

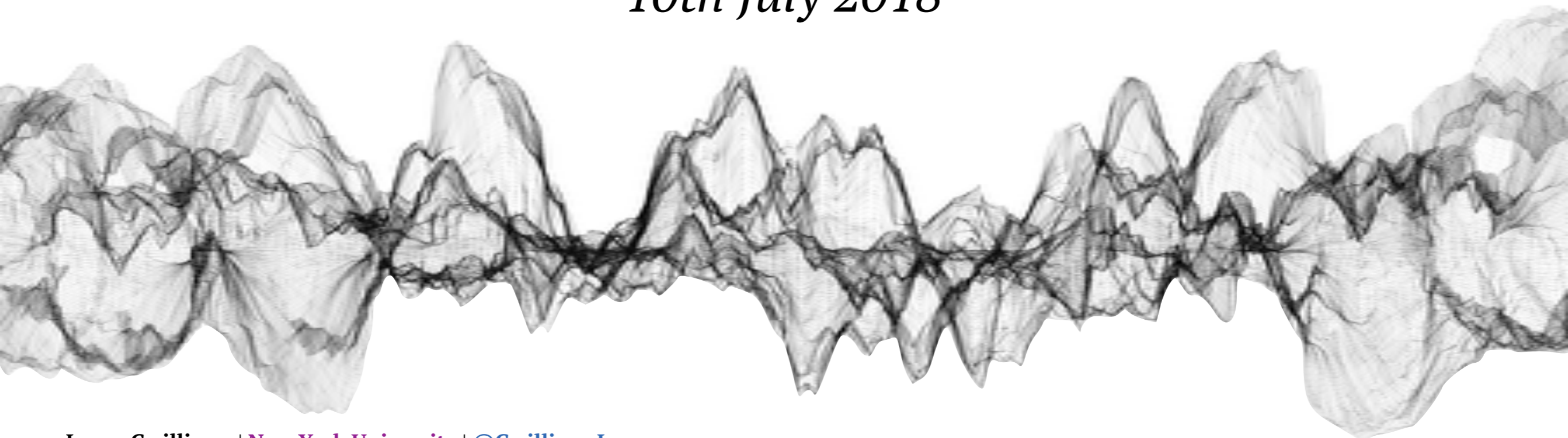


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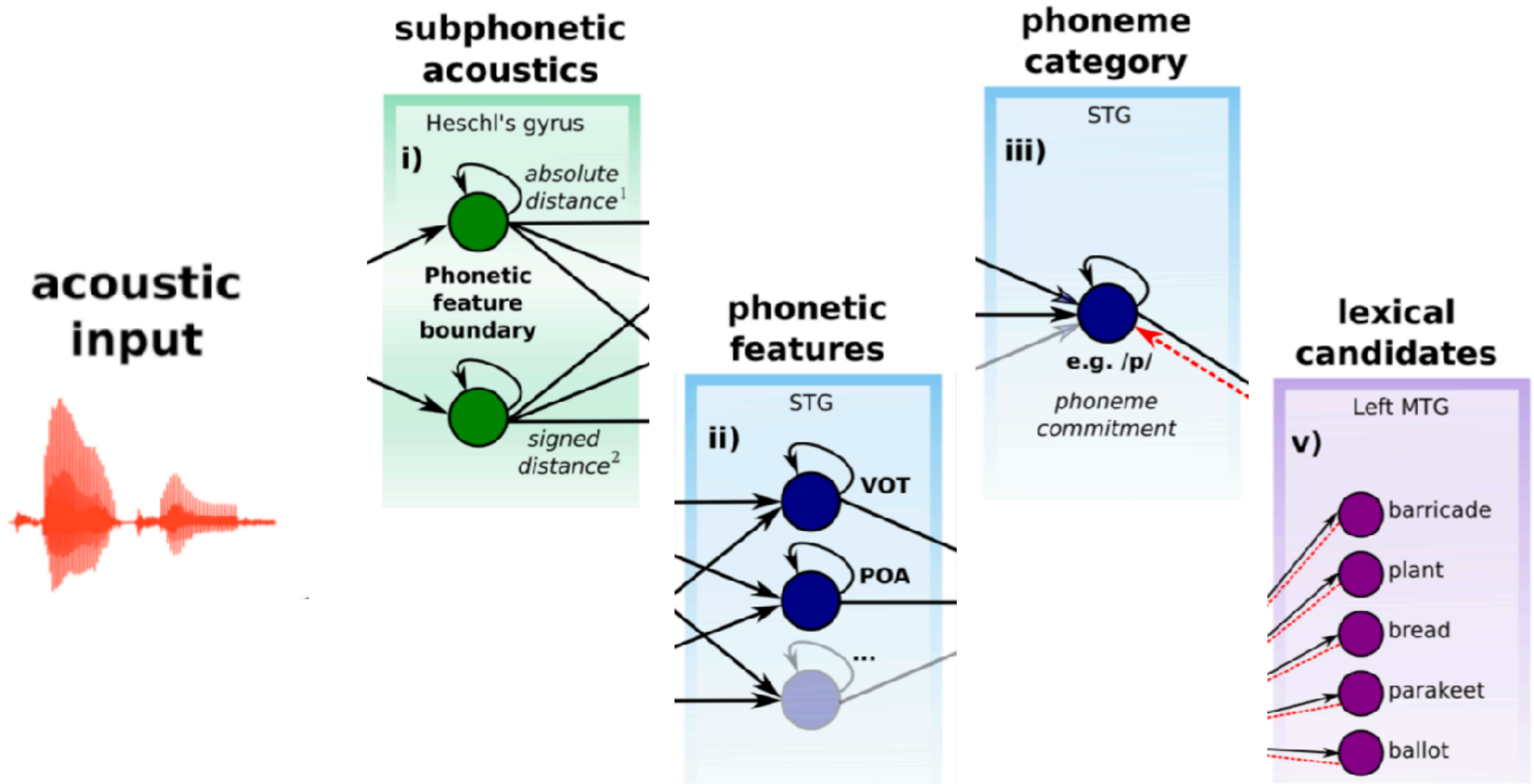
Towards a mechanistic account of speech comprehension in the human brain

Laura Gwilliams

10th July 2018



Putting together the processing pieces



Roadmap

- Completed projects
 - **Bottom-up processes:** Transforming acoustic signal into discrete phonological categories
 - **Top-down processes:** Revising that categorisation based on subsequent context

b a

Roadmap

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p a r a k e e t

Roadmap

- Completed projects

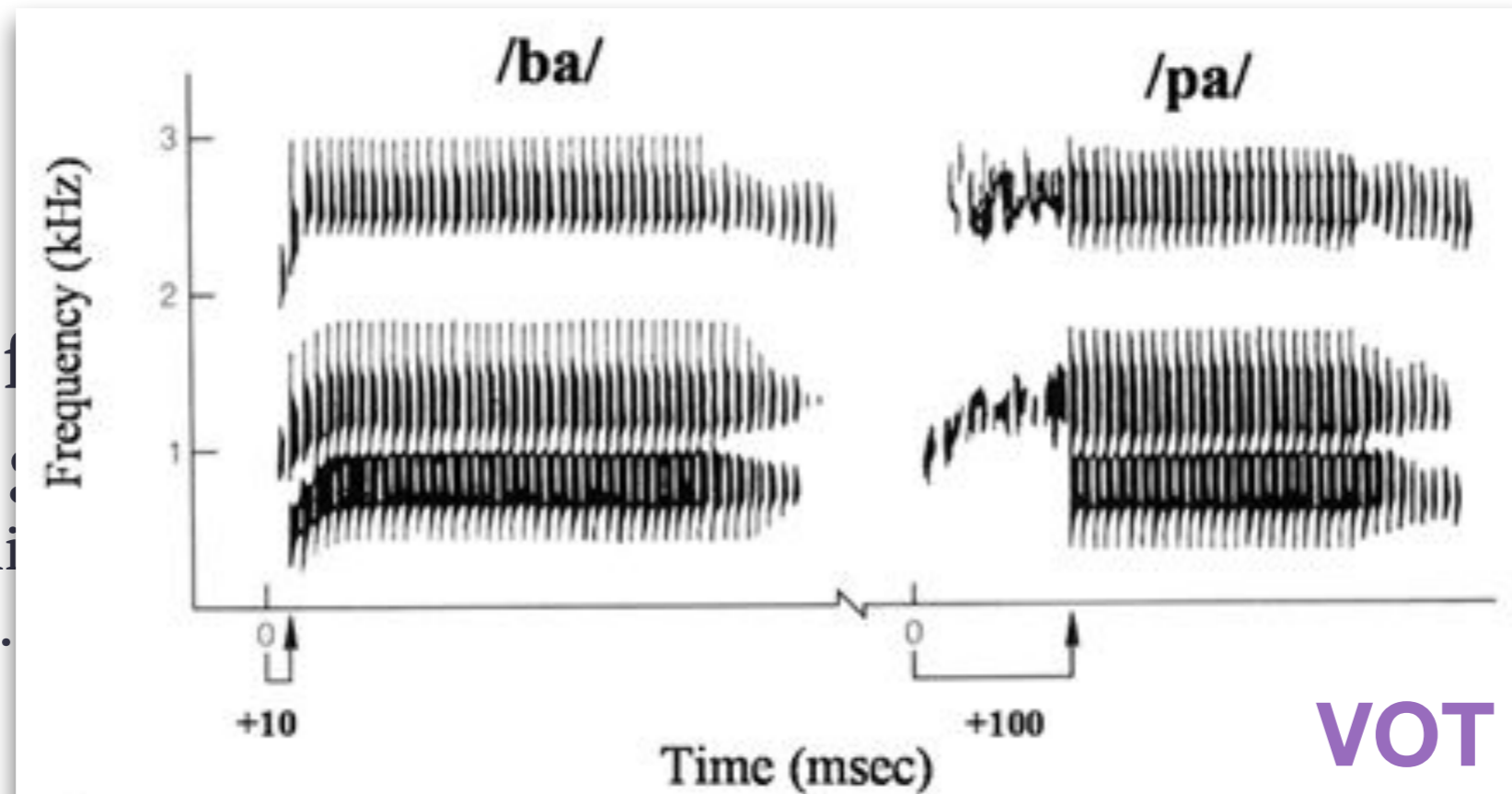
- **Bottom-up processes:** Transforming acoustic signal into discrete phonological categories
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- Future directions

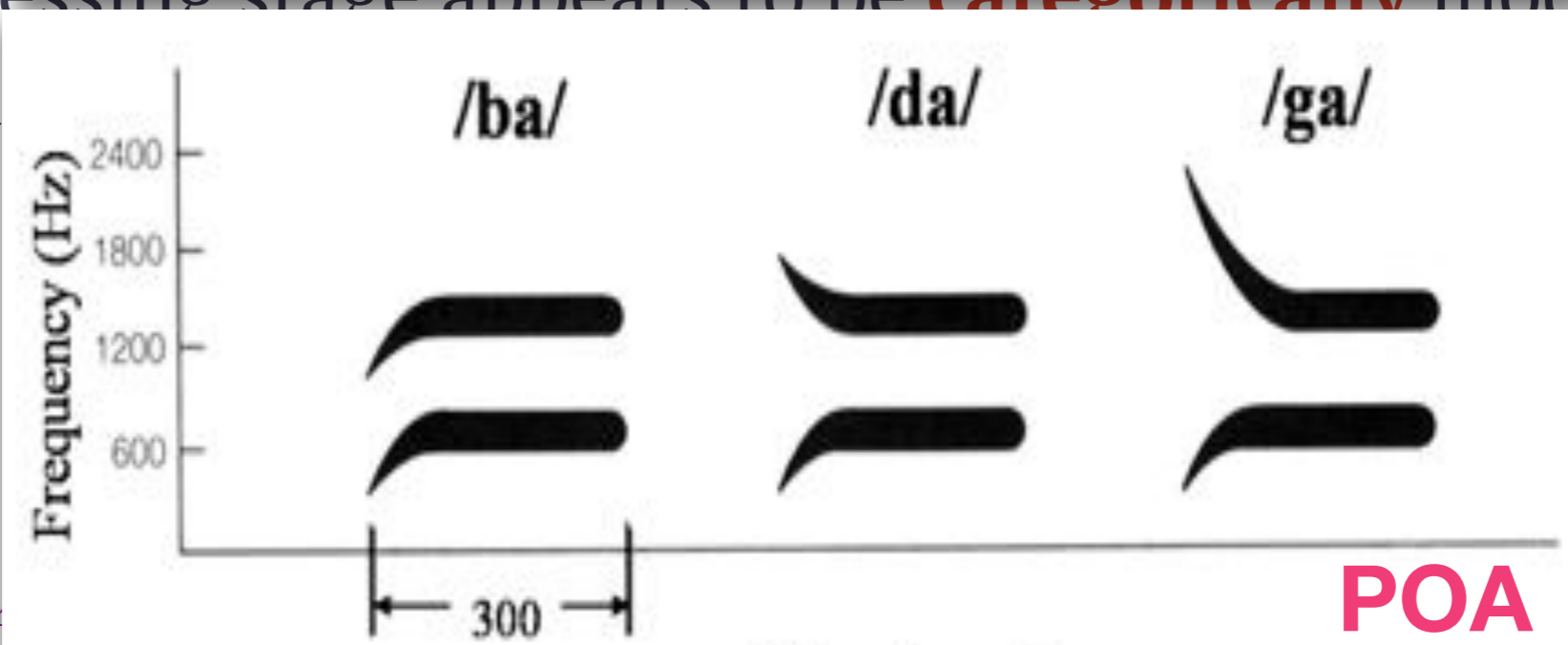
- Updating the mapping between acoustics to phonemes online through repeated **exposure** to accented speech
- Testing re-activation processes in **natural speech**

Bottom-up processing of phonemes

- Phonetic processing is sensitive to temporal precision (Liberto et al., 2003; Papanicolaou et al., 2014; Di

