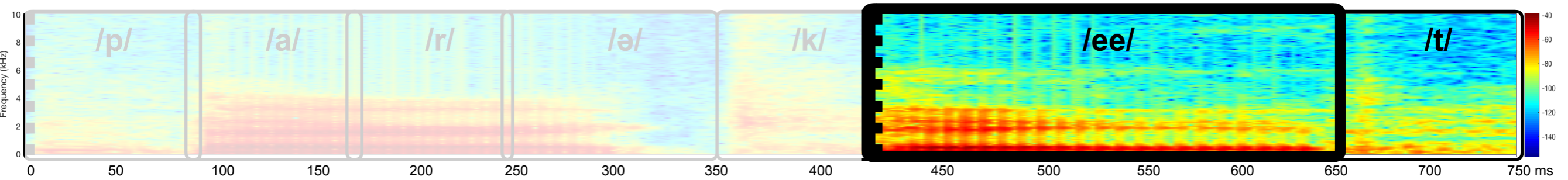
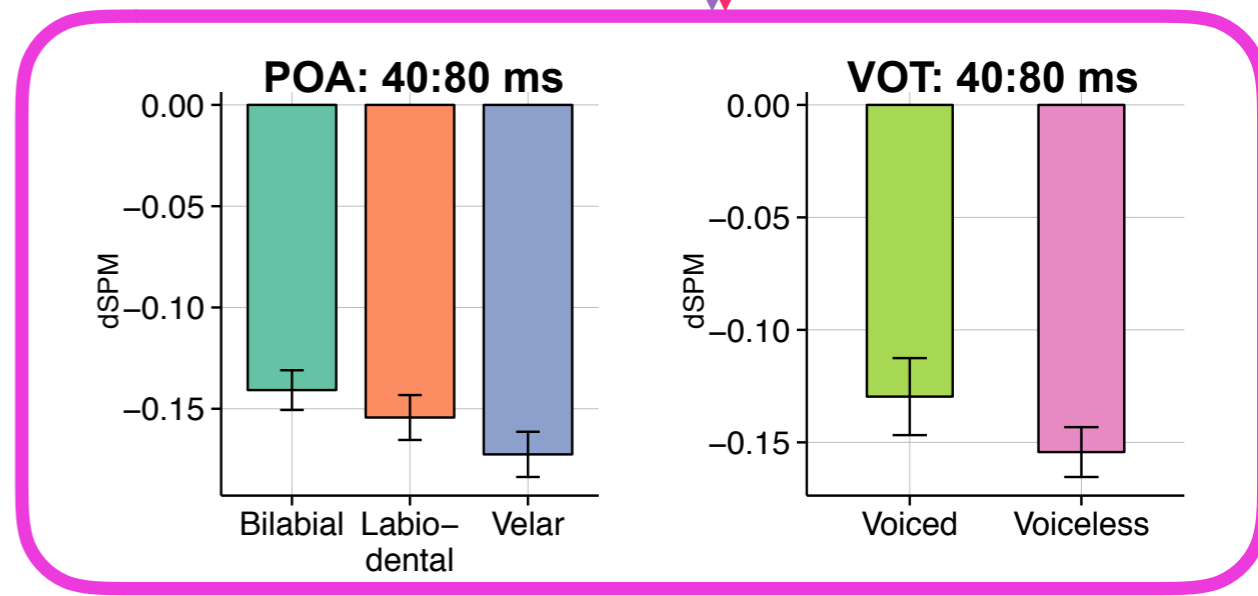
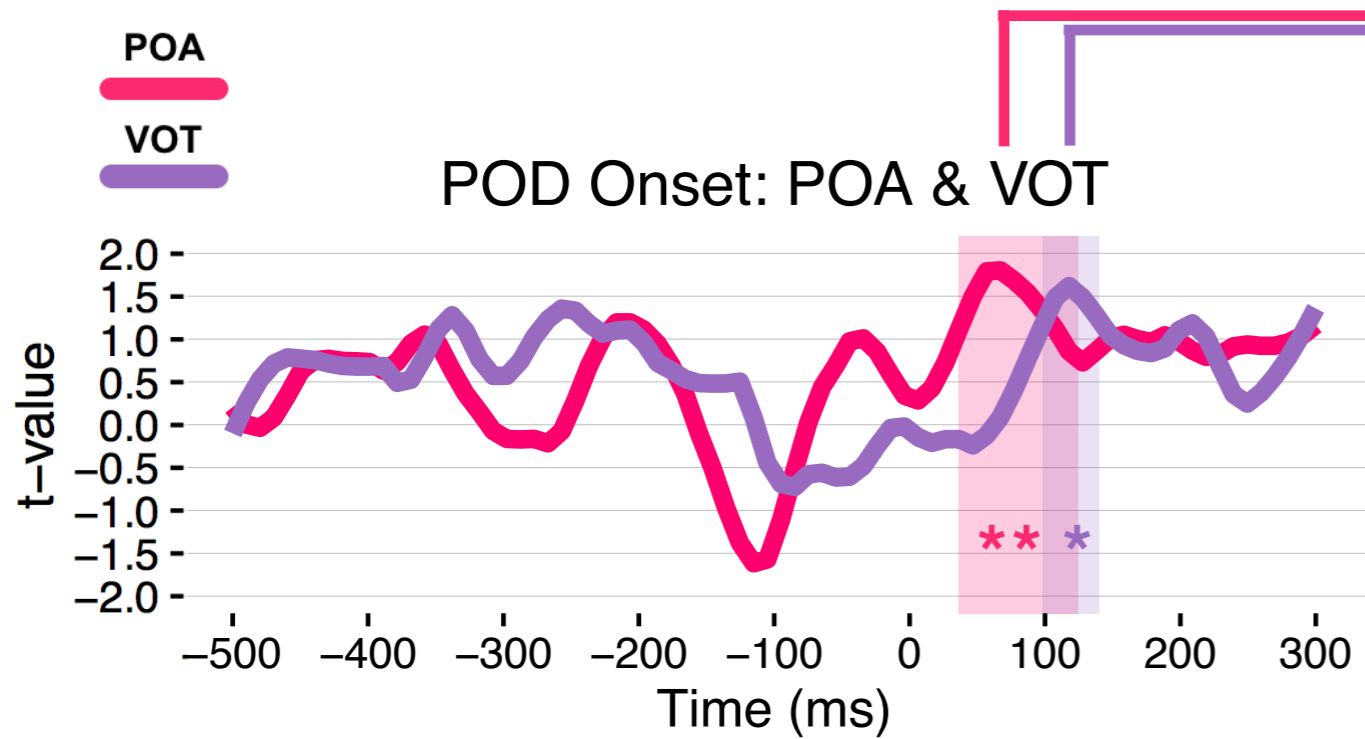
Ambiguity at POD