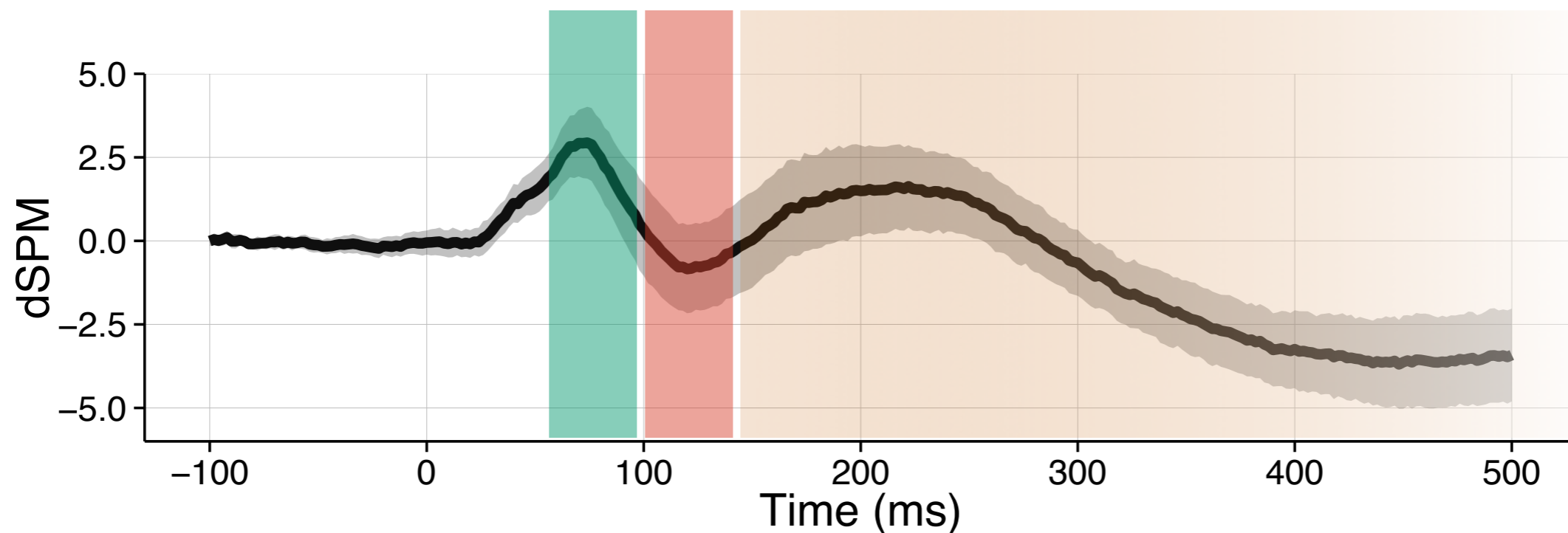


- This processing is sensitive to temporal precision (Chang et al., 2014; Di

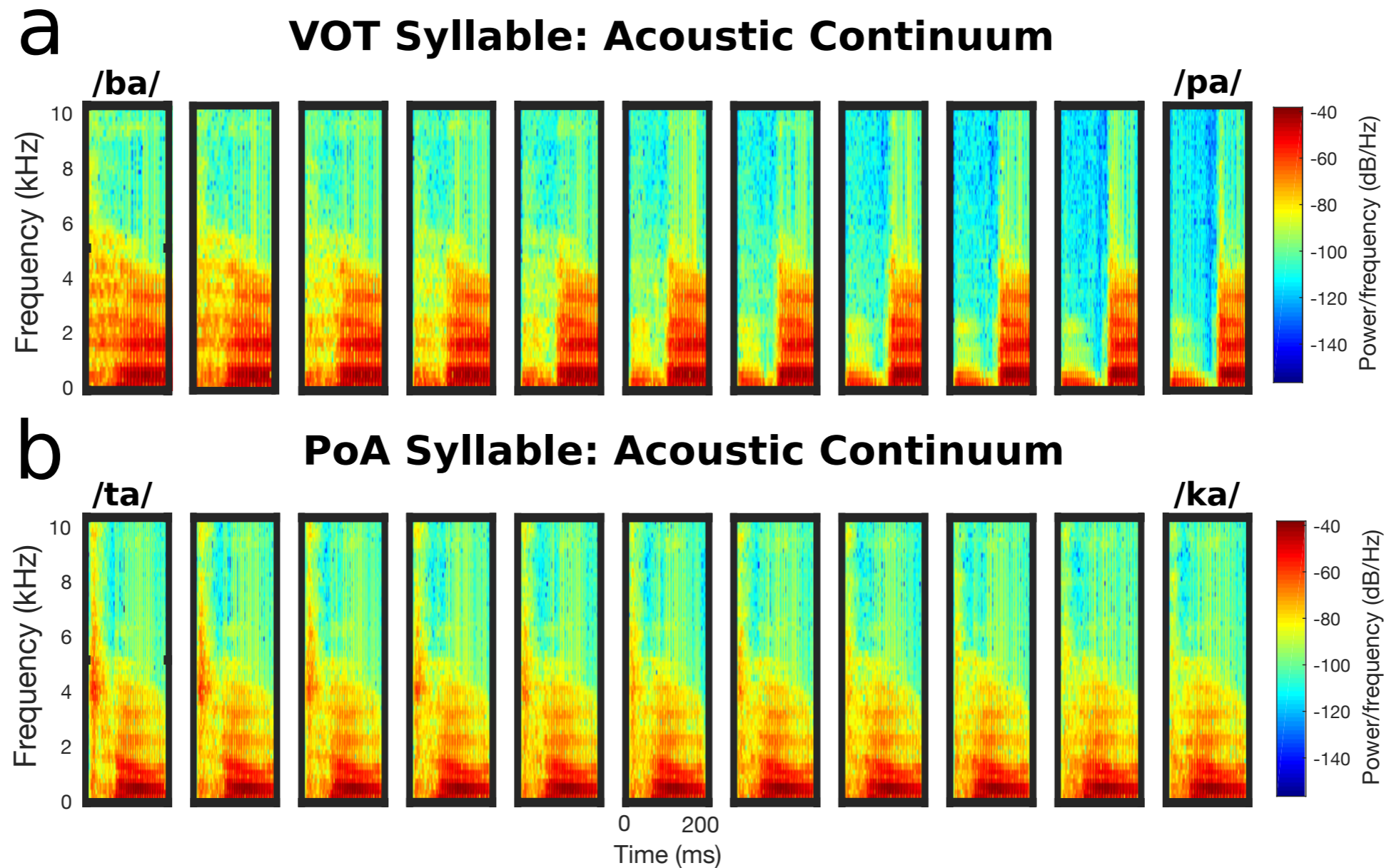


Neutralising ambiguity

At what stage of processing is phonological ambiguity alleviated?

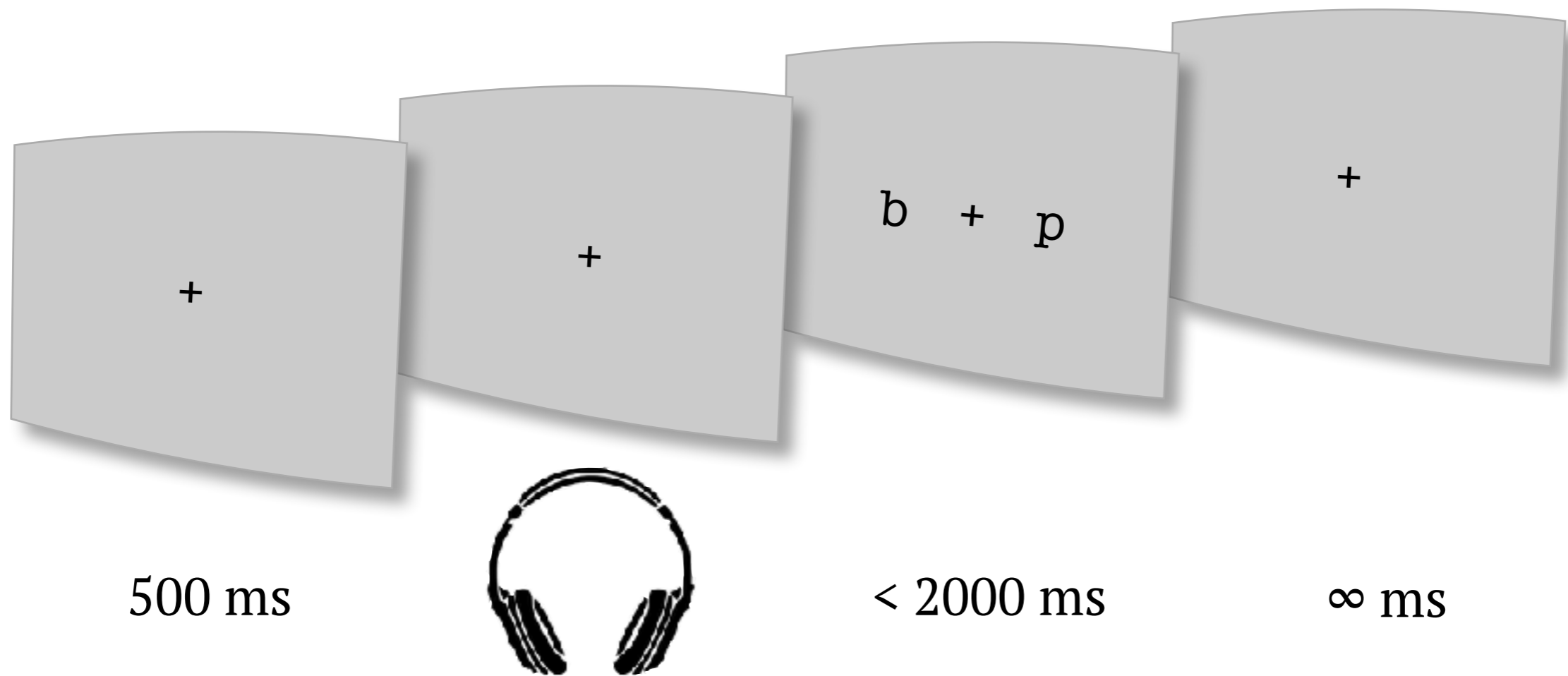


Materials

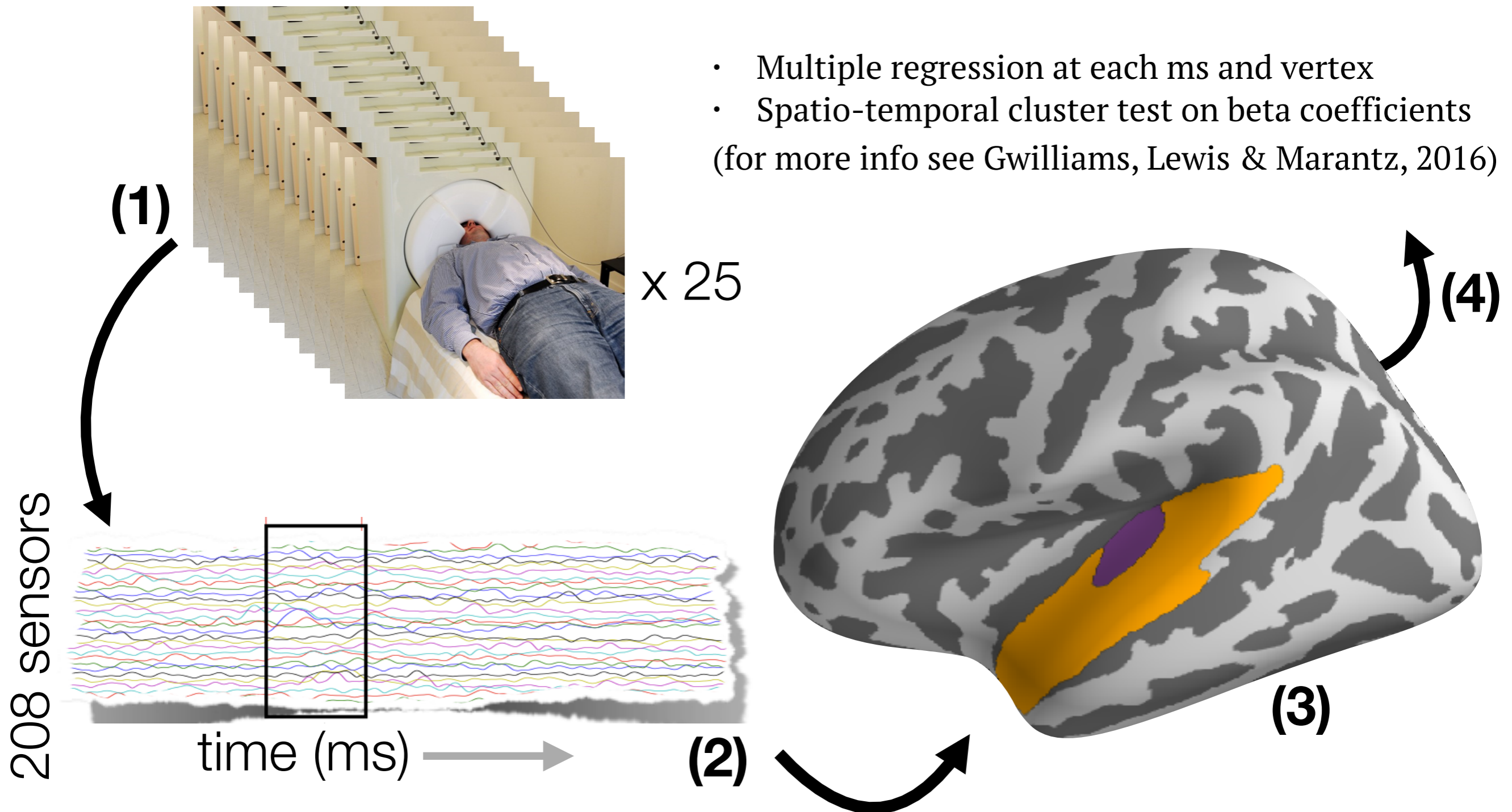


- VOT (31 pairs) {p-b, t-d, k-g} and POA (22 pairs) {t-k, p-t}

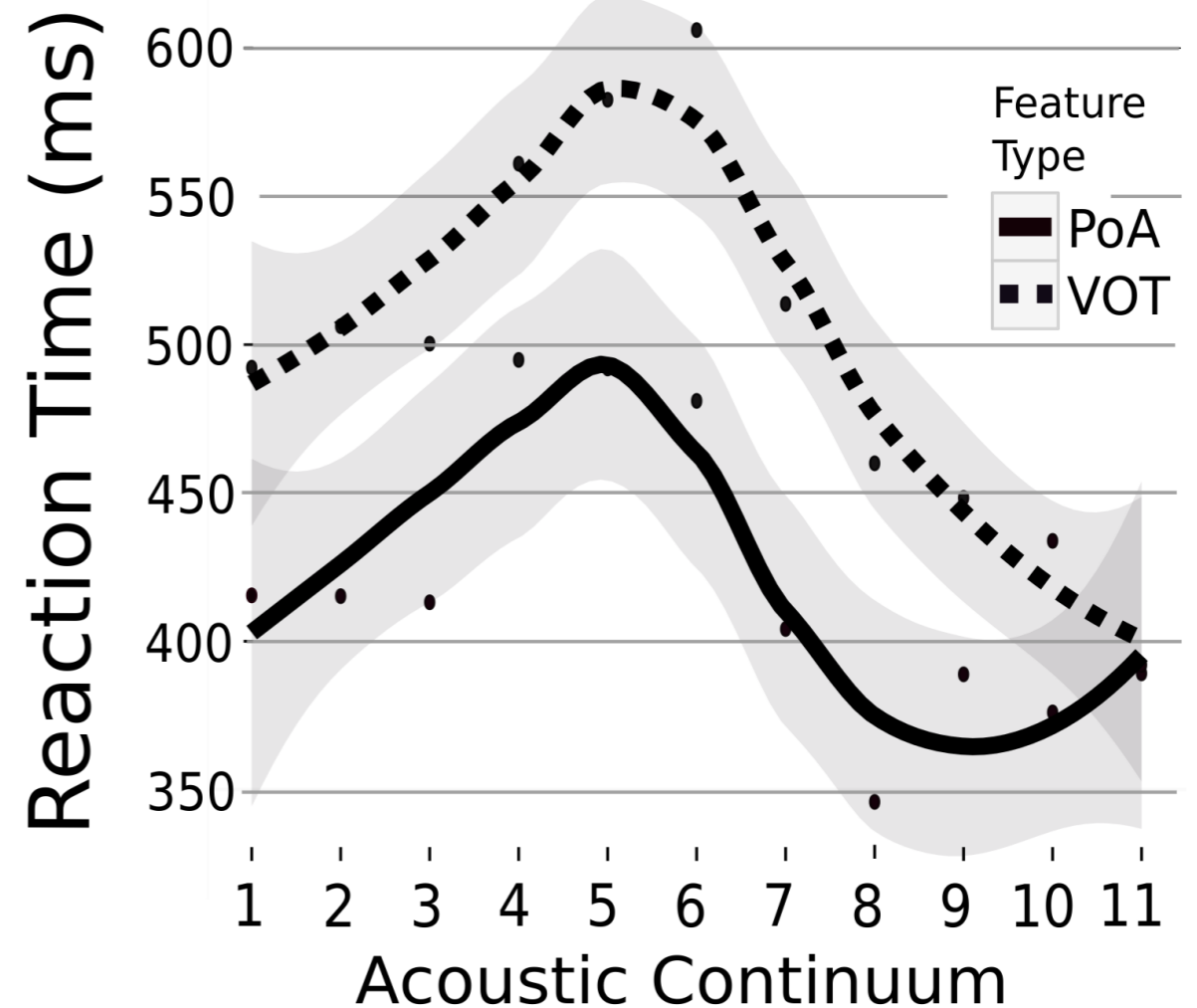
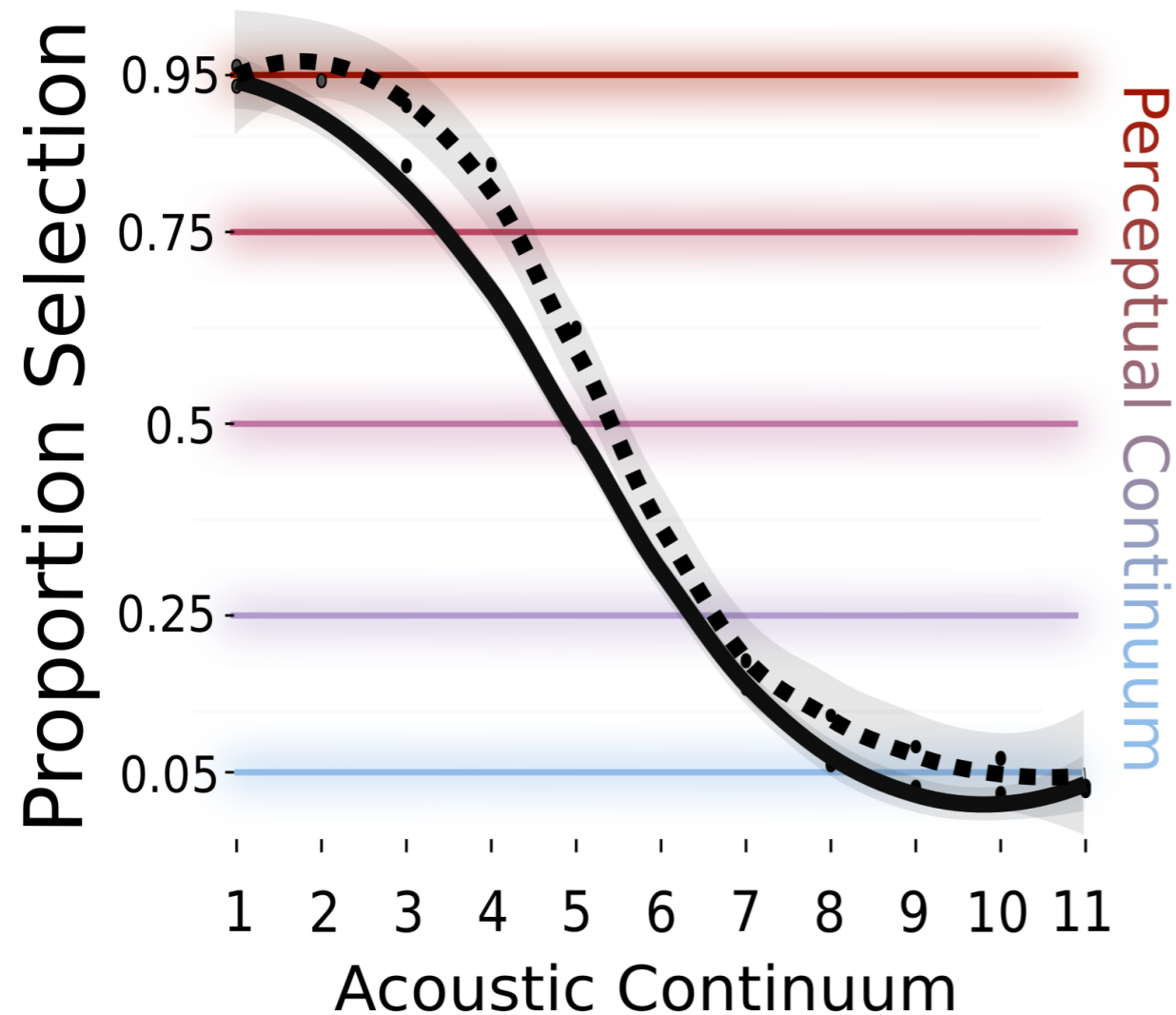
Design