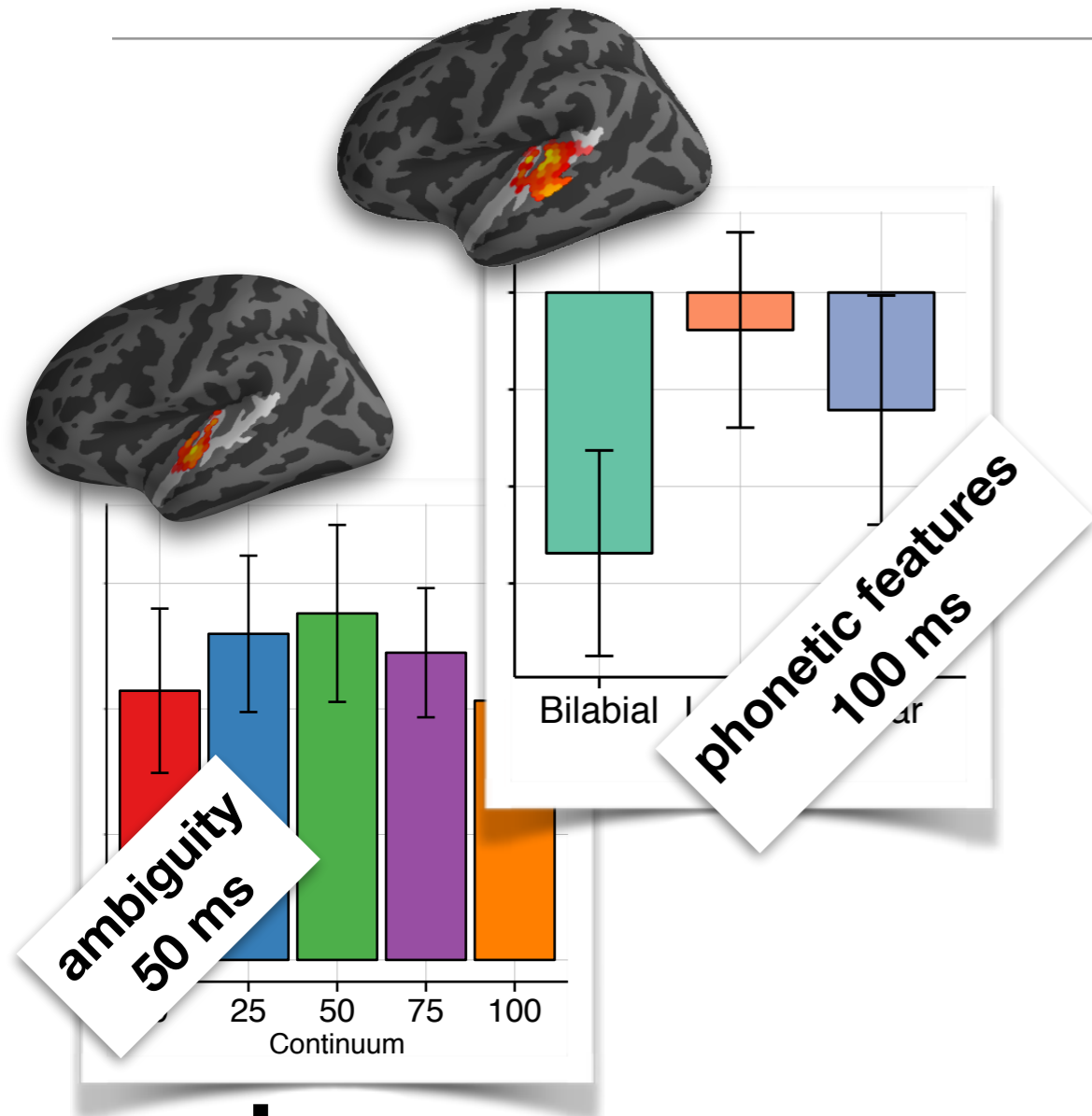
Ambiguity at POD



Ambiguity at POD



Interim Conclusion

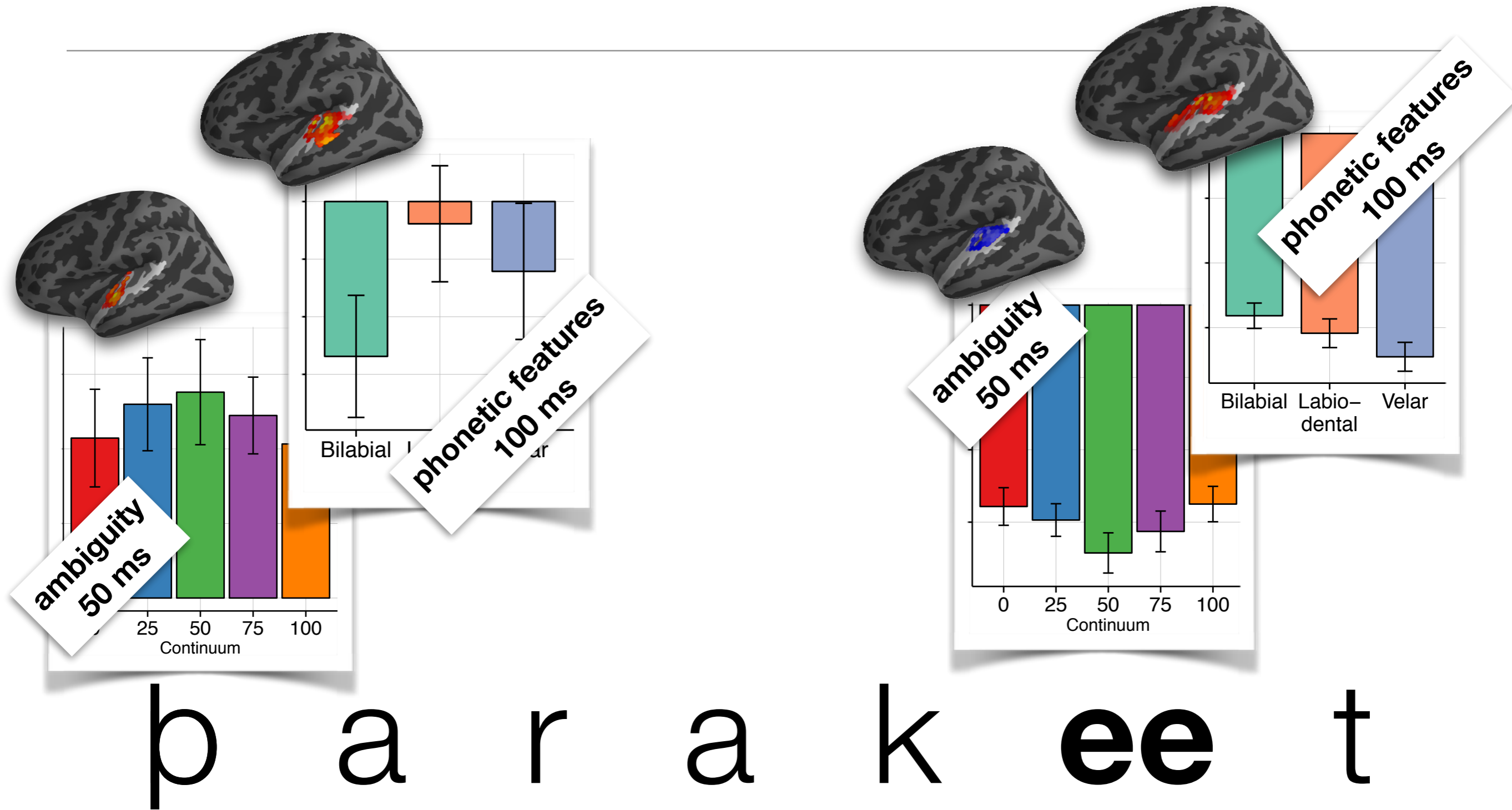


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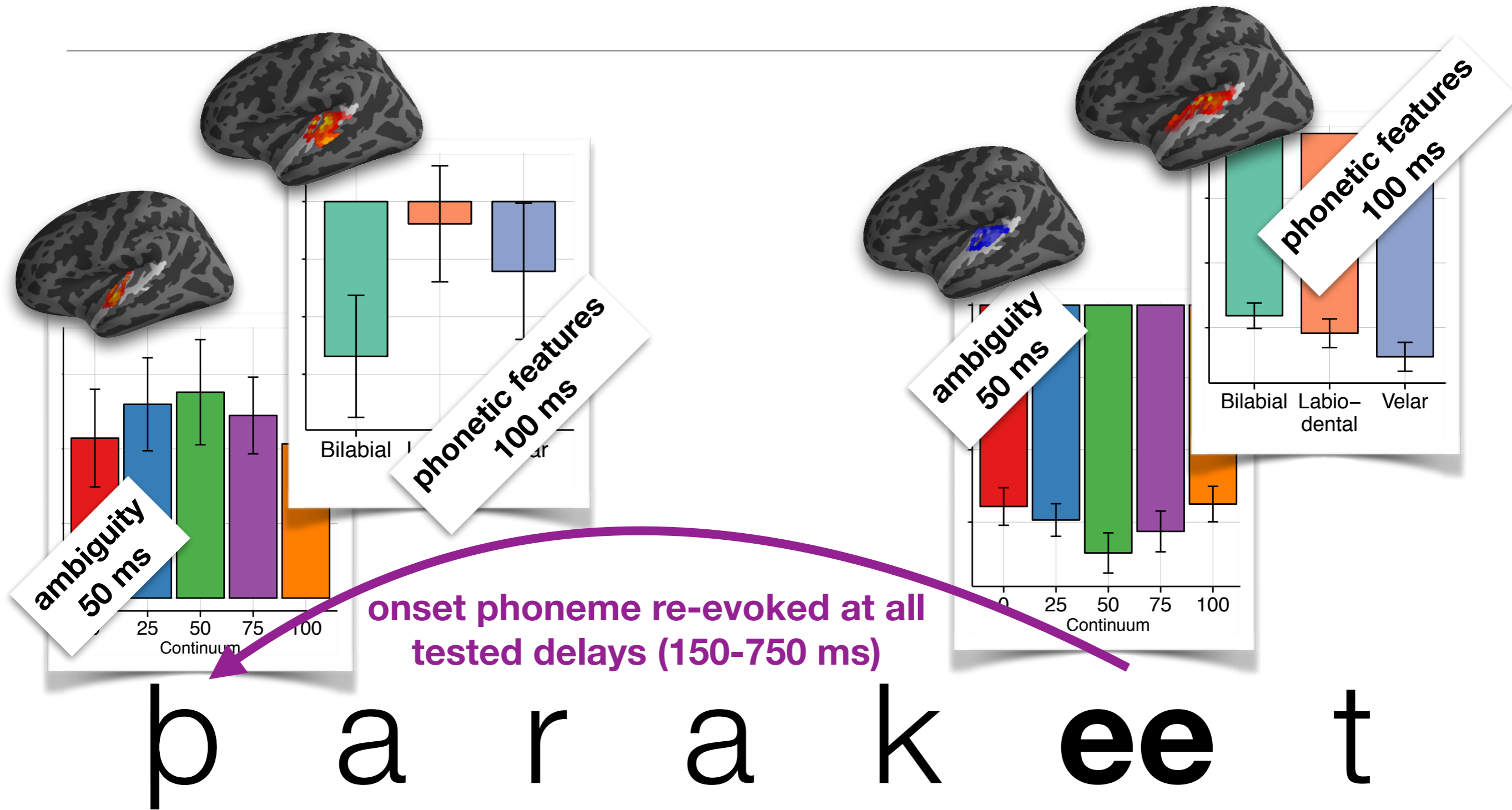


b a r a k e e t

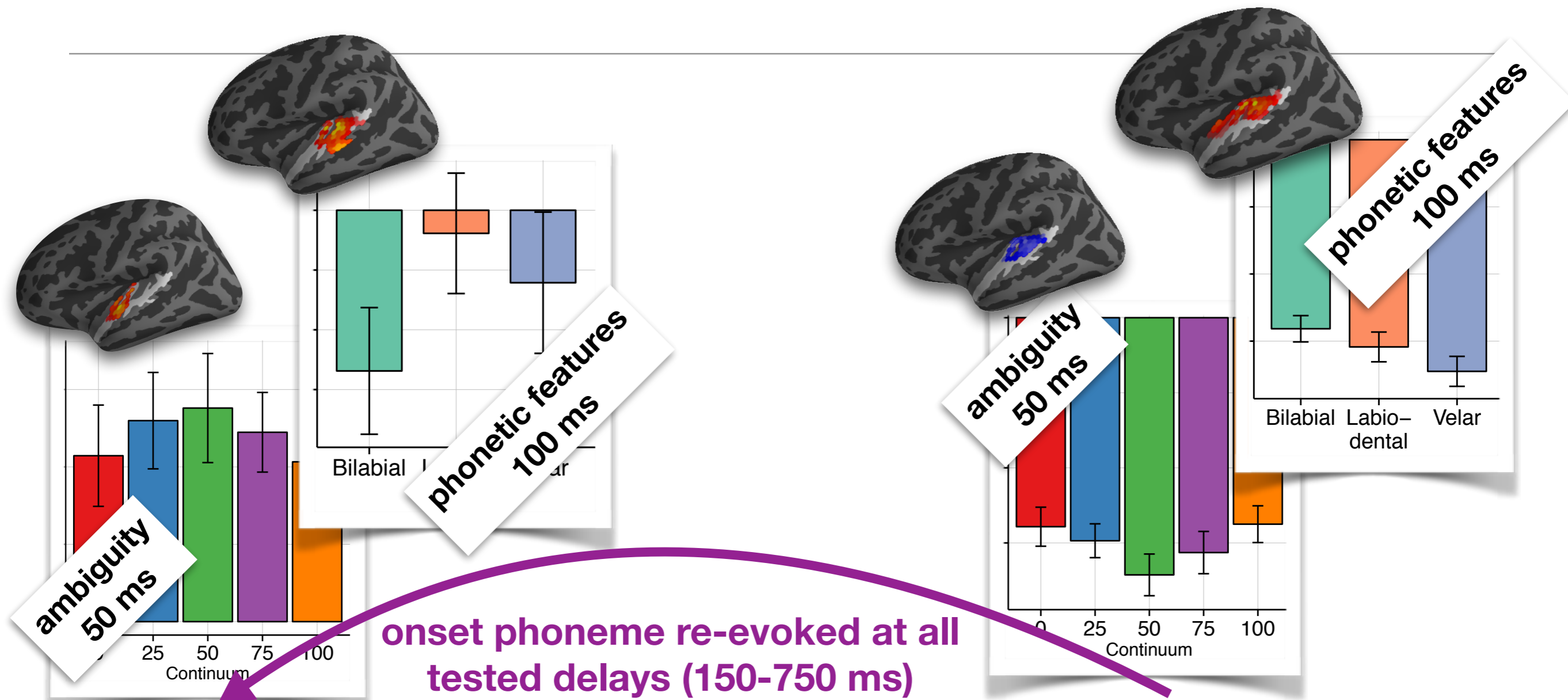
Interim Conclusion



Interim Conclusion



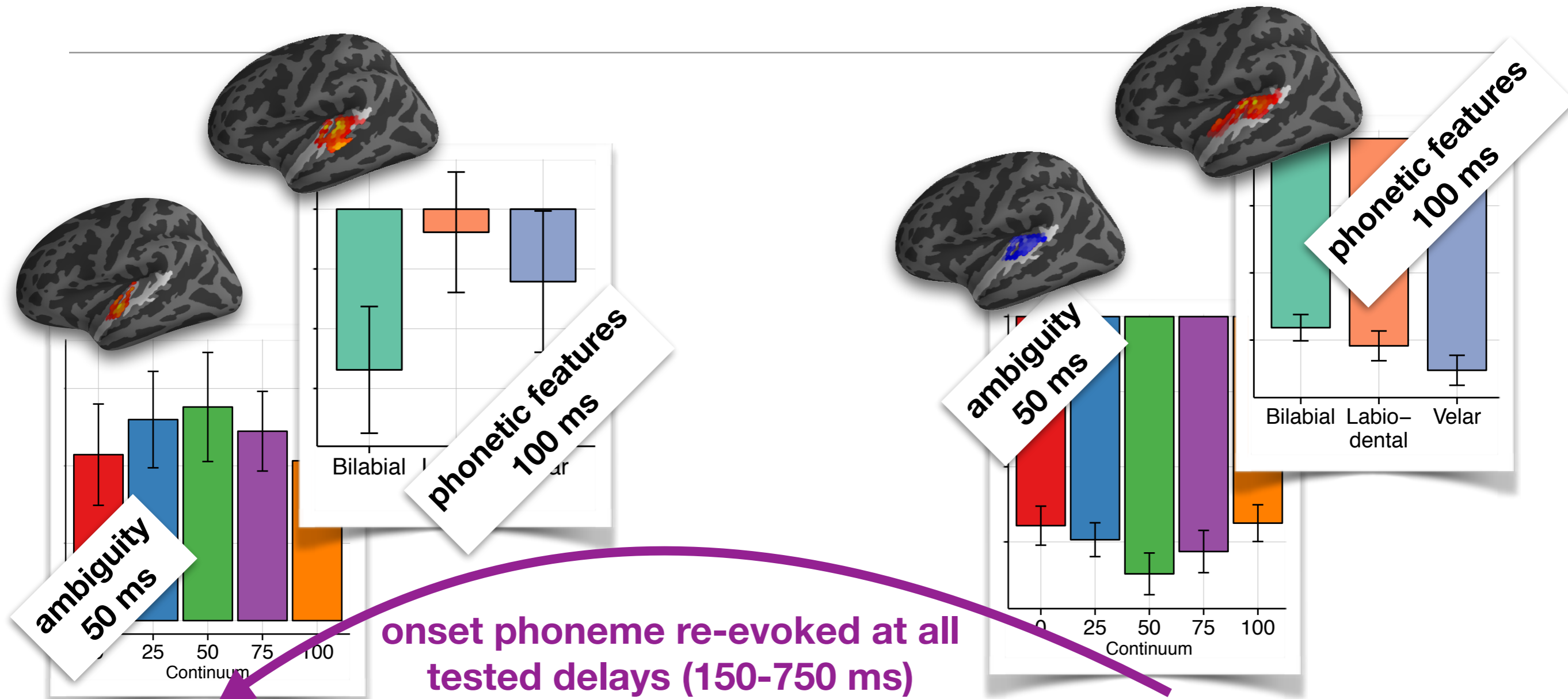
Interim Conclusion



b a r a k e e t

...commitment delay...

Interim Conclusion



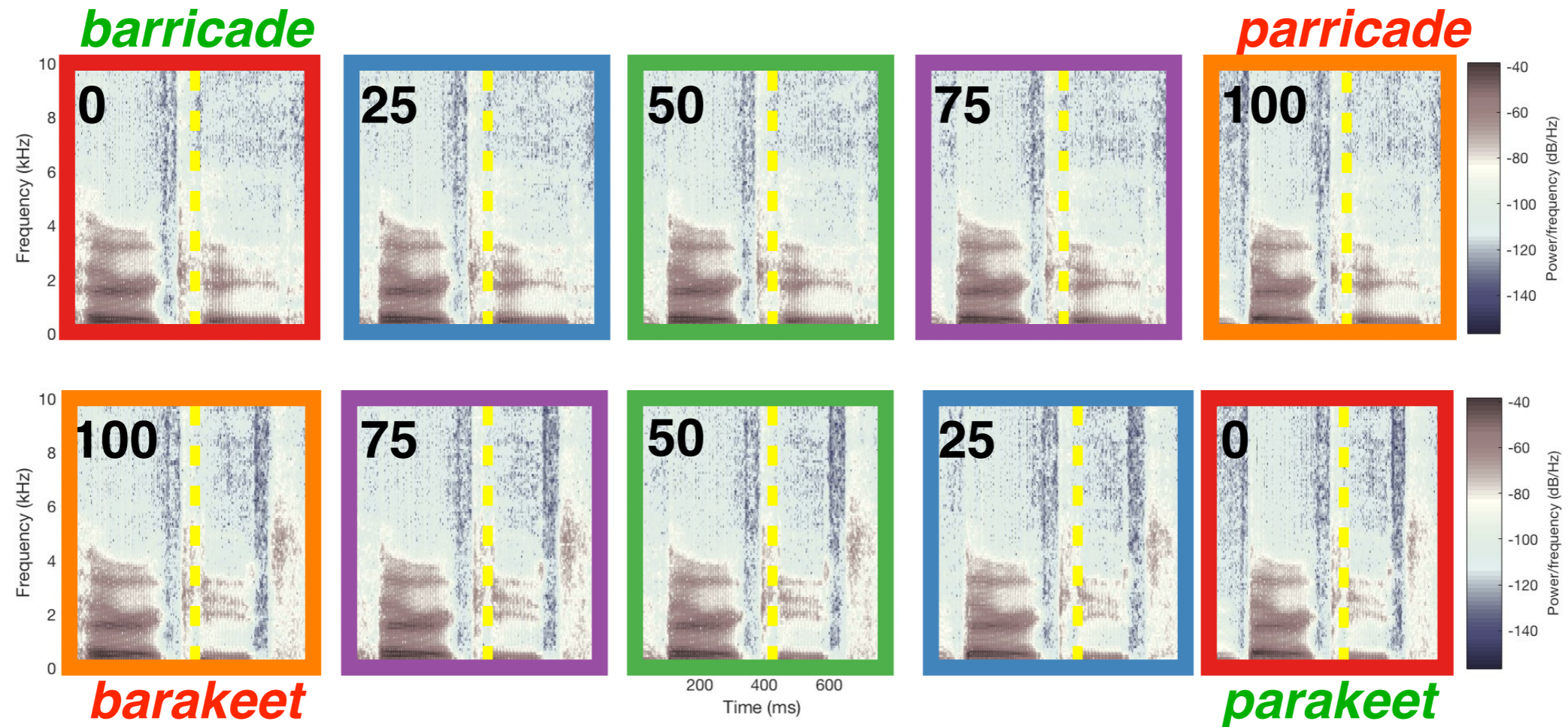
b a r a k e e t

...commitment delay...