Procedure & Analysis

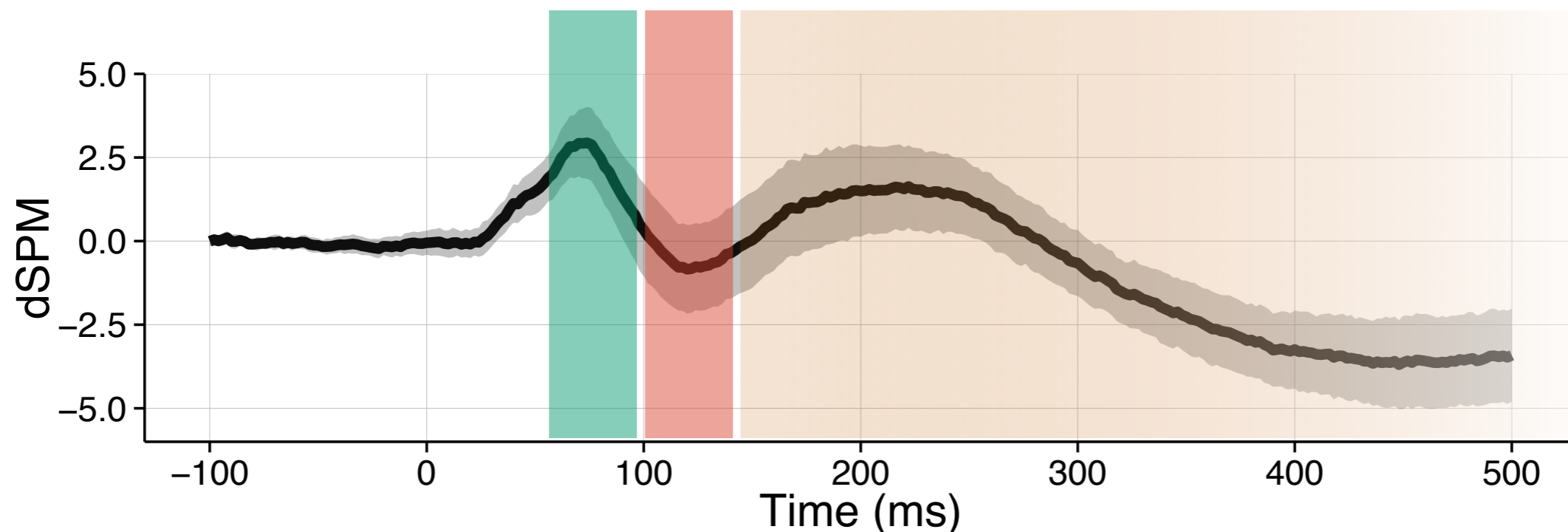


Behaviour

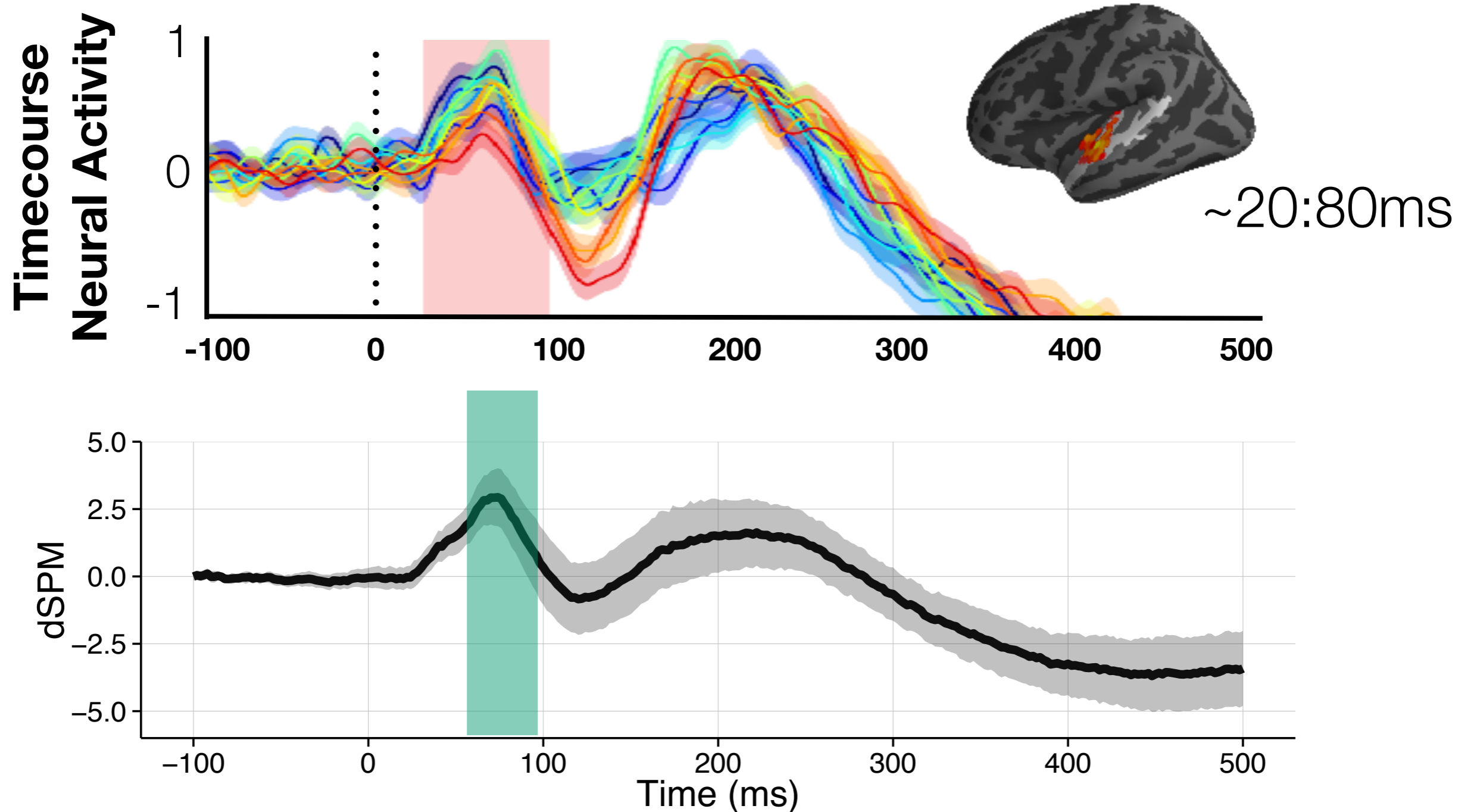


Neutralising ambiguity

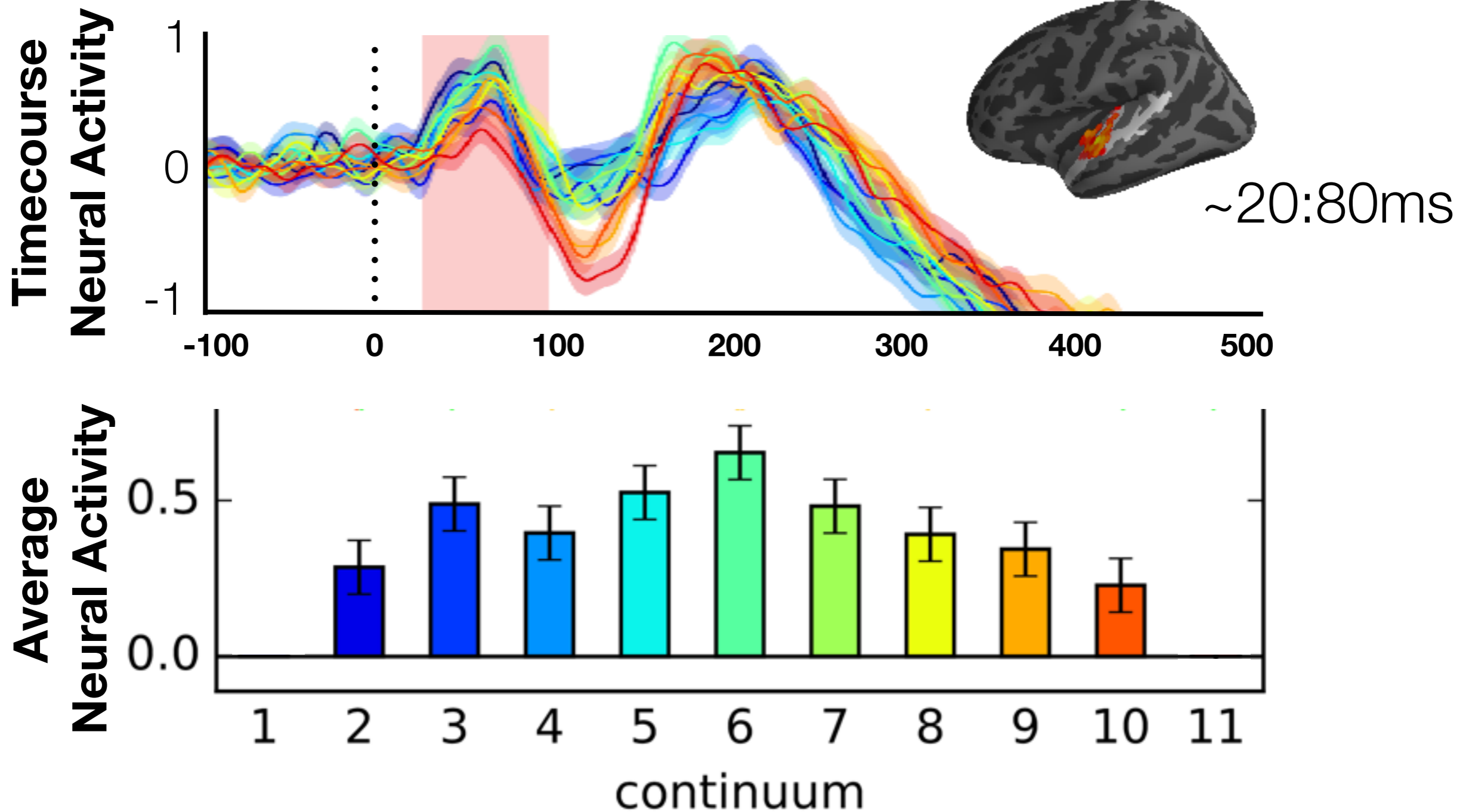
At what stage of processing is phonological ambiguity alleviated?



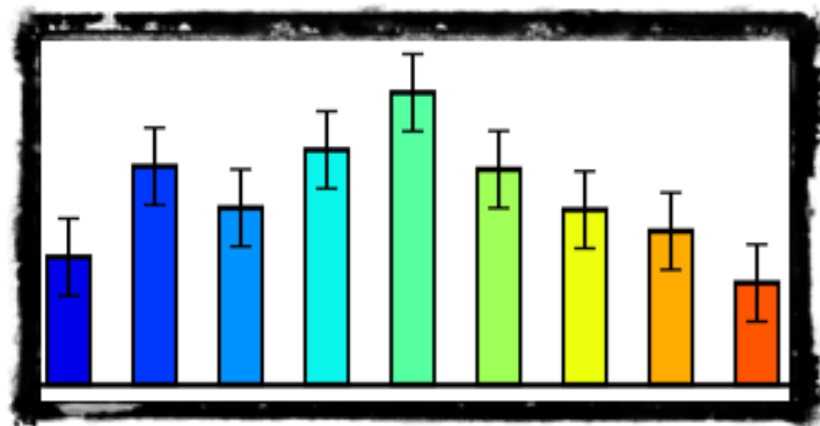
Early ambiguity responses in Heschl's gyrus



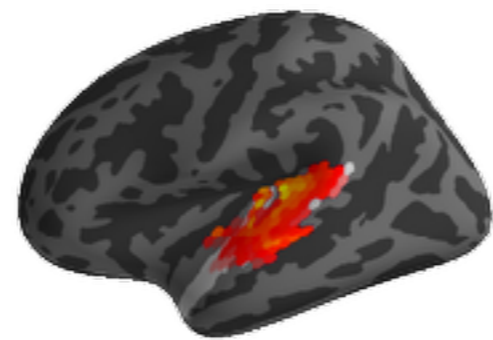
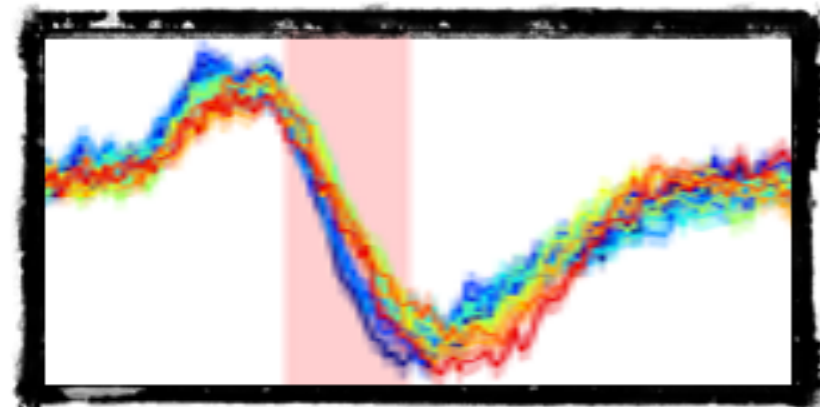
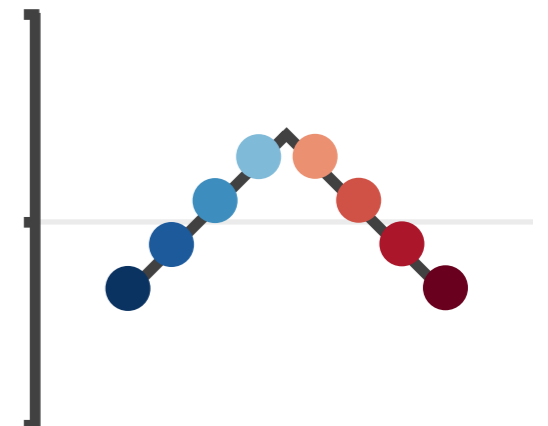
Early ambiguity responses in Heschl's gyrus



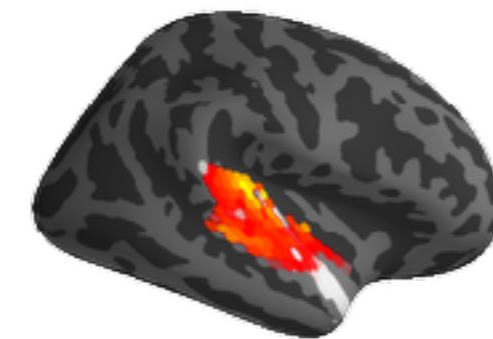
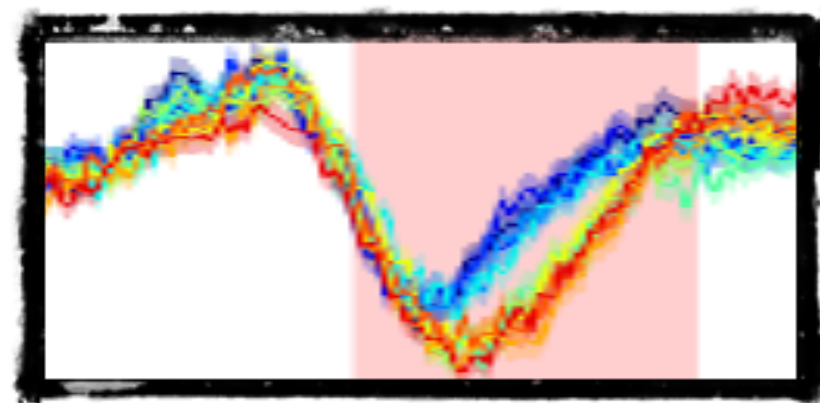
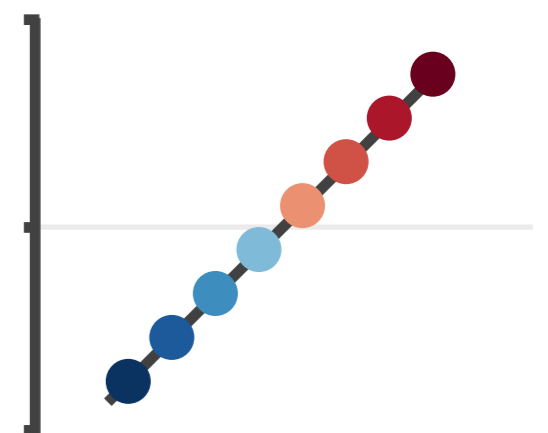
Replicating the categorical trajectory using MEG