Today's Questions

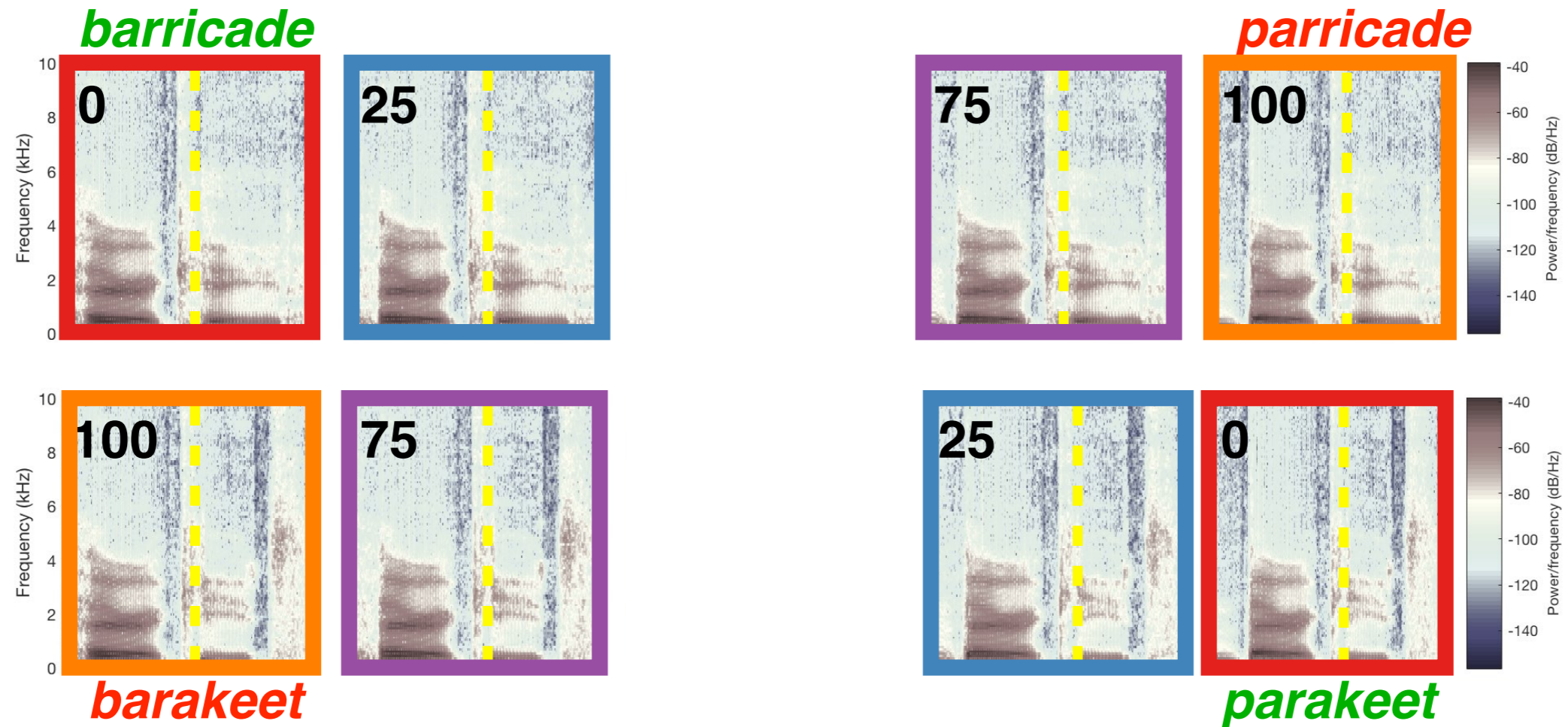
What is the **time-limit** on how late subsequent context can be received?

Example Continuum Pair



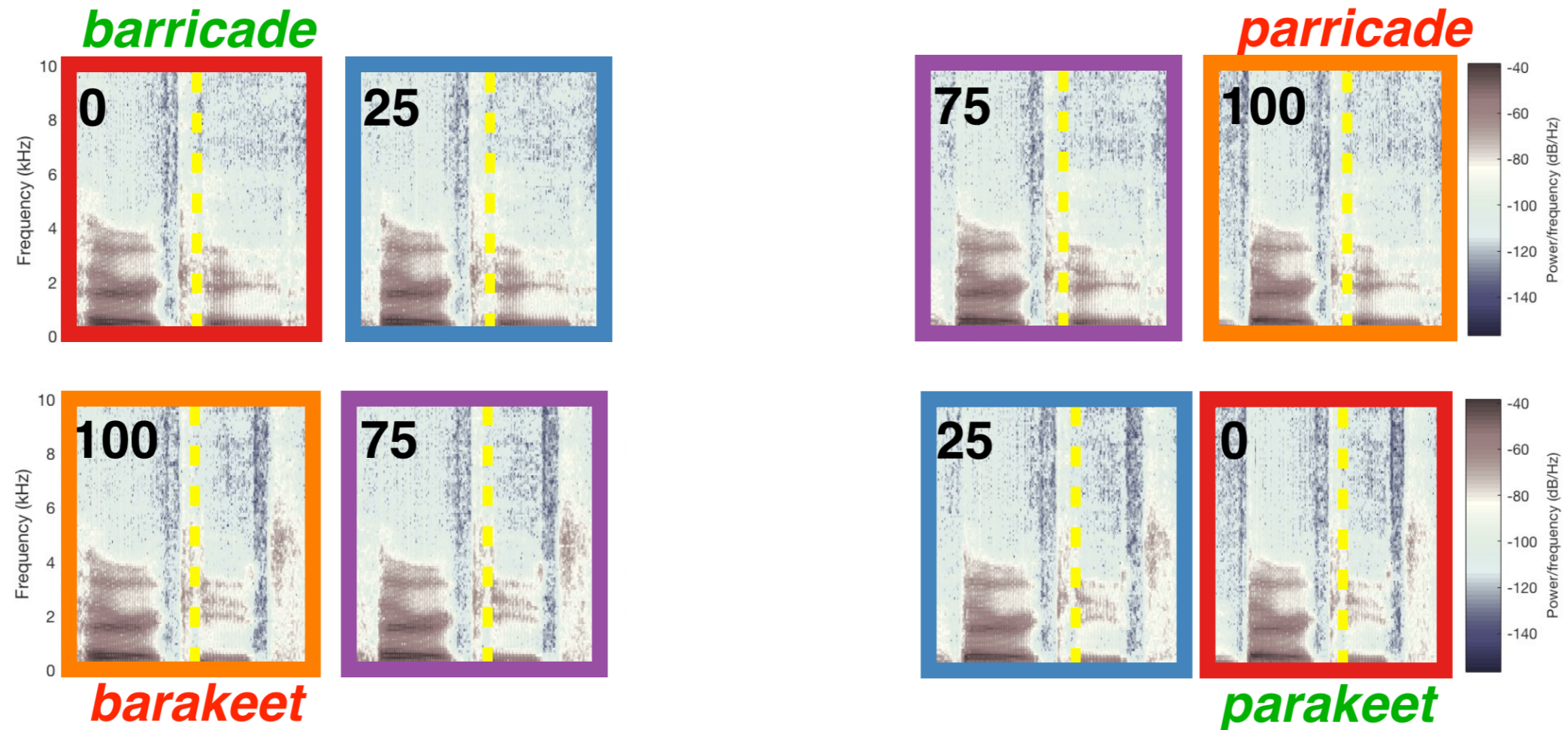
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Example Continuum Pair



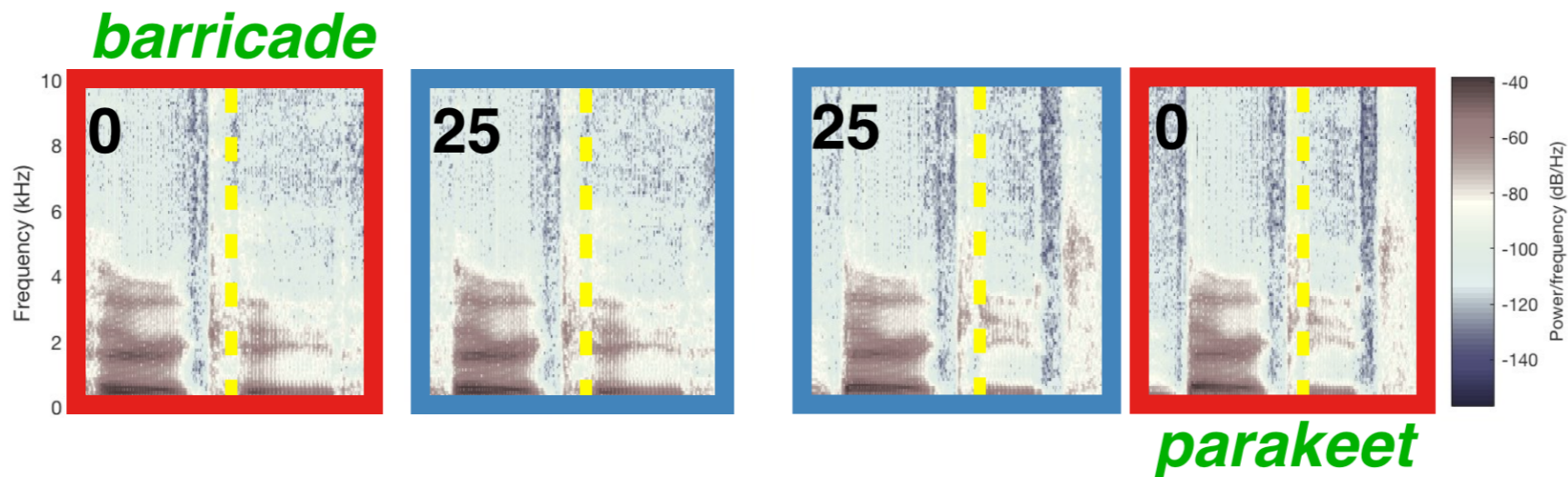
- Point of Disambiguation (POD) ranged 3-8 phonemes / 150-750 ms

Example Continuum Pair

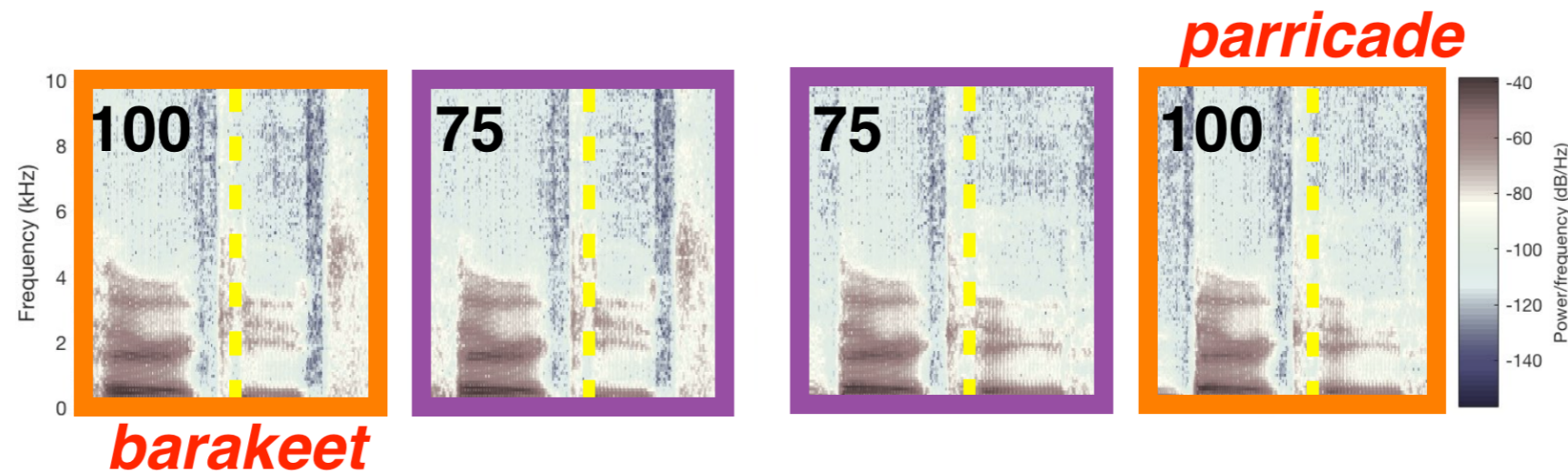


- Point of Disambiguation (POD) ranged 3-8 phonemes / 150-750 ms

Example Continuum Pair

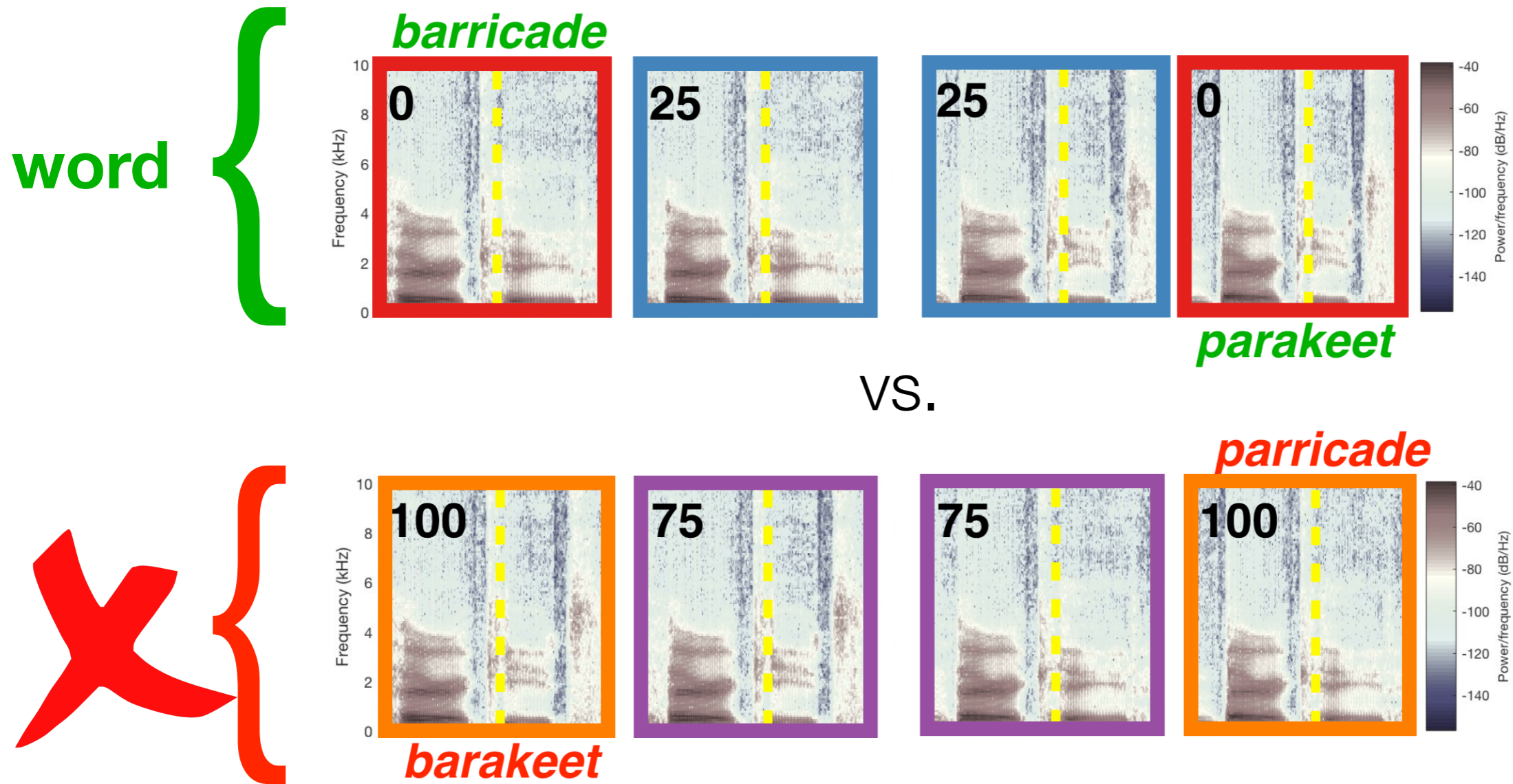


VS.



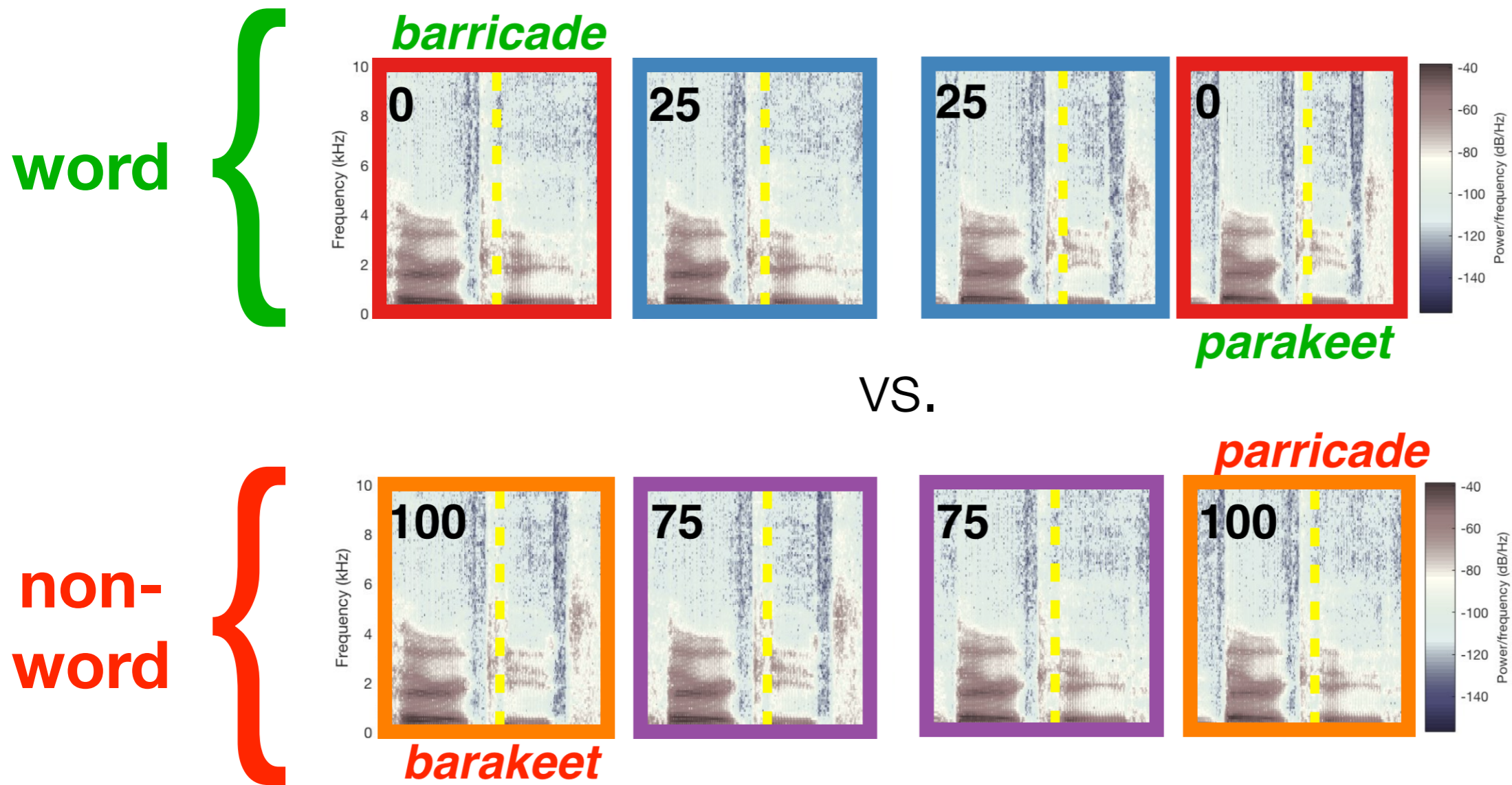
- Point of Disambiguation (POD) ranged 3-8 phonemes / 150-750 ms

Example Continuum Pair



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

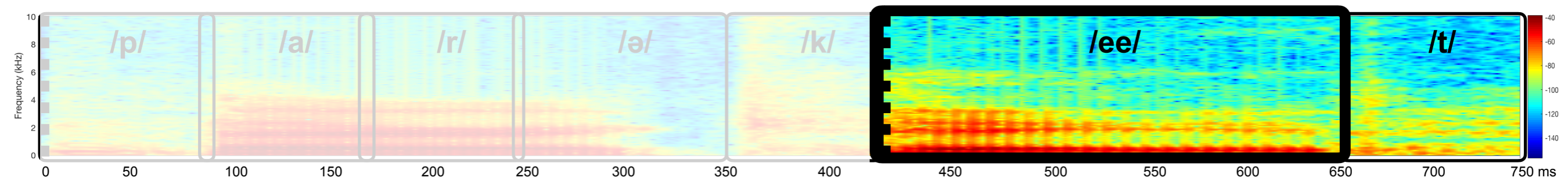
Example Continuum Pair



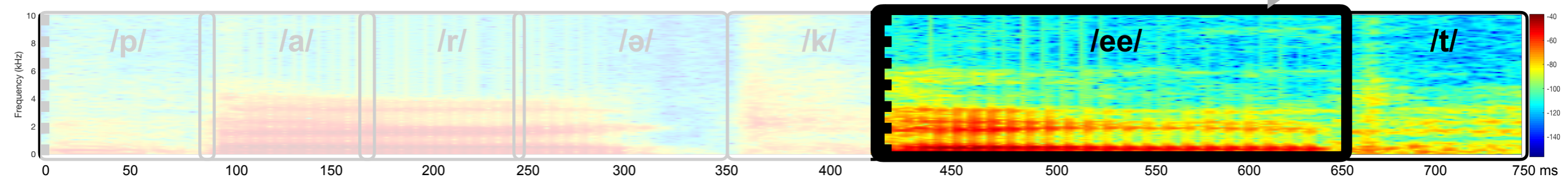
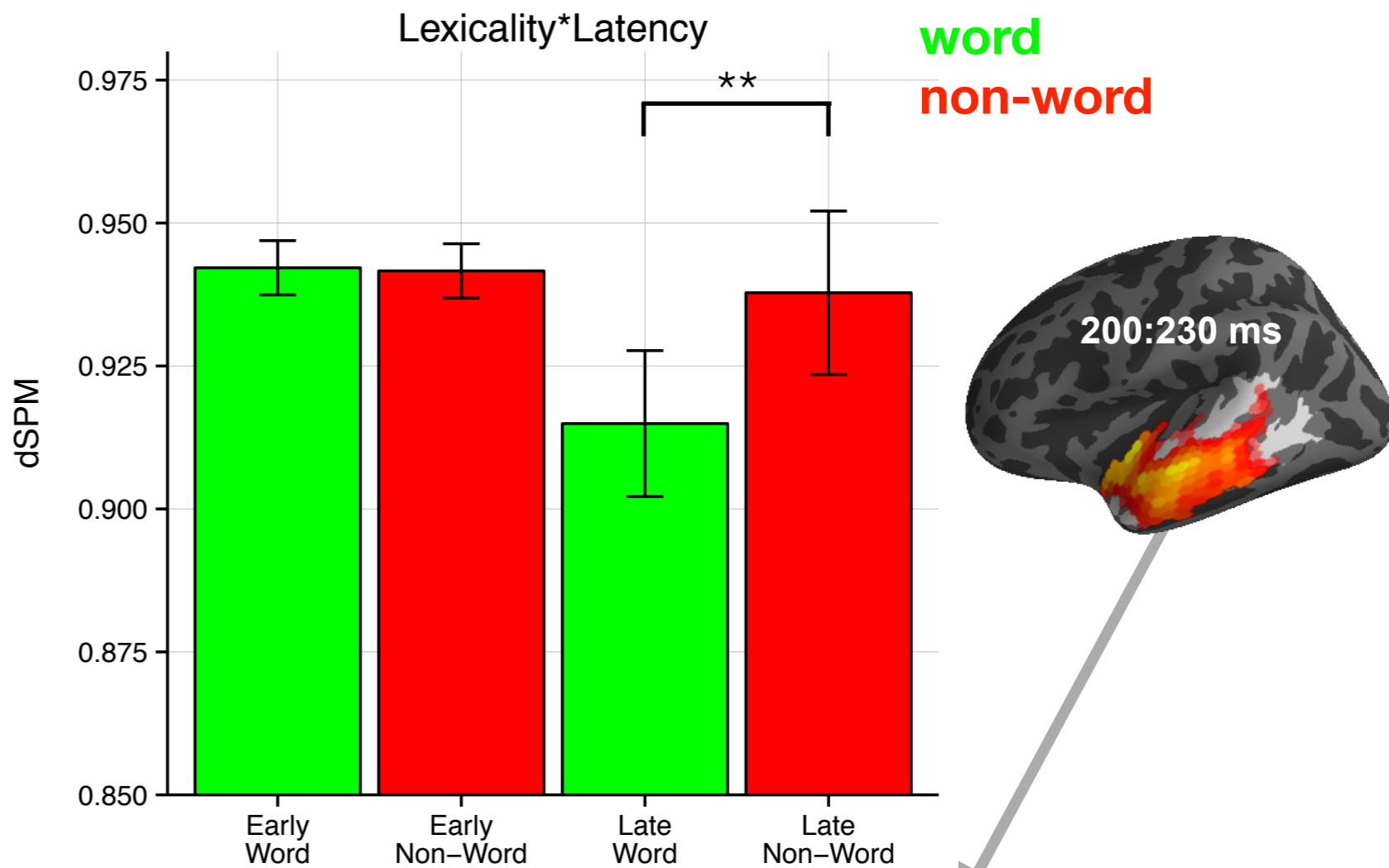
- Point of Disambiguation (POD) ranged 3-8 phonemes / 150-750 ms