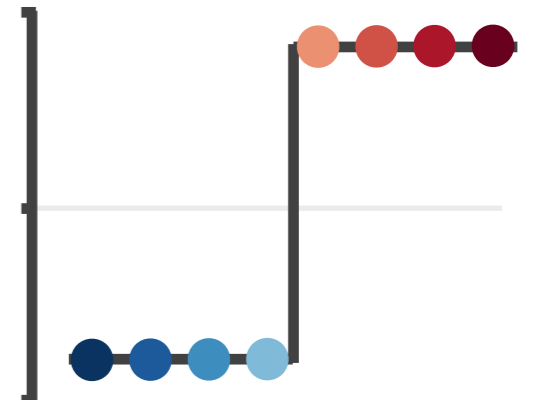
~20:80ms
ambiguity



~80:150ms
linear

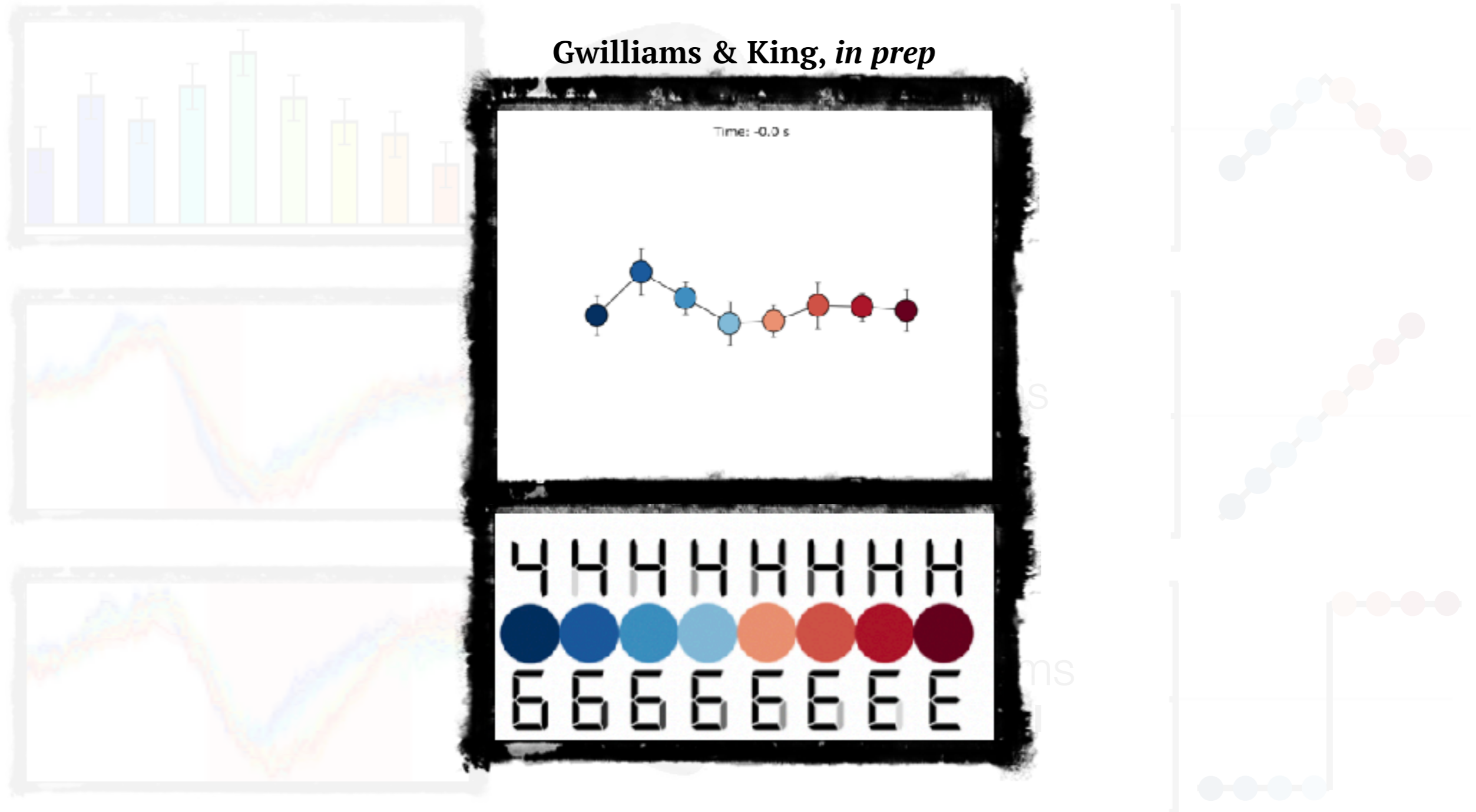


~100:200ms
categorical



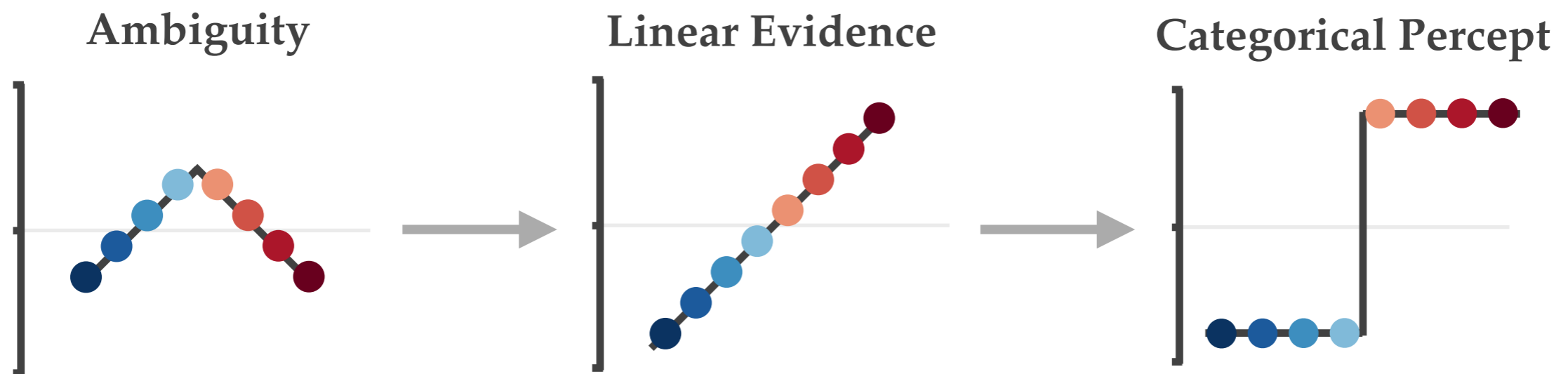
Interesting links in a different domain

Gwilliams & King, *in prep*

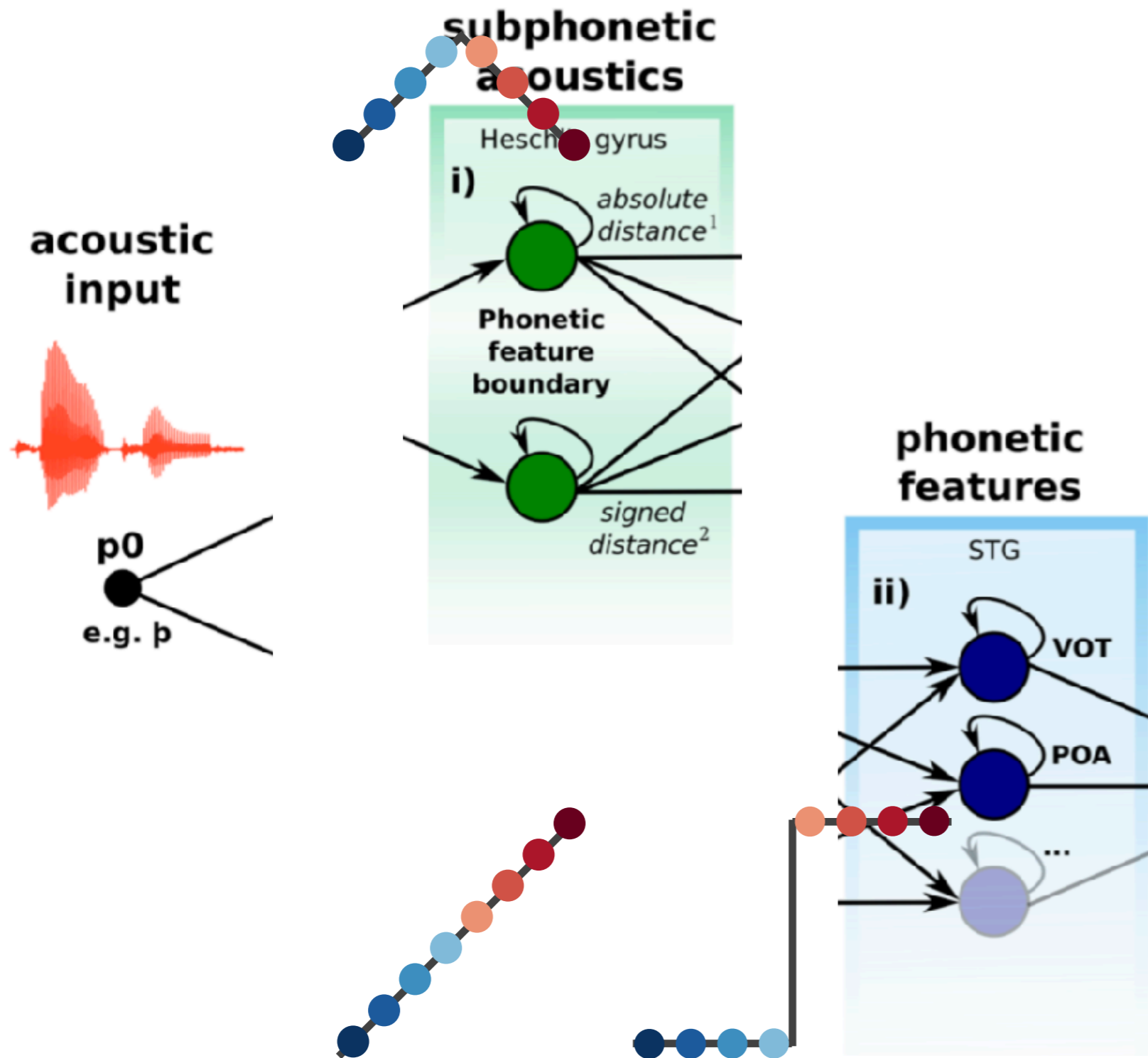


Experiment 1 Conclusions

- Responses shift from being modulated **linearly** to being modulated **categorically** (domain general?)
- Very **early sensitivity to phonological boundaries** in left Heschl's gyrus – occurs *before* categorisation (speech specific?)



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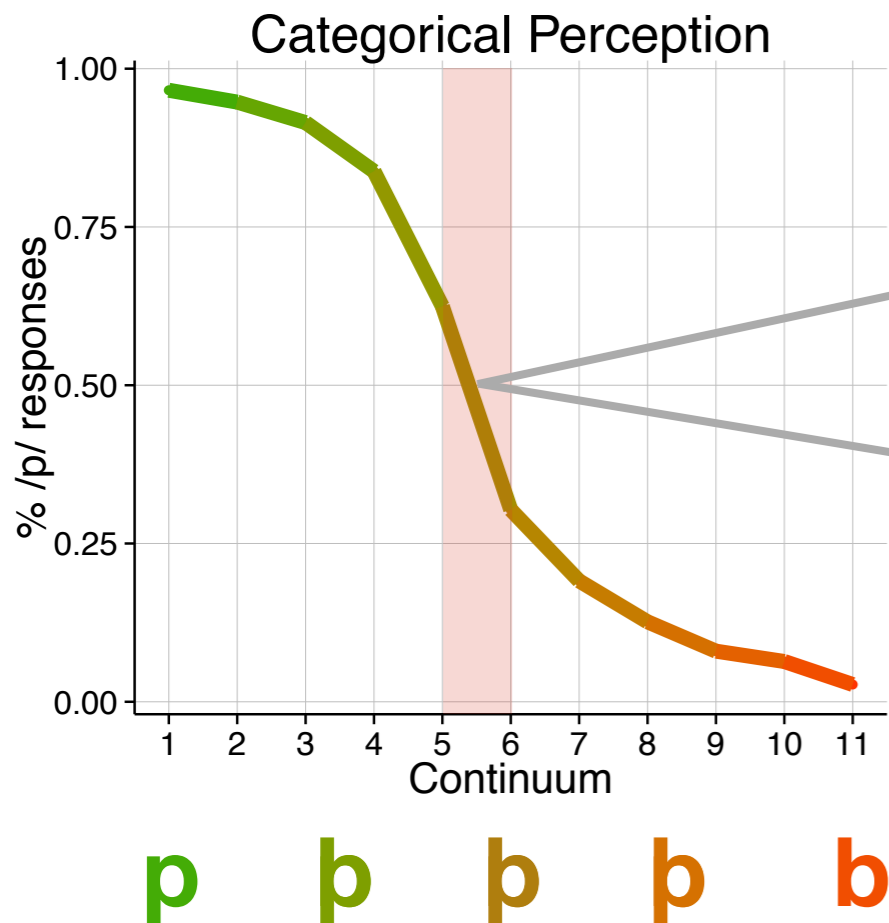
p a r a k e e t

Top-down Influences on Perception

- Context occurring *after* an acoustic signal can be integrated to **update 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

(this is a parakeet)



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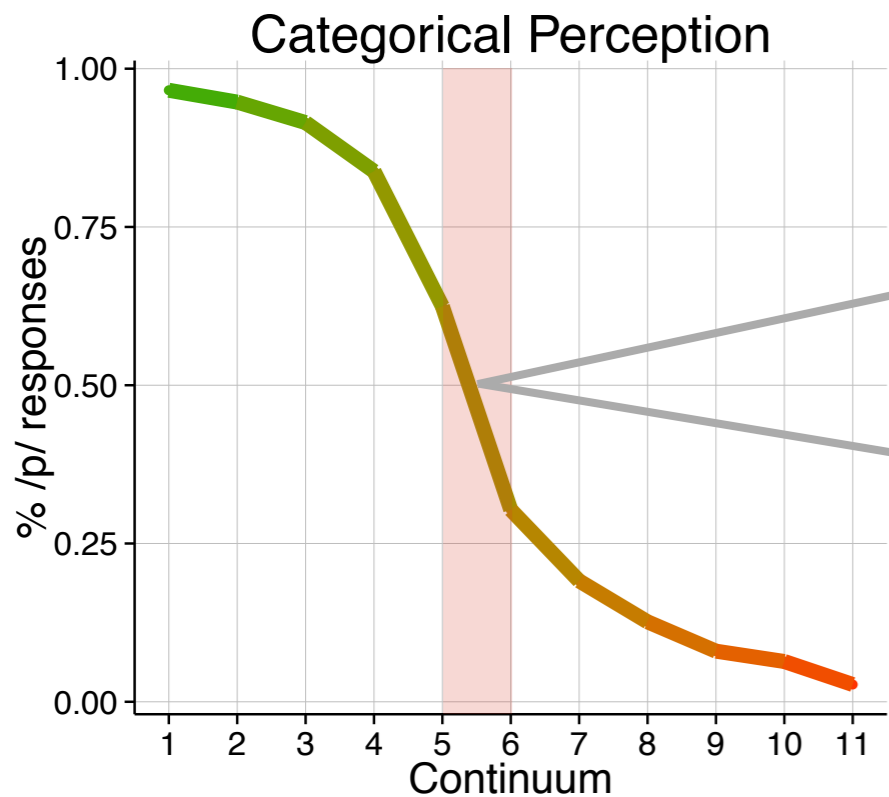


(this is a barricade)

“**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)

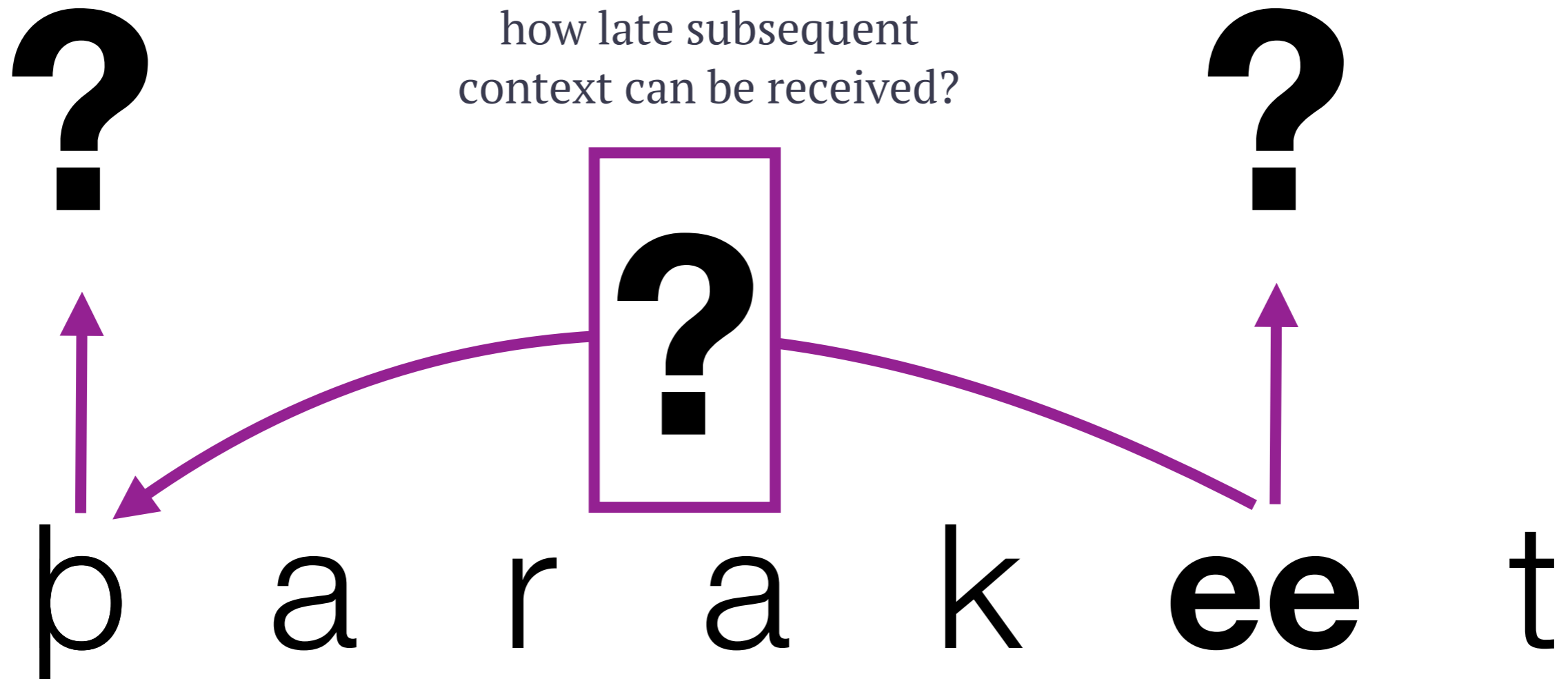
Today's Questions

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

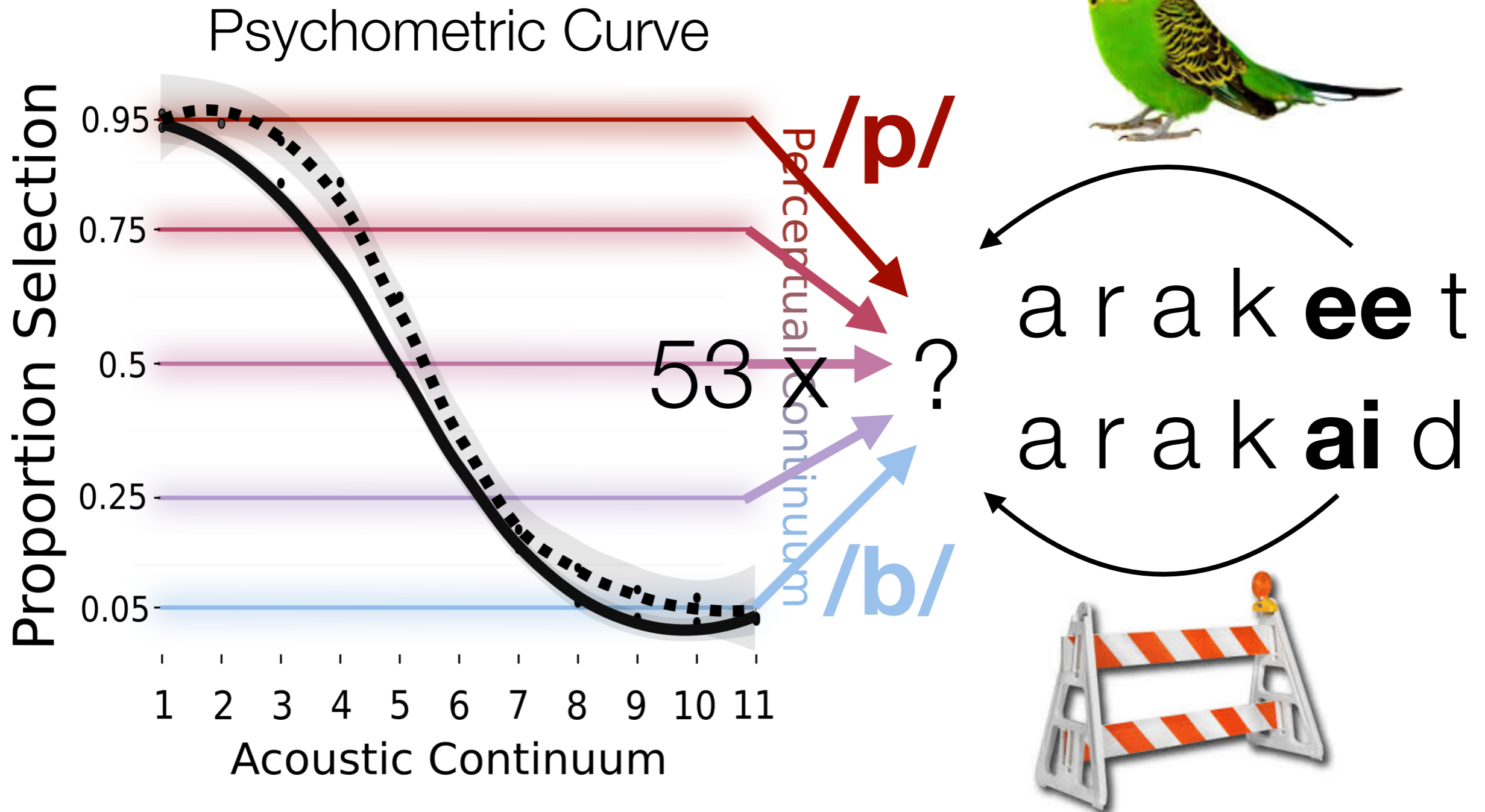
i could focus on the ambiguity resolution part here, rather than the original response to ambiguity. then, tie in the ambiguity response part later, linking it with AI?

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

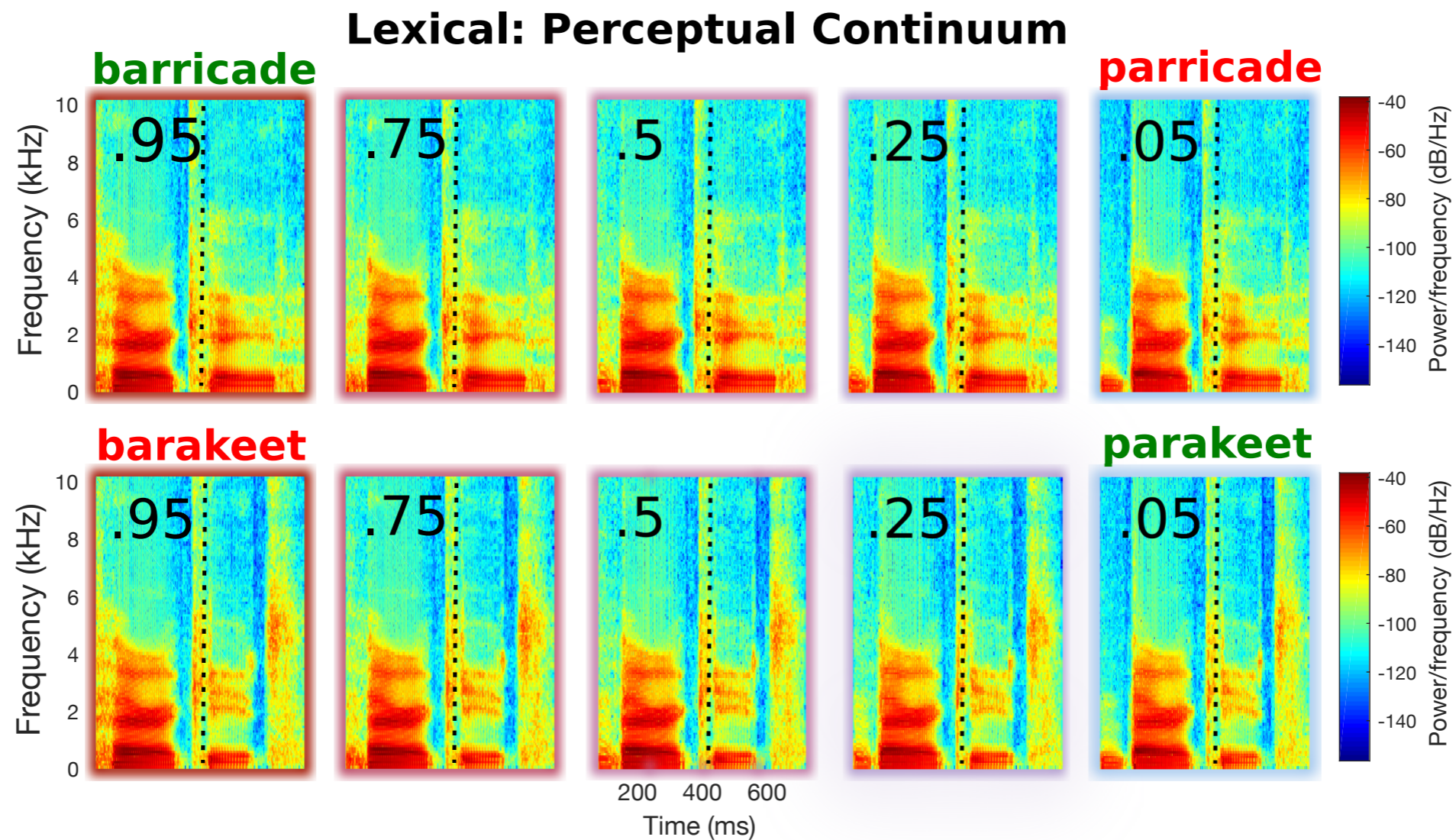
What is the **time-limit** on how late subsequent context can be received?



Design & Materials

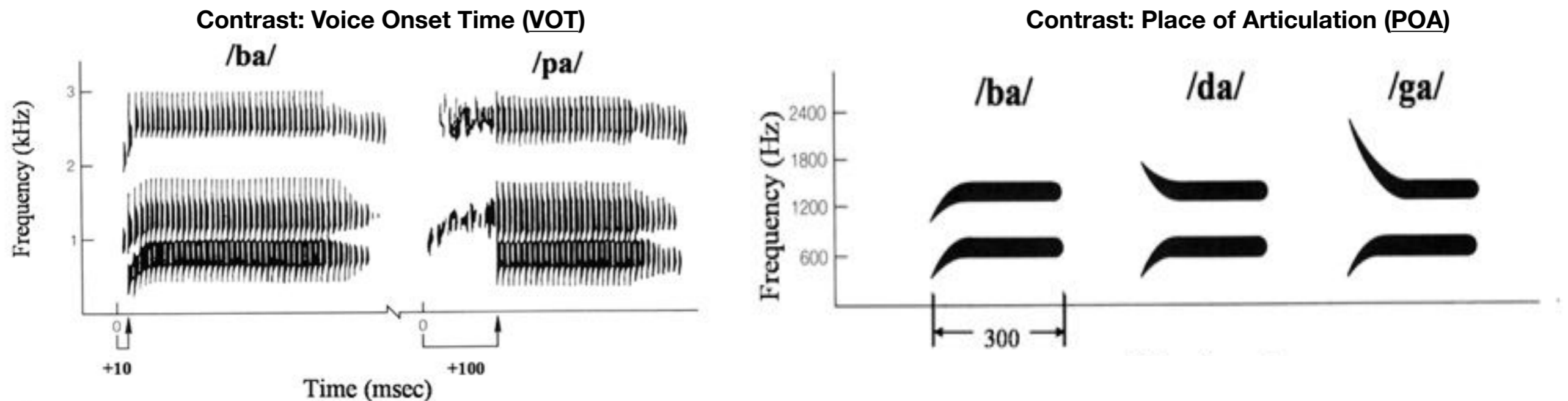


Design & Materials



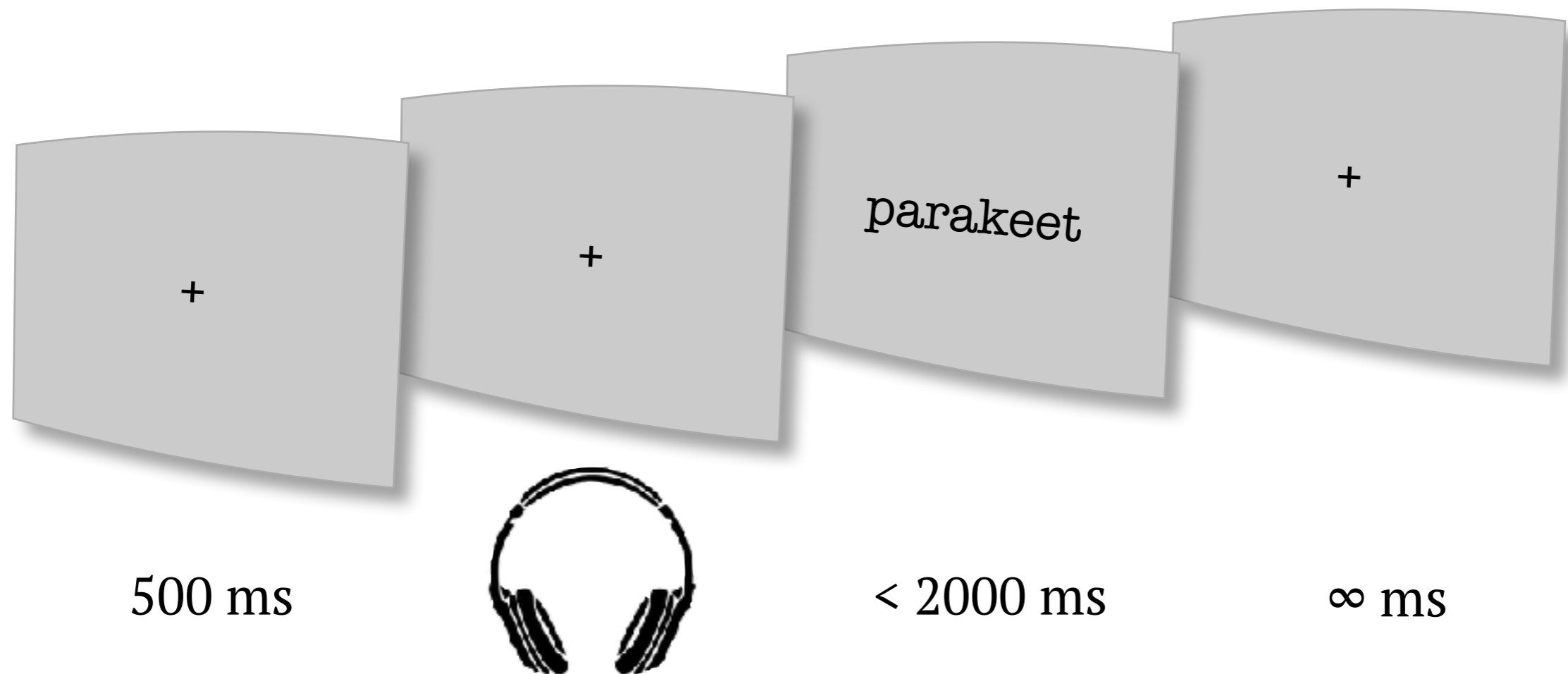
- Point of Disambiguation (POD) ranged 3-8 phonemes / 150-750 ms
- VOT (31 pairs) {p-b, t-d, k-g} and POA (22 pairs) {t-k, p-t}