Commitment Before POD

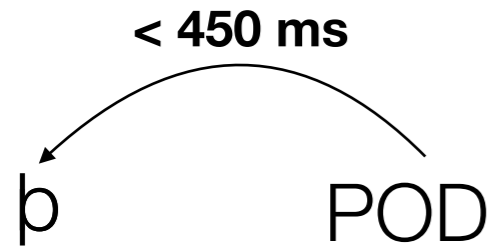
Commitment Before POD



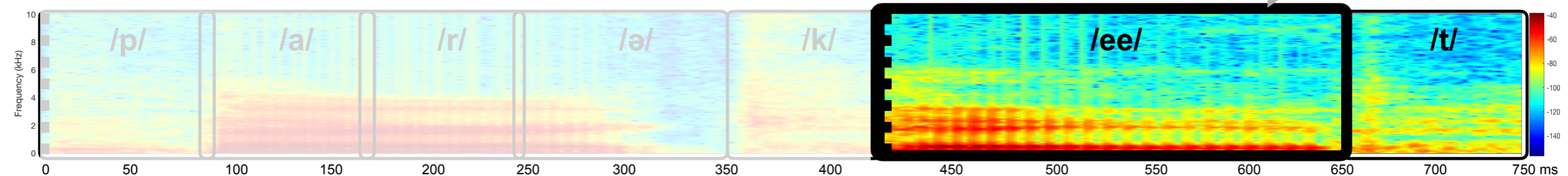
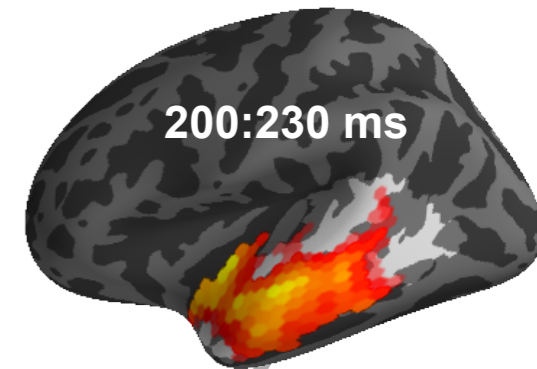
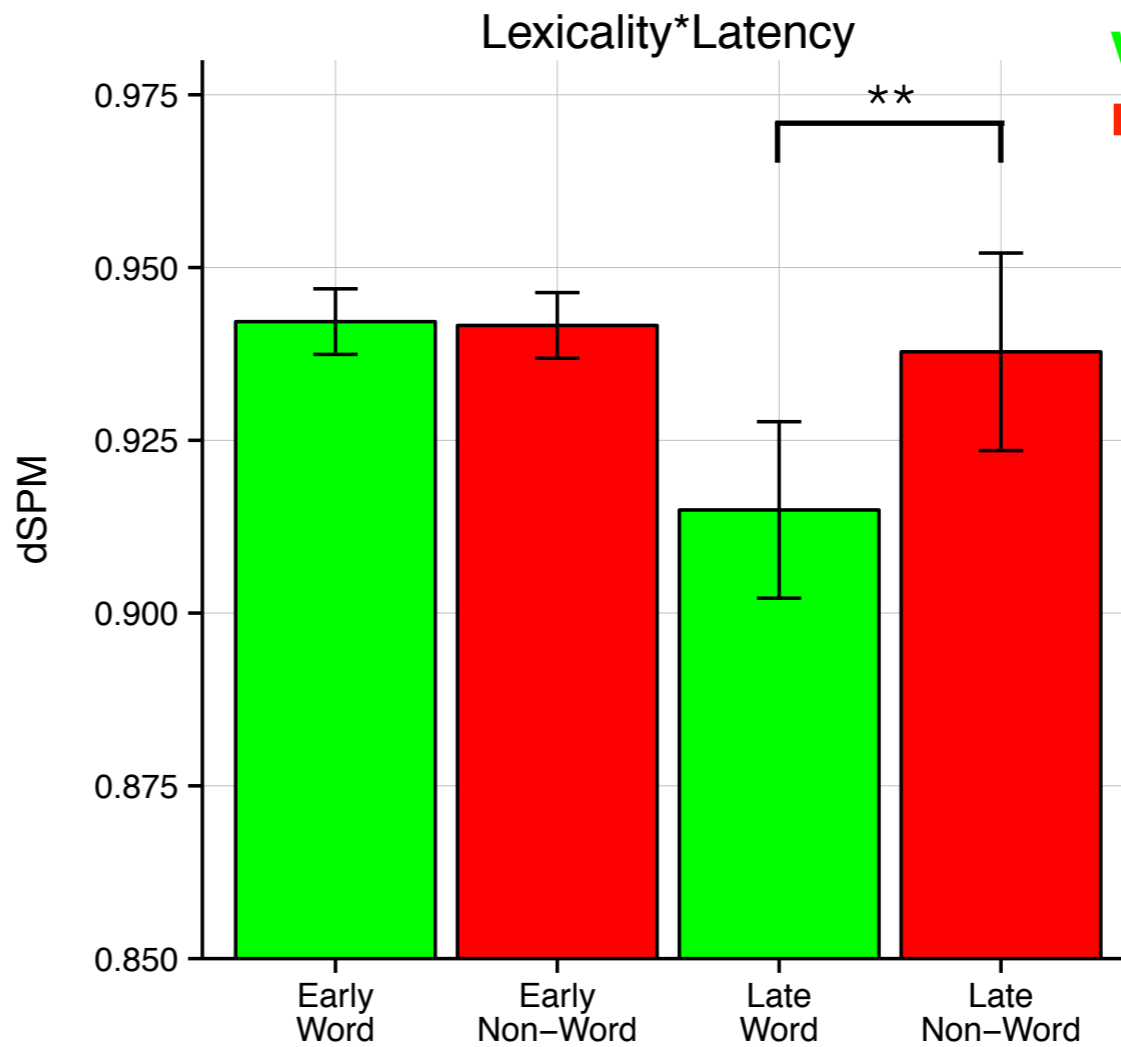
Commitment Before POD



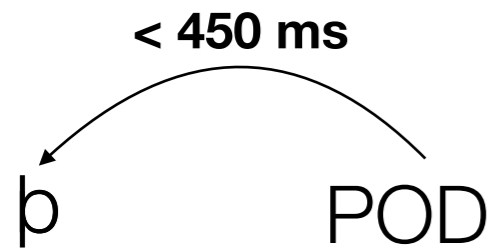
Commitment Before POD



Early: POD earlier than 450 ms after word onset

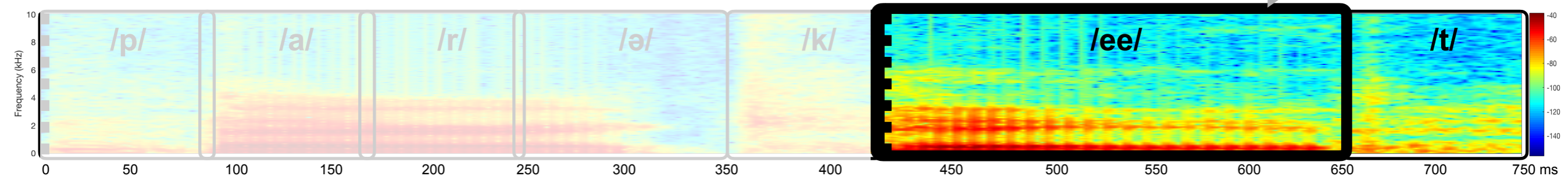
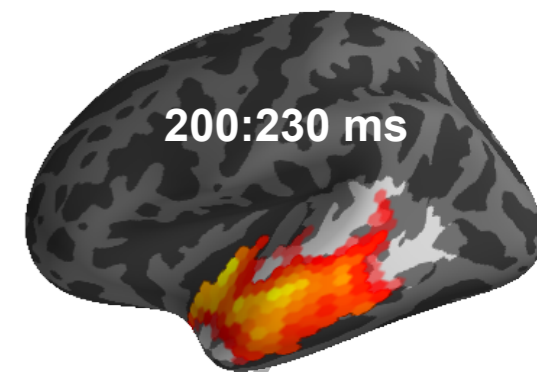
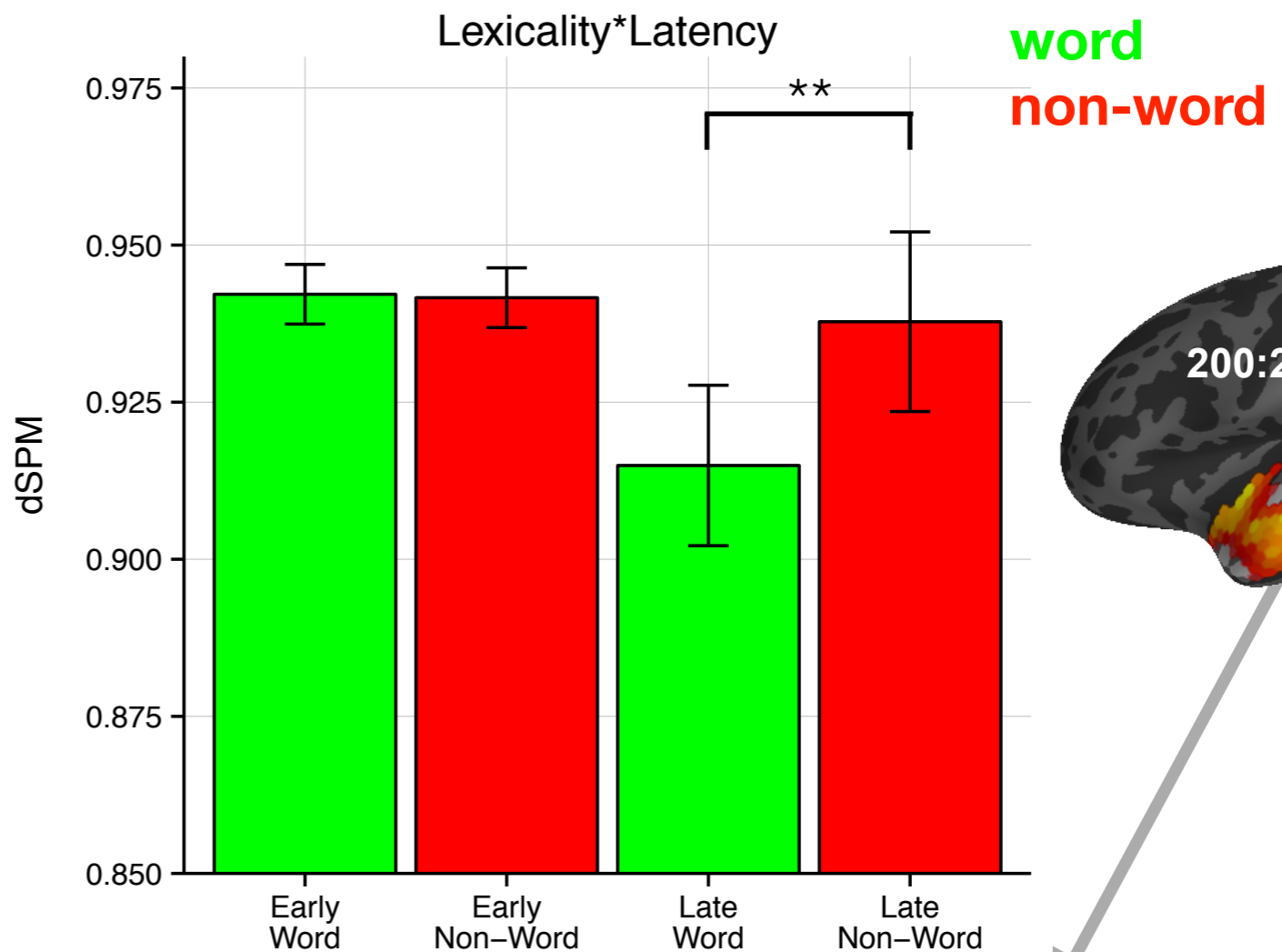


Commitment Before POD



Early: POD earlier than 450 ms after word onset

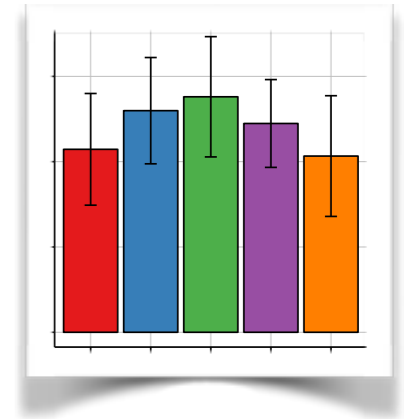
Late: POD later than 450 ms after word onset



Conclusion

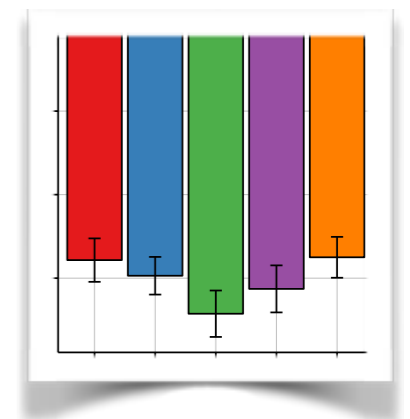
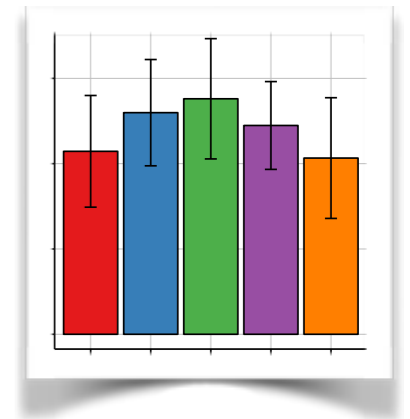
Conclusion

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



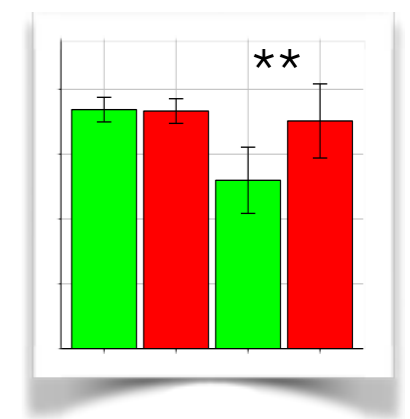
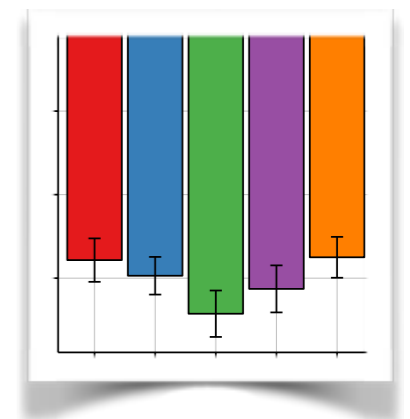
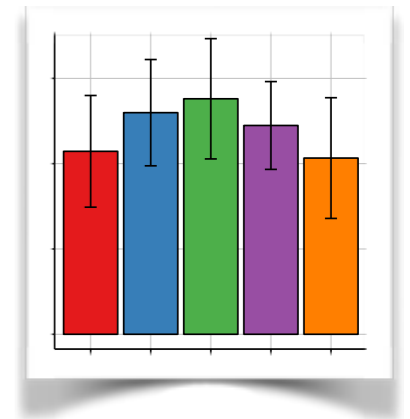
Conclusion

- 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



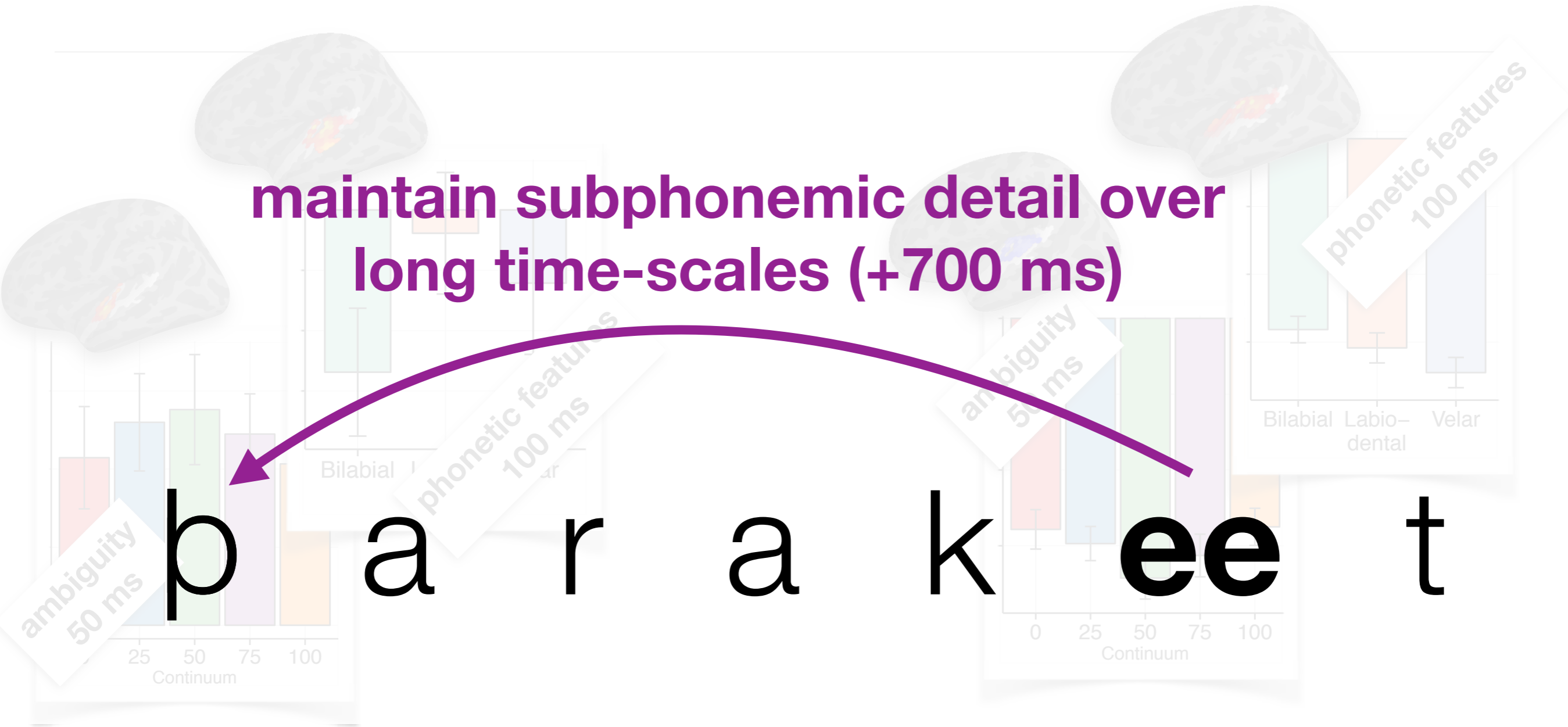
Conclusion

- 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



Conclusion

maintain subphonemic detail over long time-scales (+700 ms)



Conclusion

maintain subphonemic detail over long time-scales (+700 ms)

b a r a k e e t

commit to most likely phonological interpretation ~450 ms

With big thanks to:

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



Funding: G1001 Abu Dhabi Institute

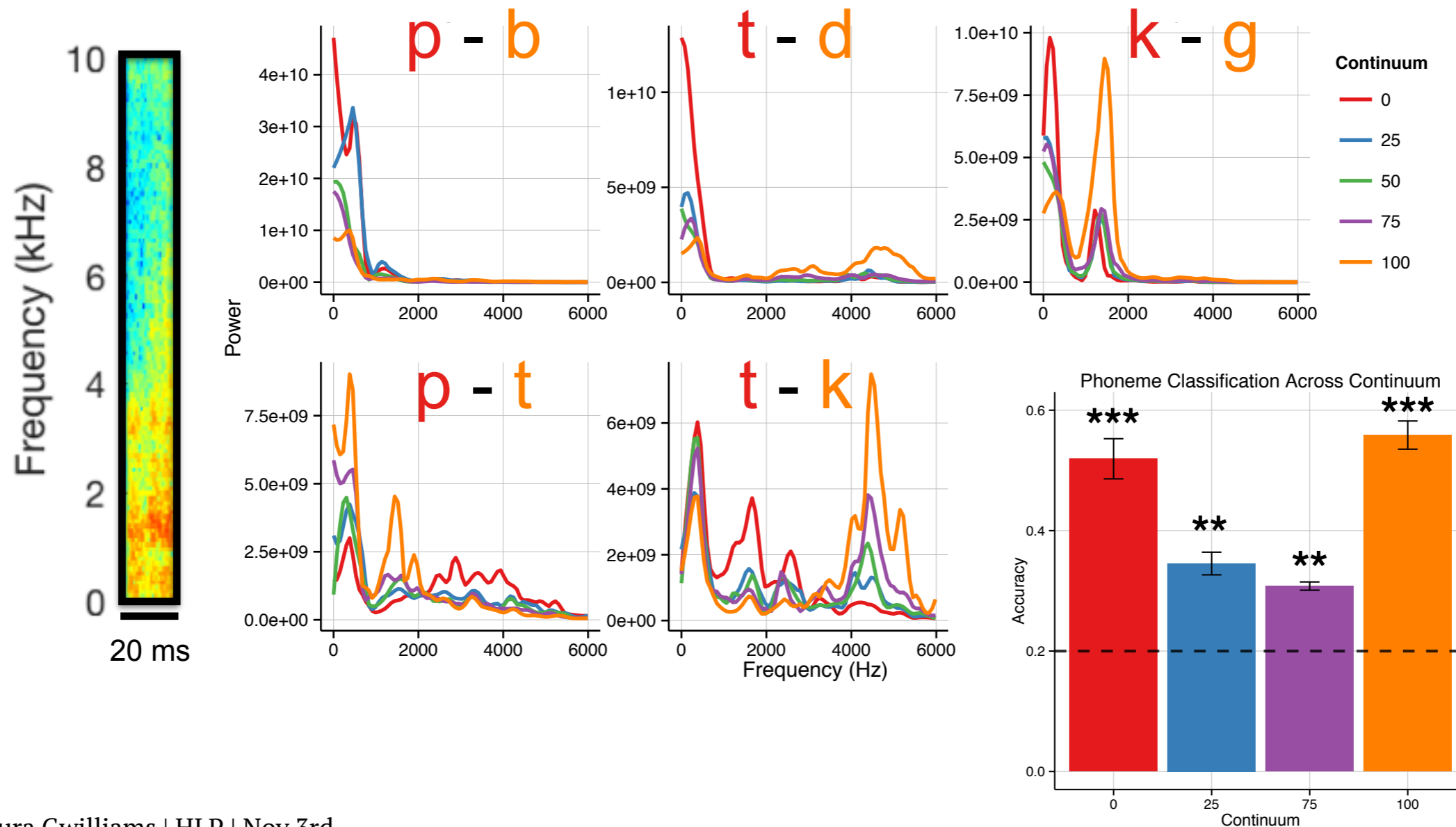
Example Stimuli Pairs

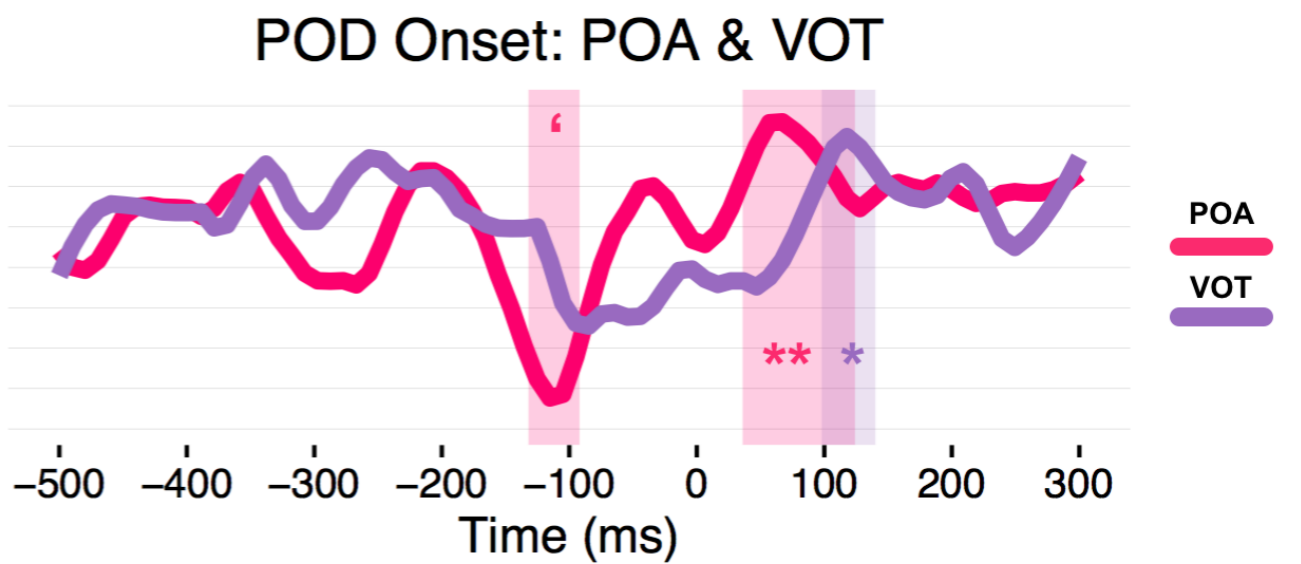
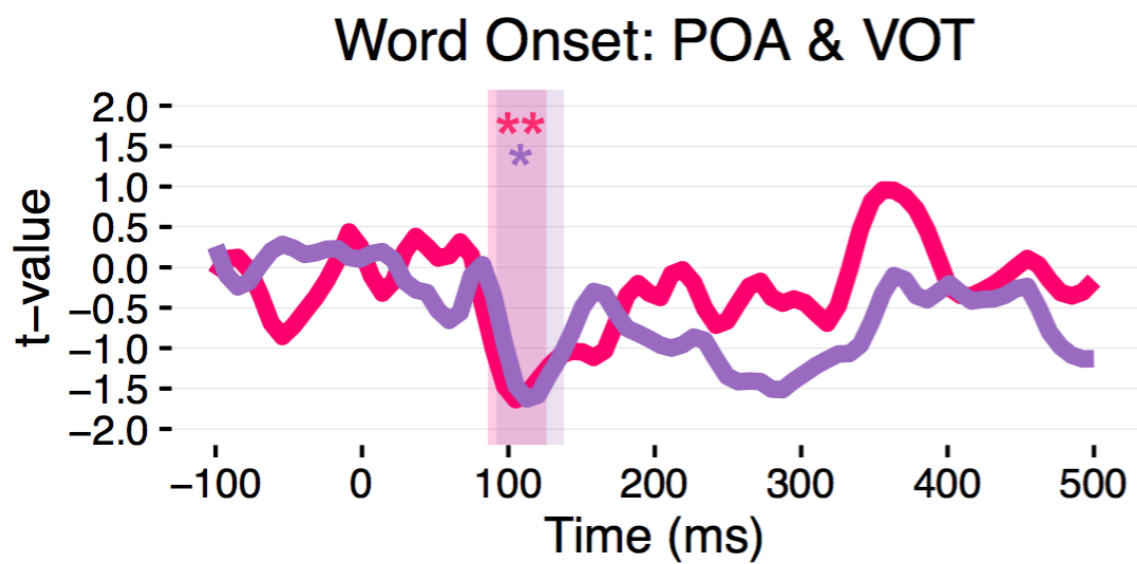
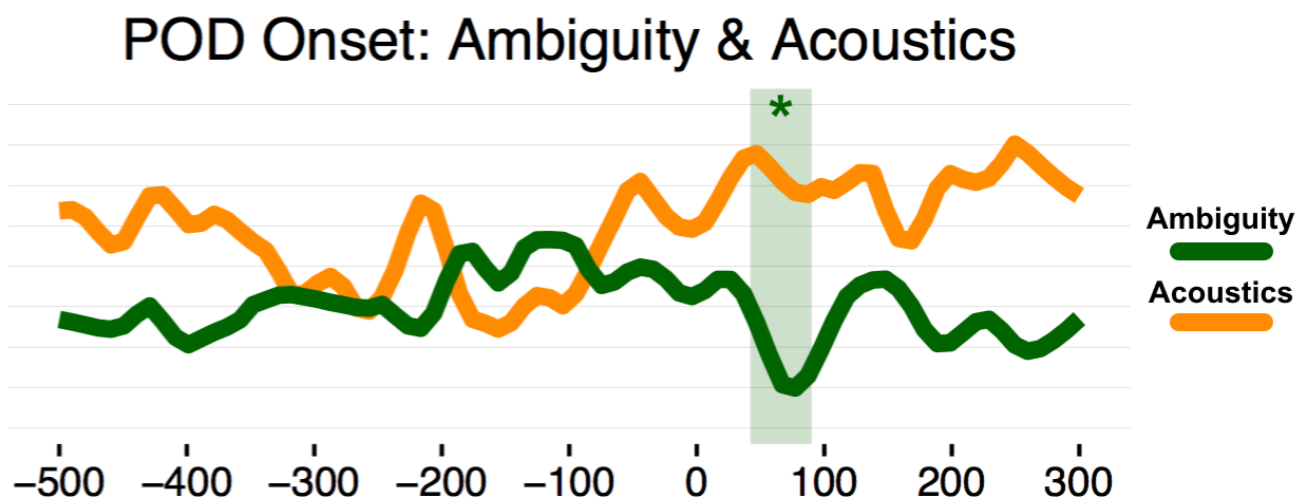
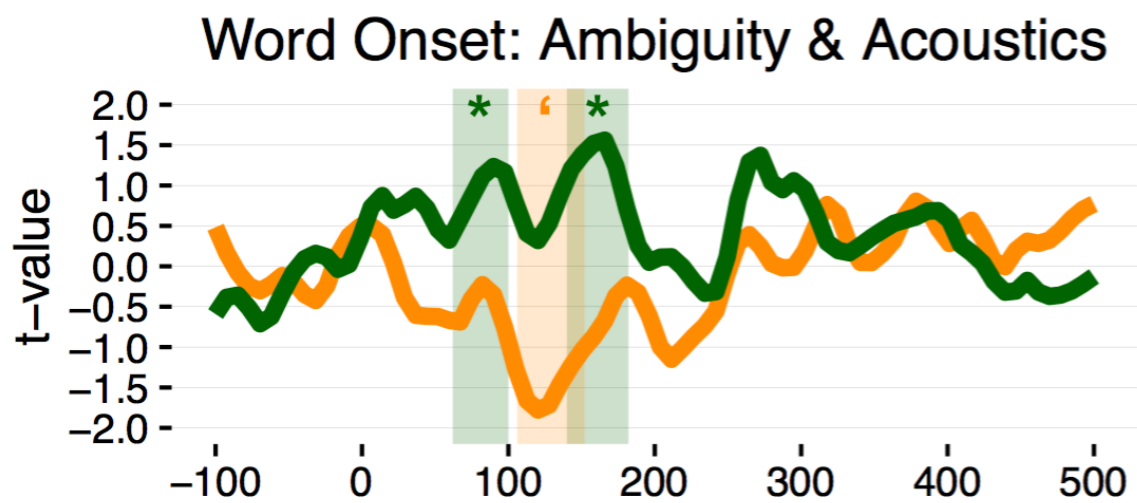
potent	total
dwindle	twinkle
bubbly	publish
primal	triumph
direct	tirade
crash	grasp
democratic	temporary
chemically	temperature
commodity	tomorrow
badger	pageant
percolate	turkeys
crochet	grotesque