Design & Materials

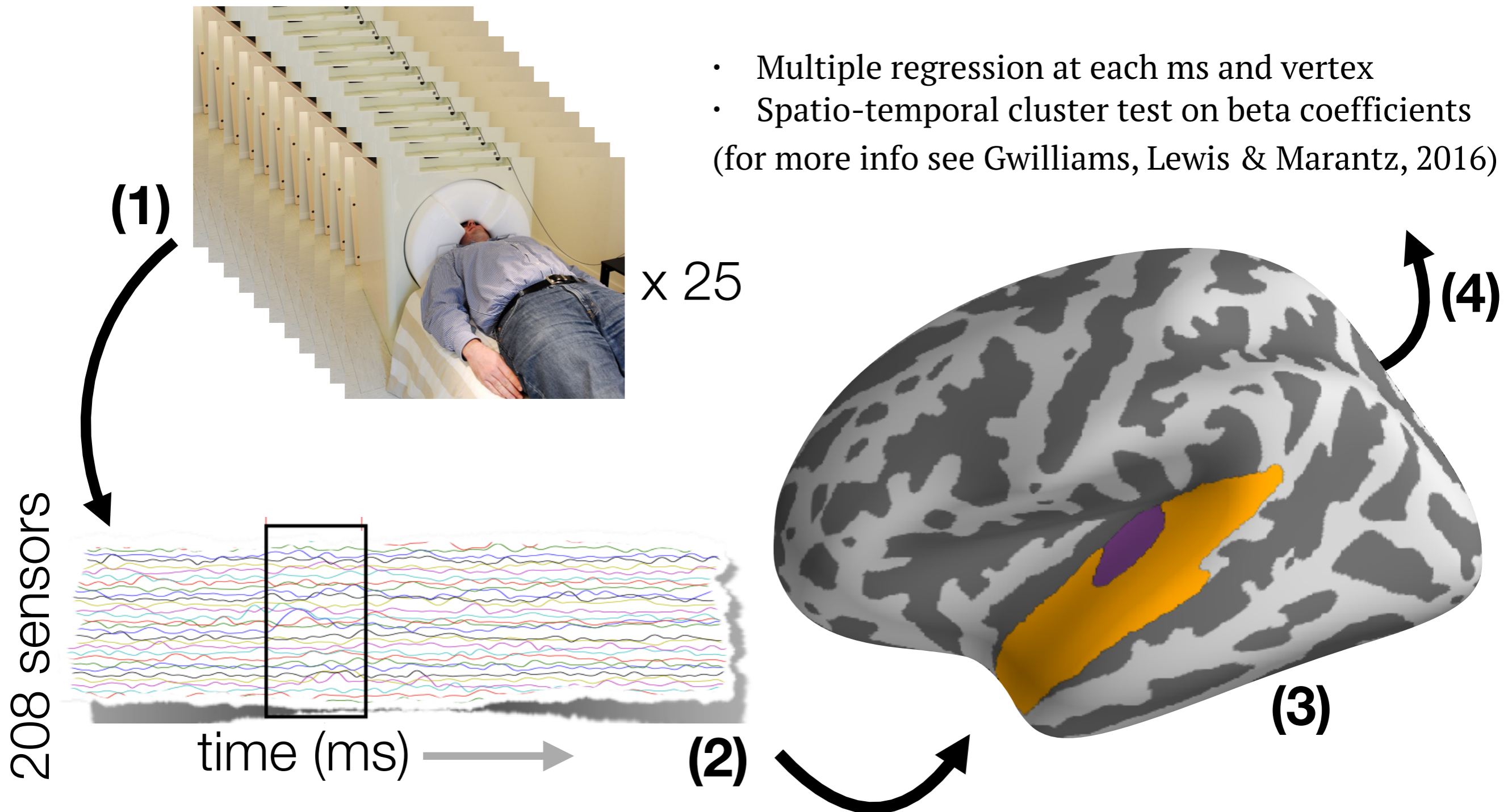


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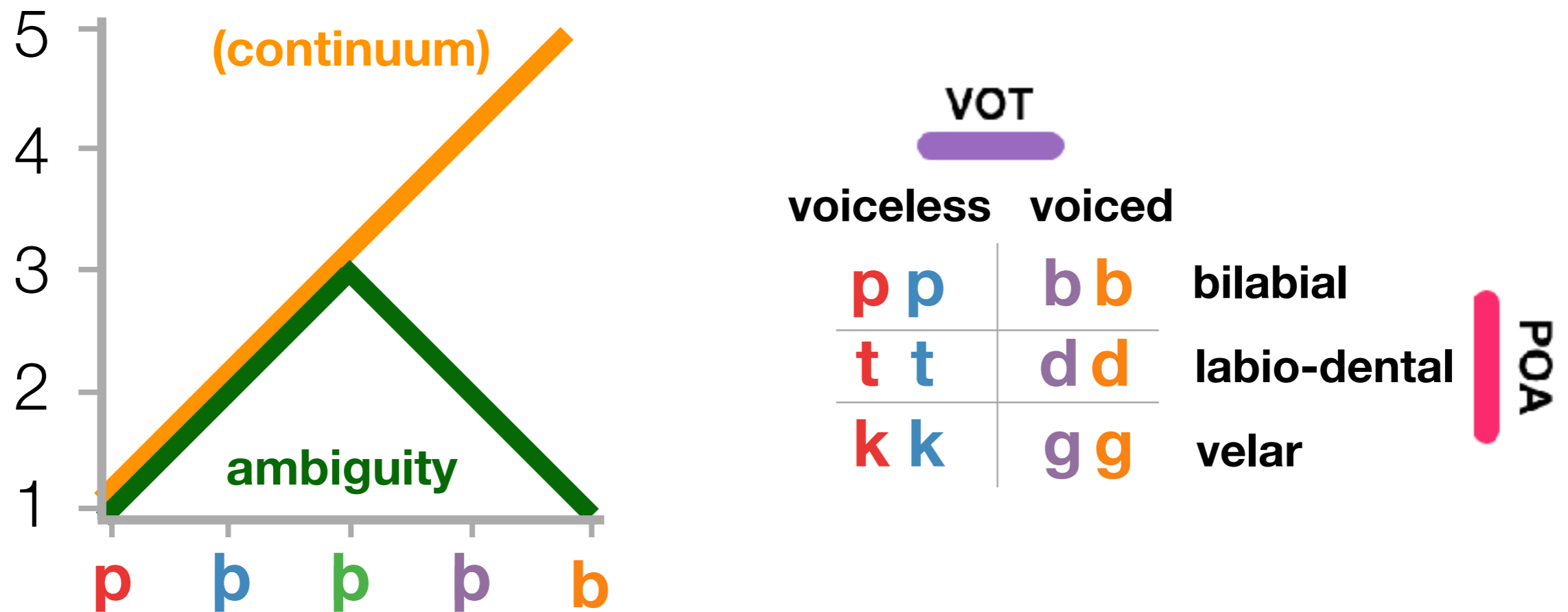
Design & Materials



Procedure & Analysis



Four Experimental Variables



Today's Questions

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

?