bazaar	position
choir	twilight
decades	technician
dreadlock	treadmill
delaware	telephone
capitalise	tapestries
curling	girlish
depositor	topography
balloon	pollute
caucuses	talkative
blunt	plunge
beneficial	penicillin

Ambiguity at Onset

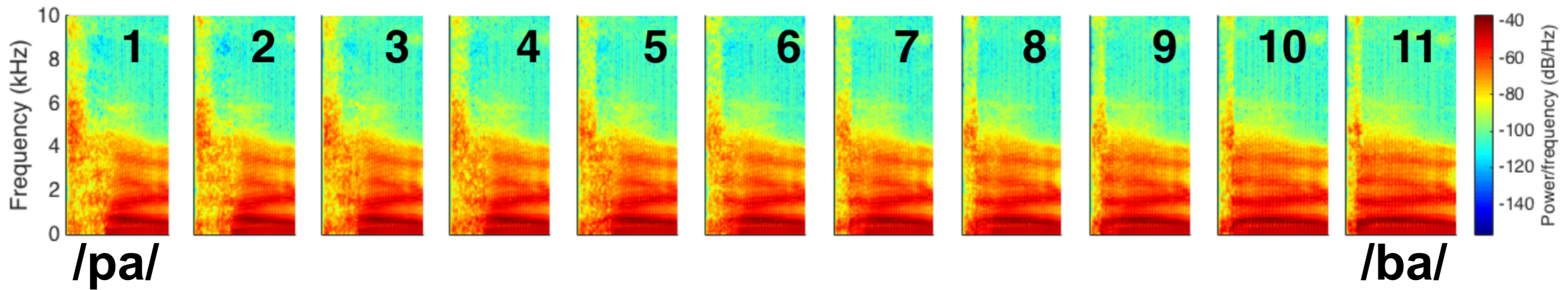
- 50 ms is **very** early — what information is present in the input that could determine phonological category?



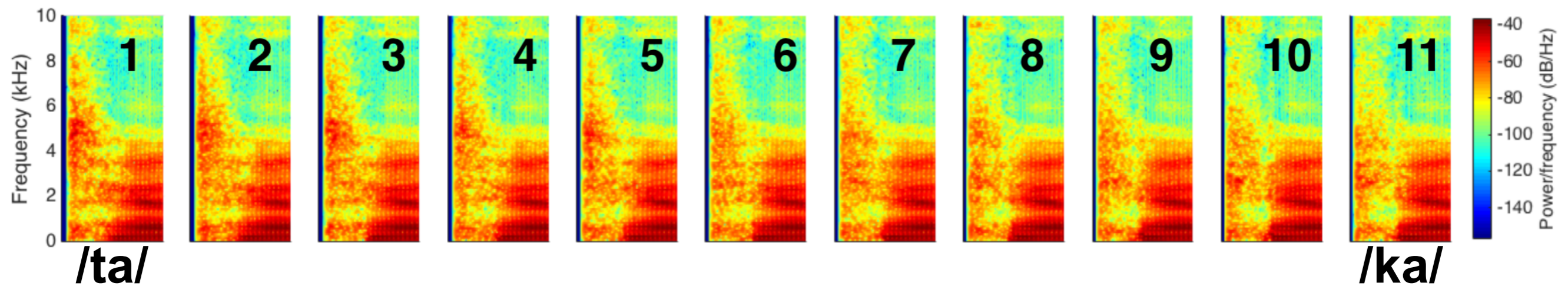


Experiment 1: Design & Materials

- Voice onset time (VOT) - {p-b, t-d, k-g}

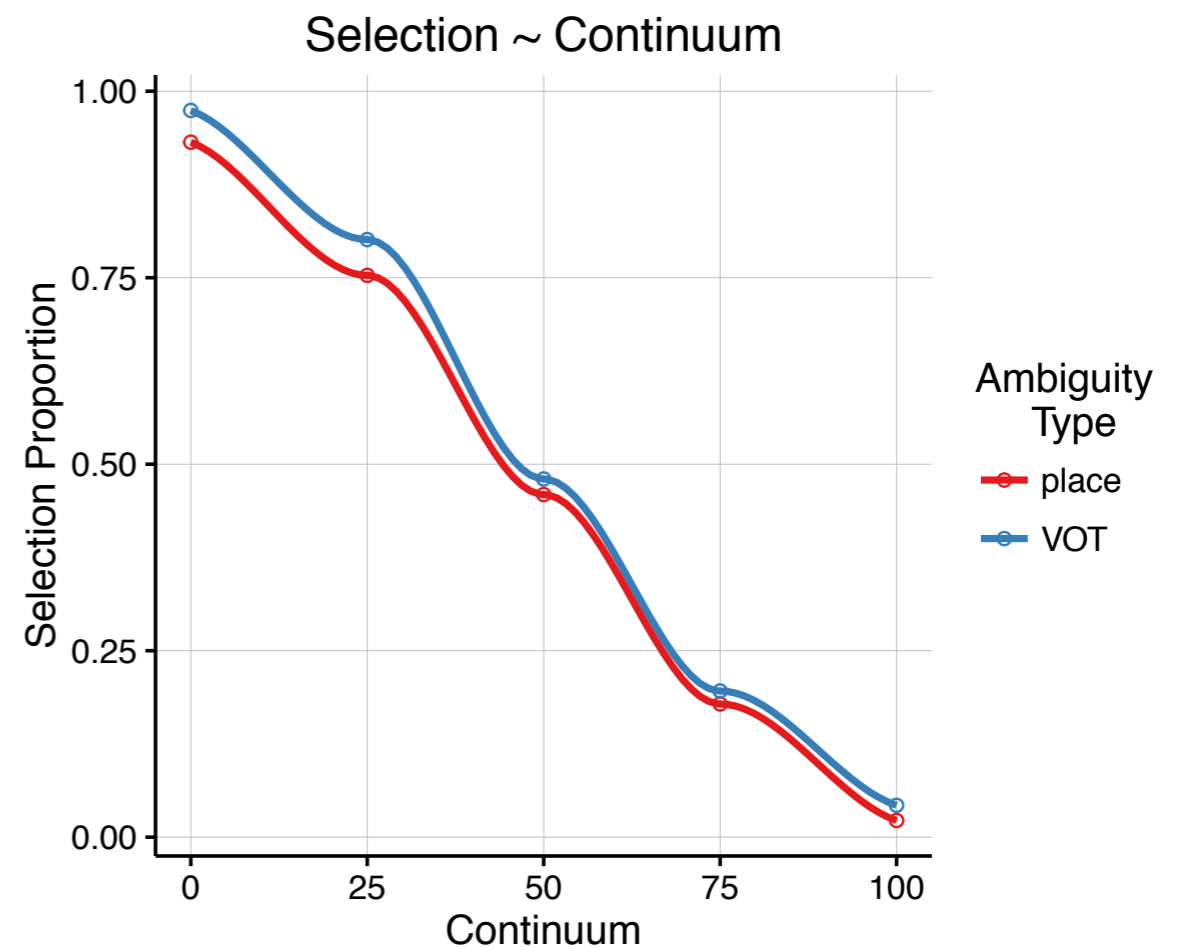
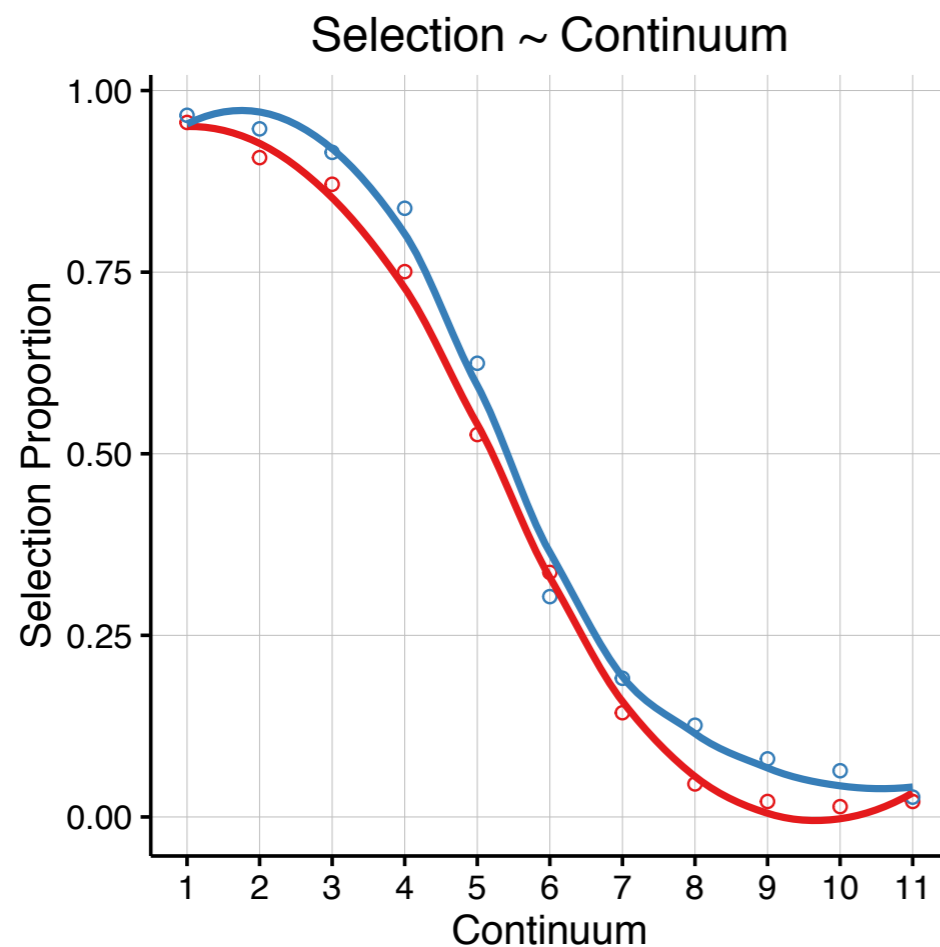


- Place of articulation (PoA) - {t-k, p-t}

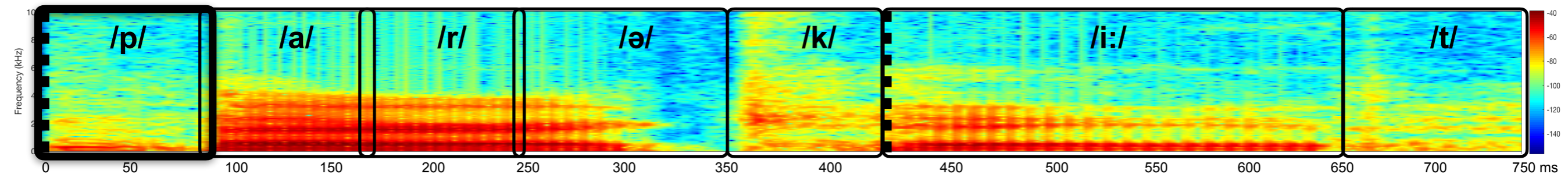
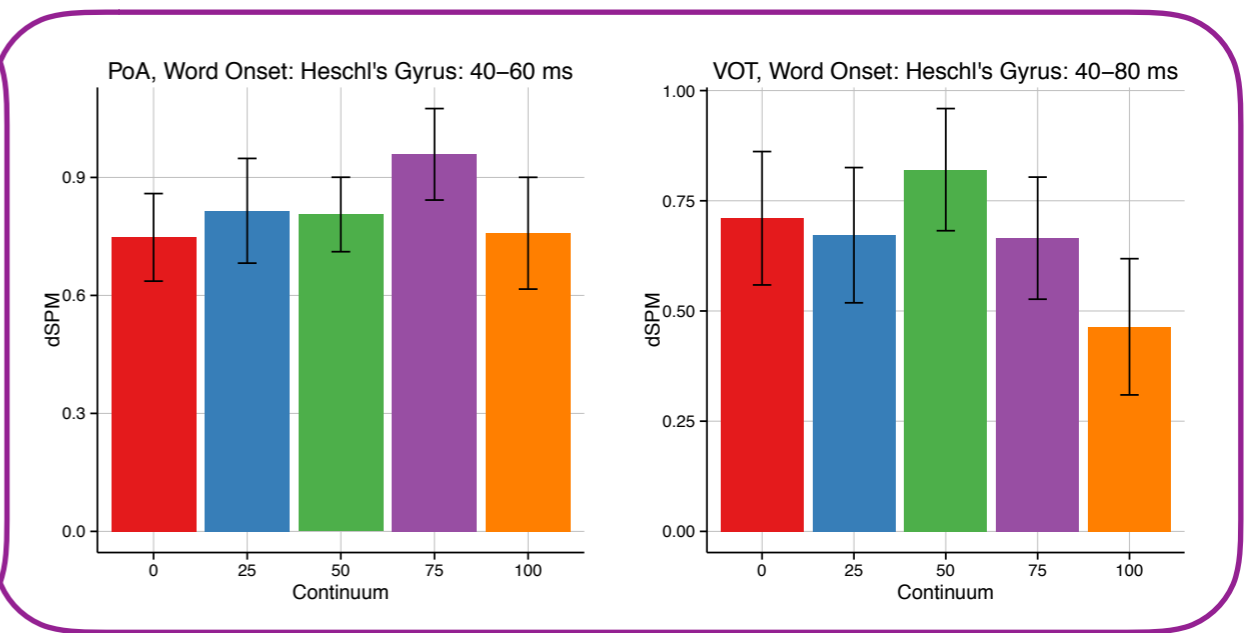
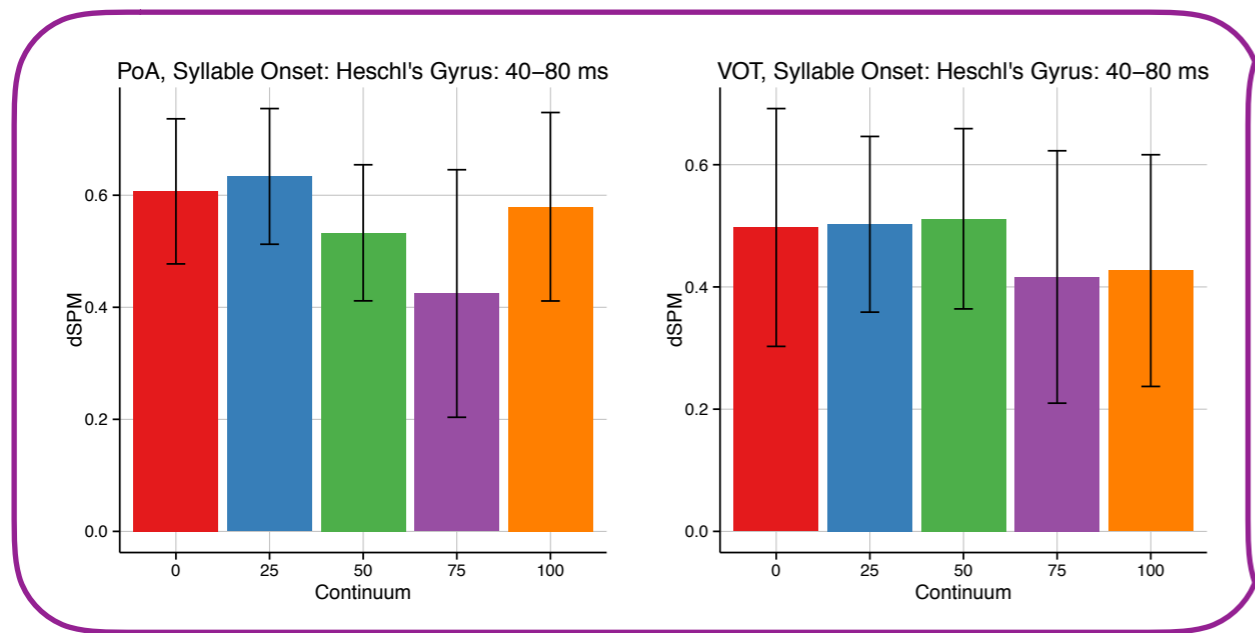
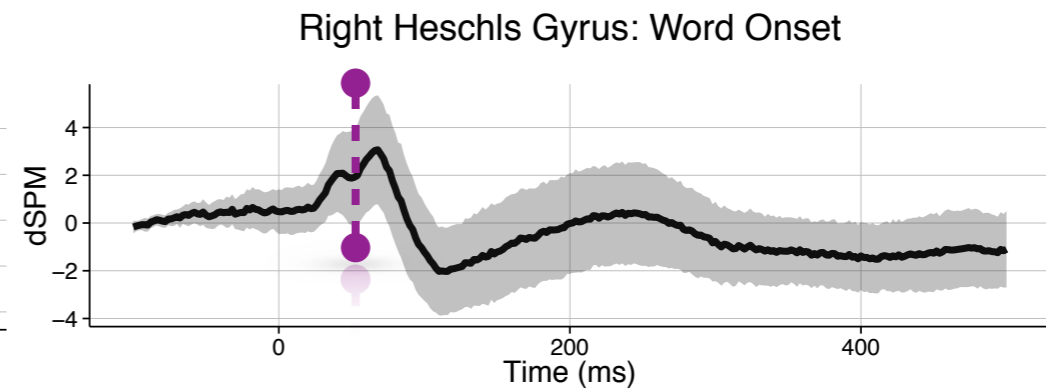
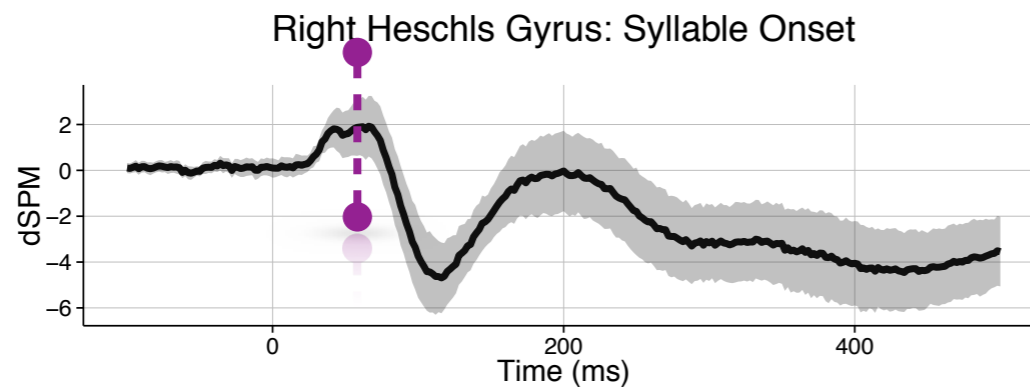


Experiment 1: Design & Materials

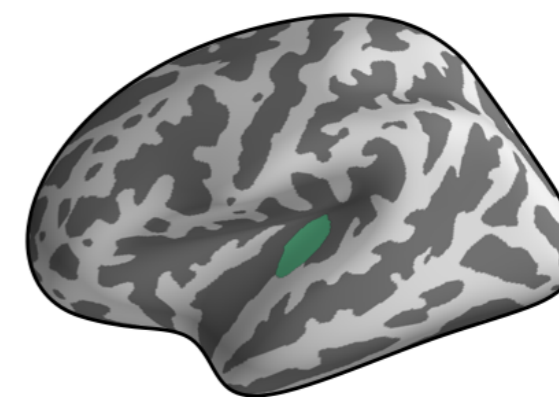
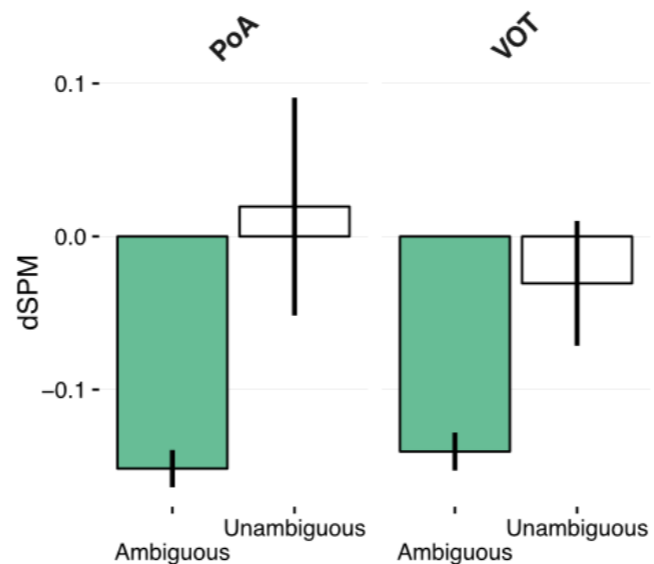
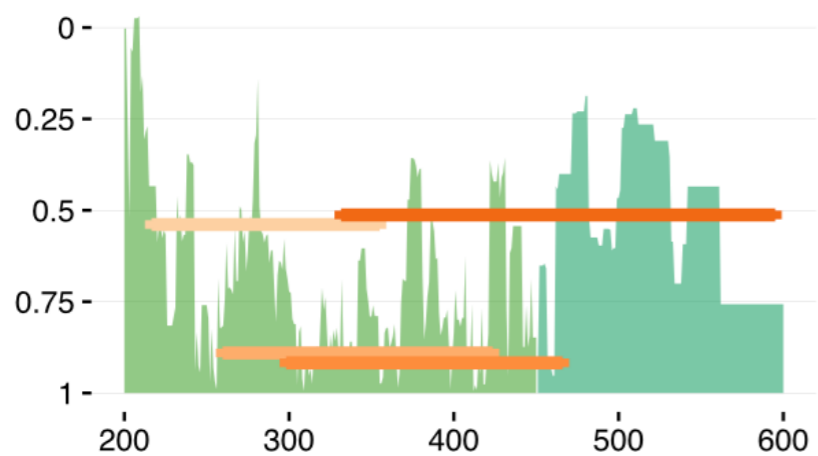
- Re-sampled the continuum to match perceptual categorisation



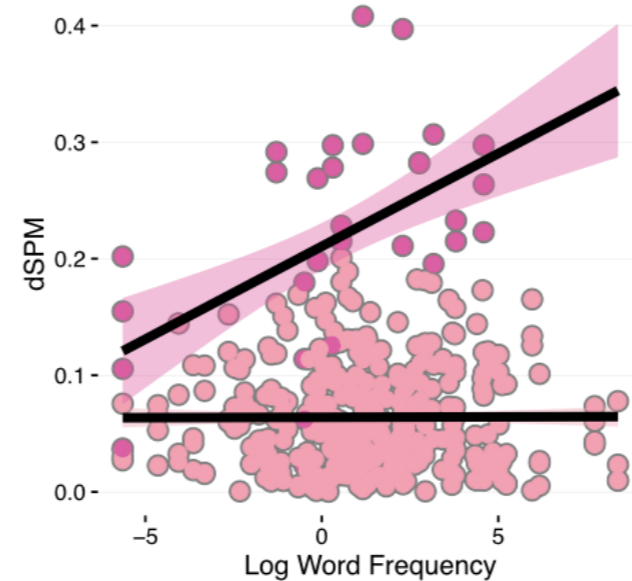
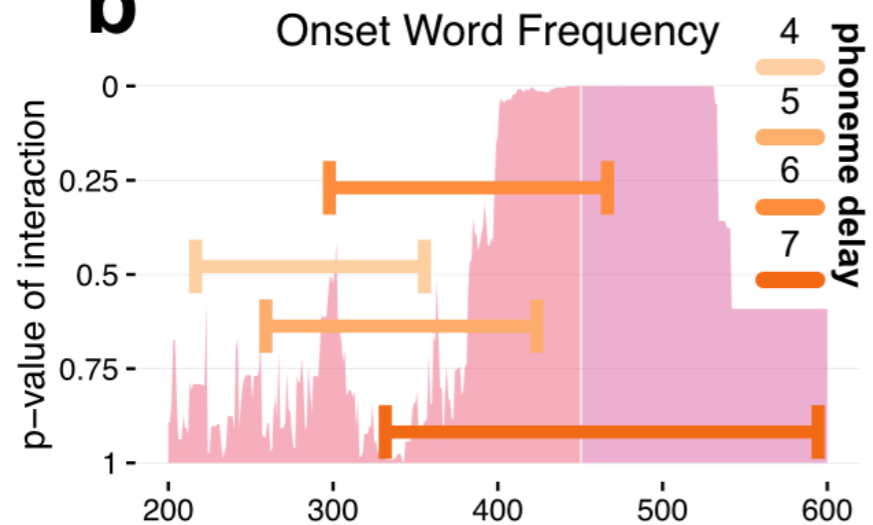
No Ambiguity Effect in Right Hemisphere



a Phoneme Ambiguity



b Onset Word Frequency



c Lexical Resolution