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a

r

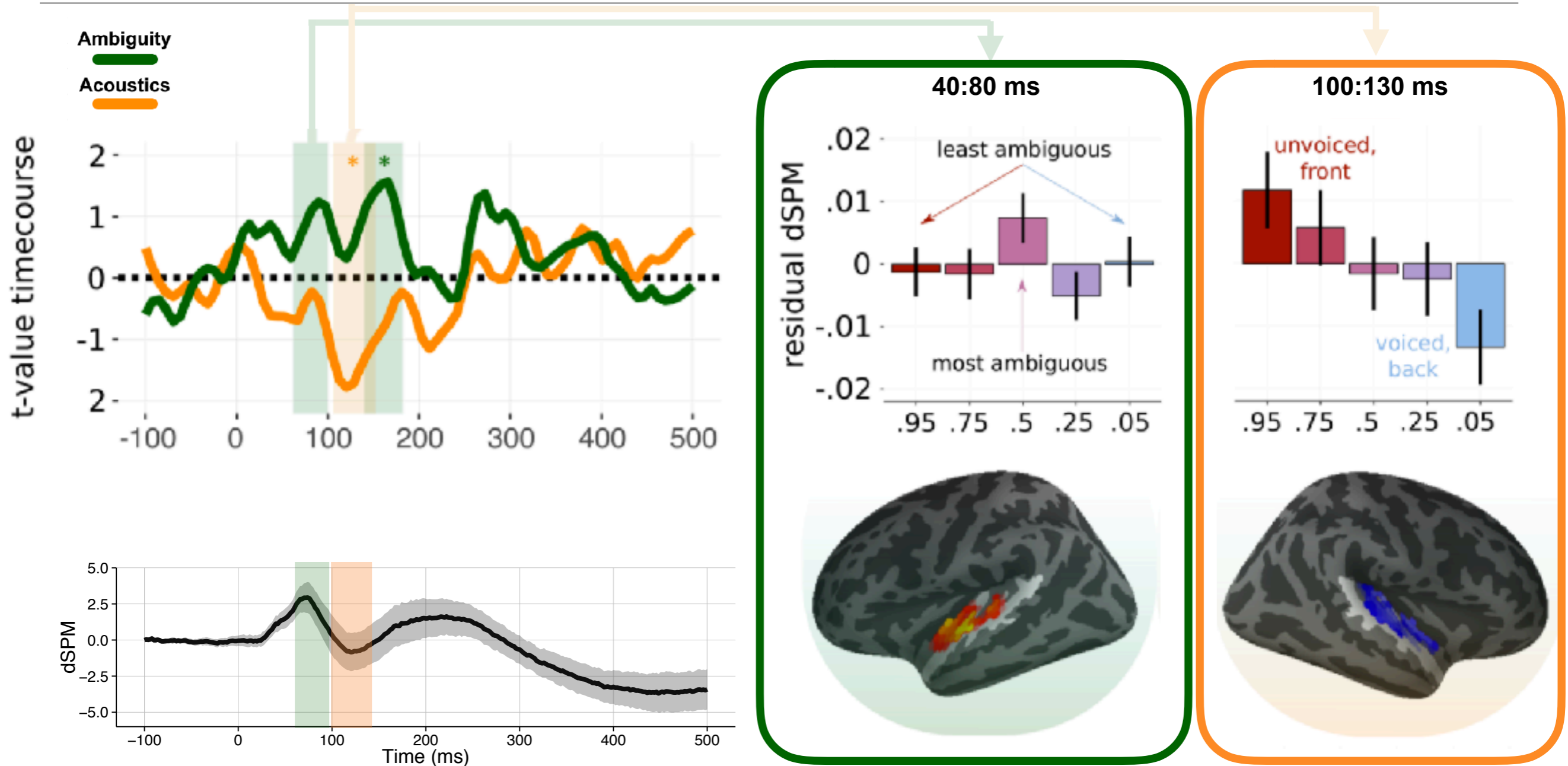
a

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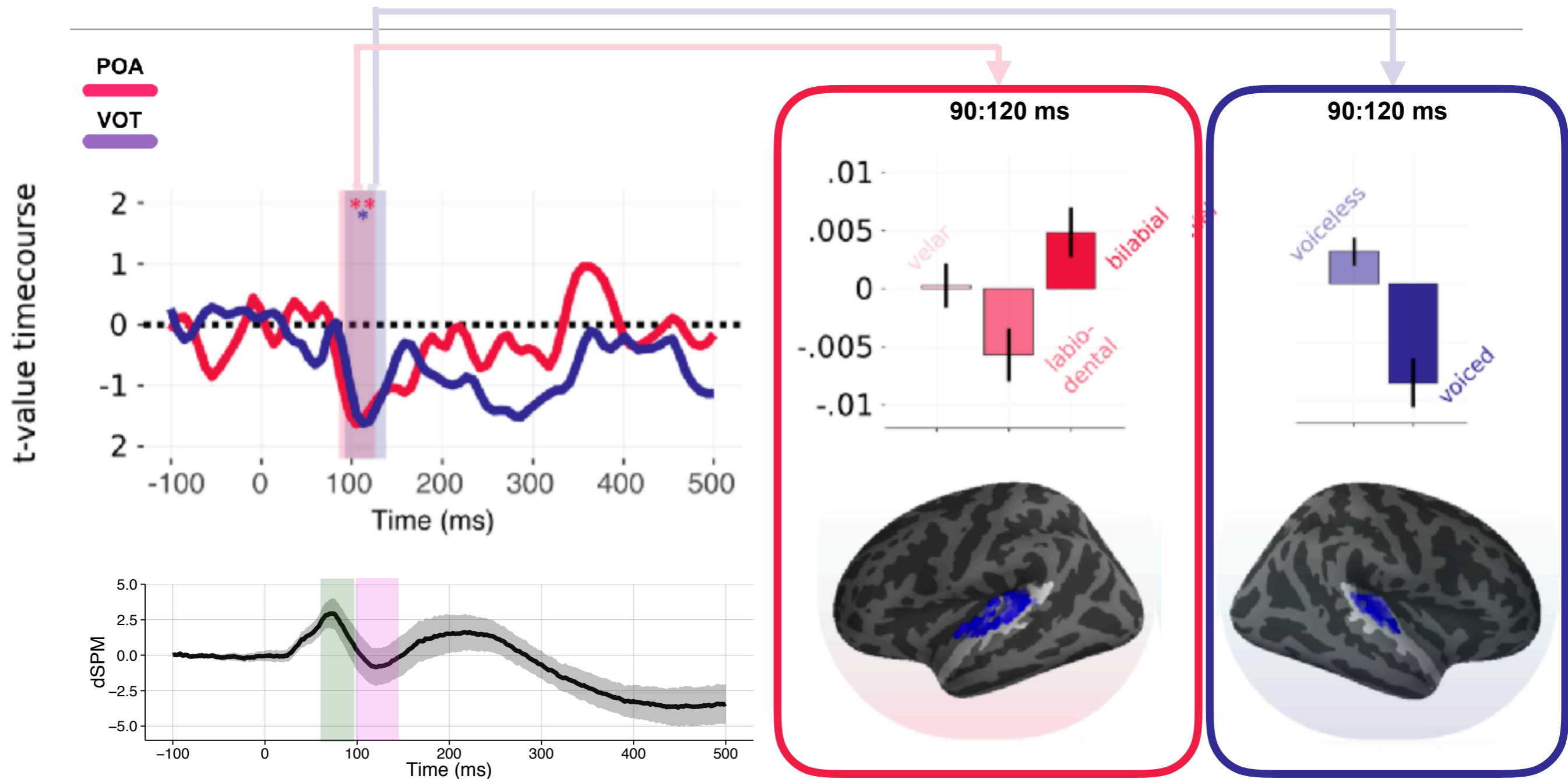
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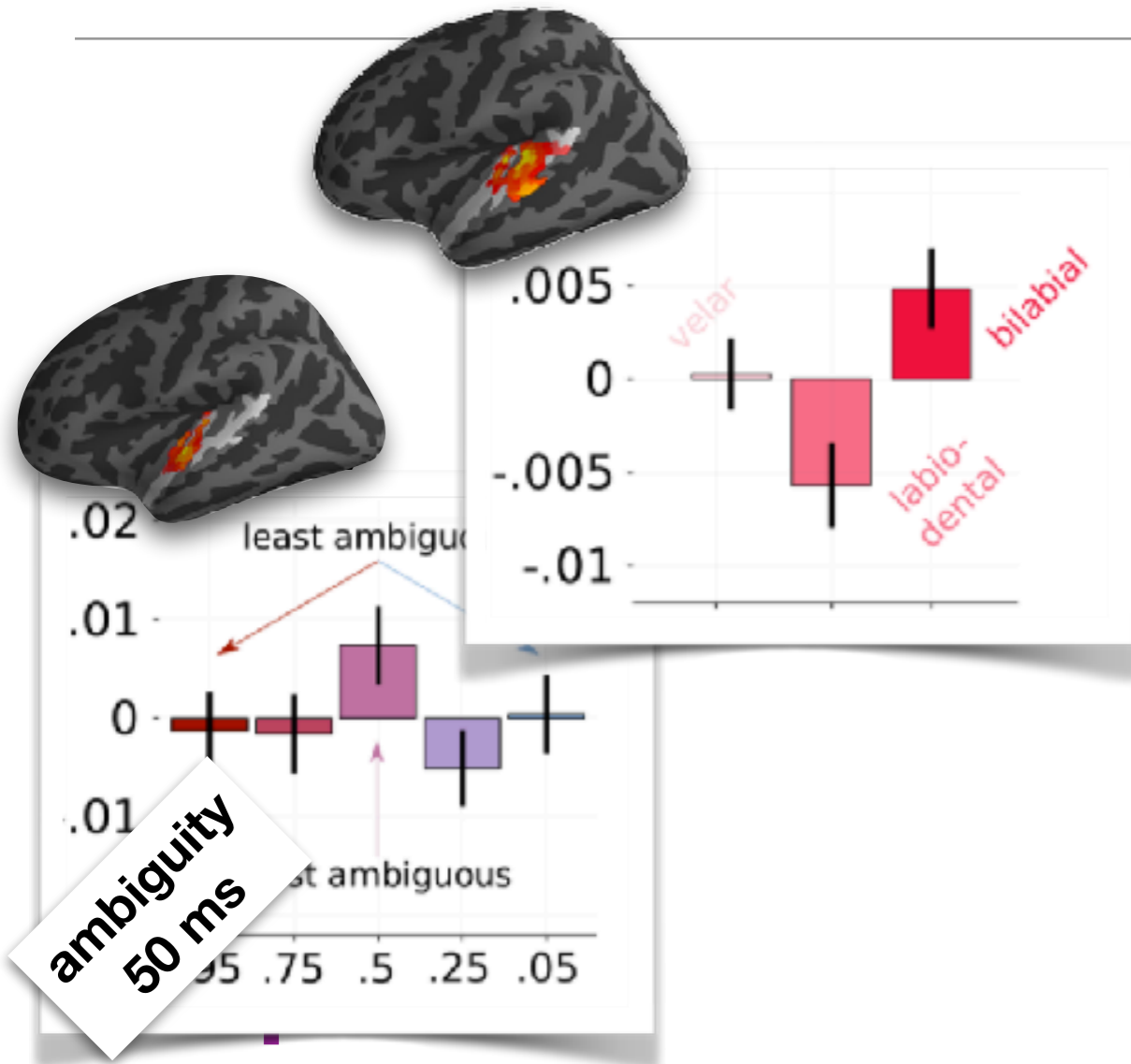
Subphonetics at Onset



Phonetic Features at Onset

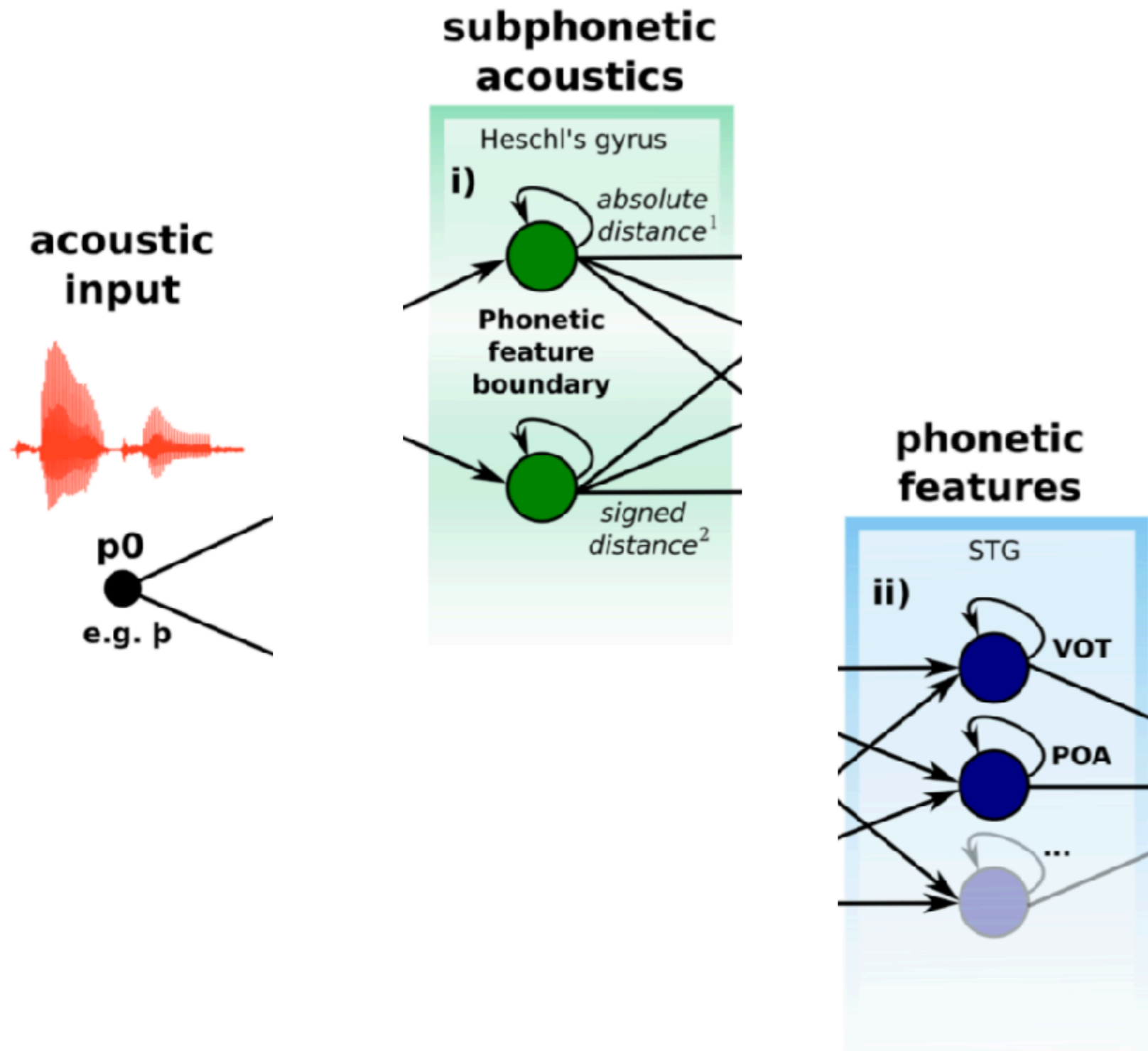


Interim Conclusion

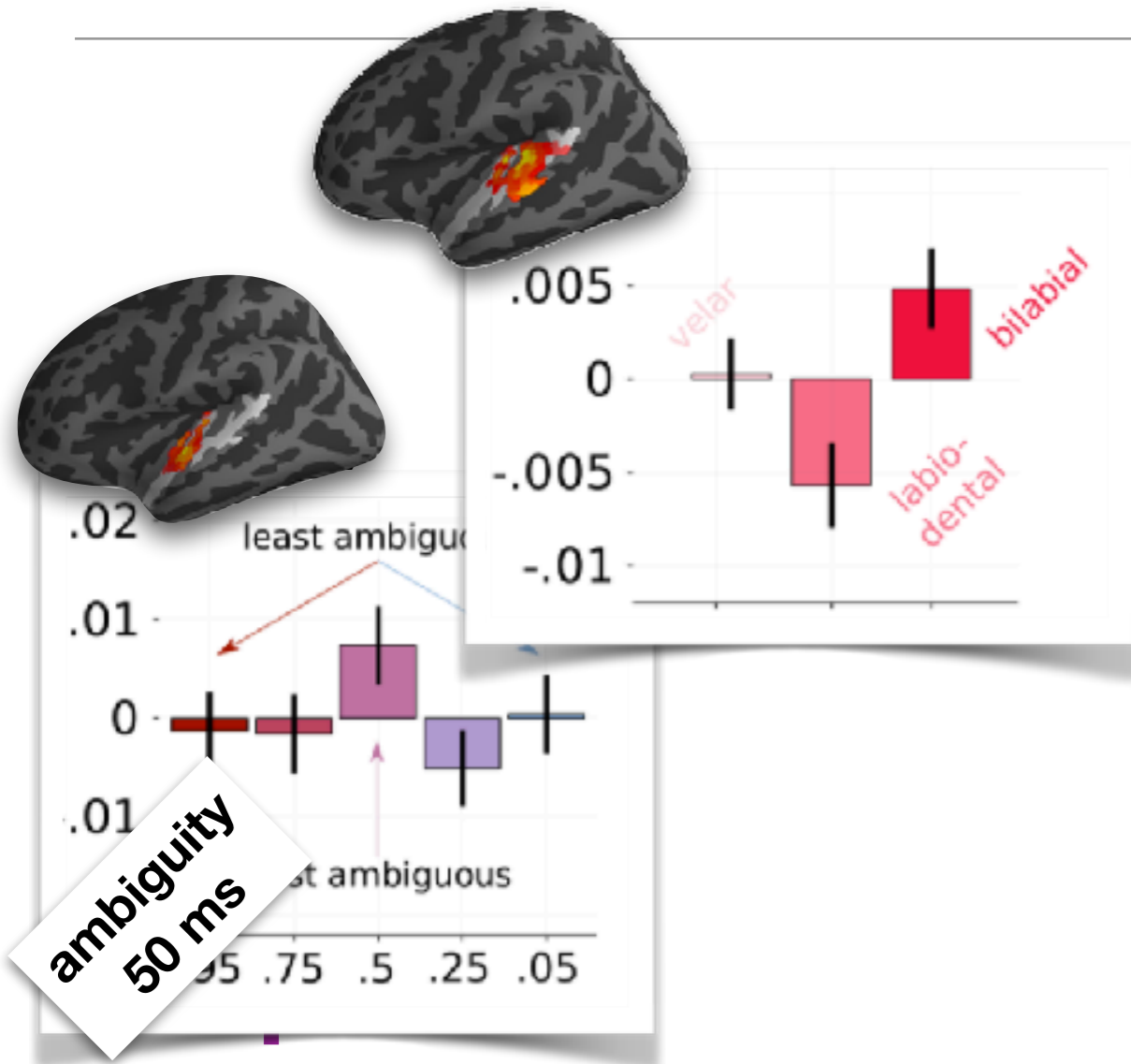


p a r a k e e t

Putting together the processing pieces



Interim Conclusion

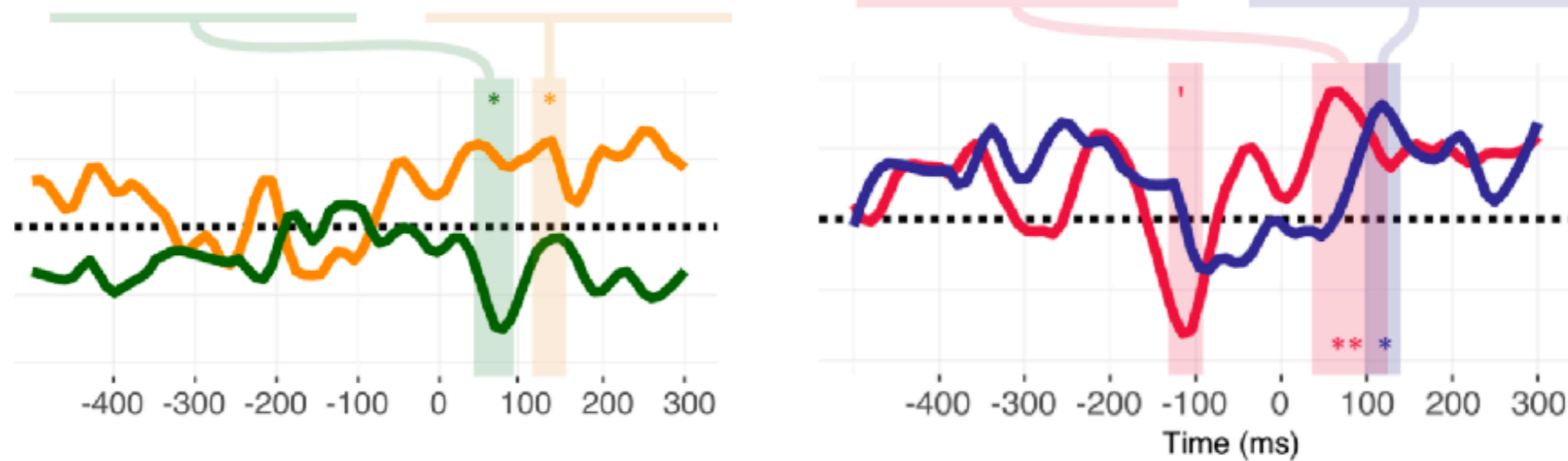


?

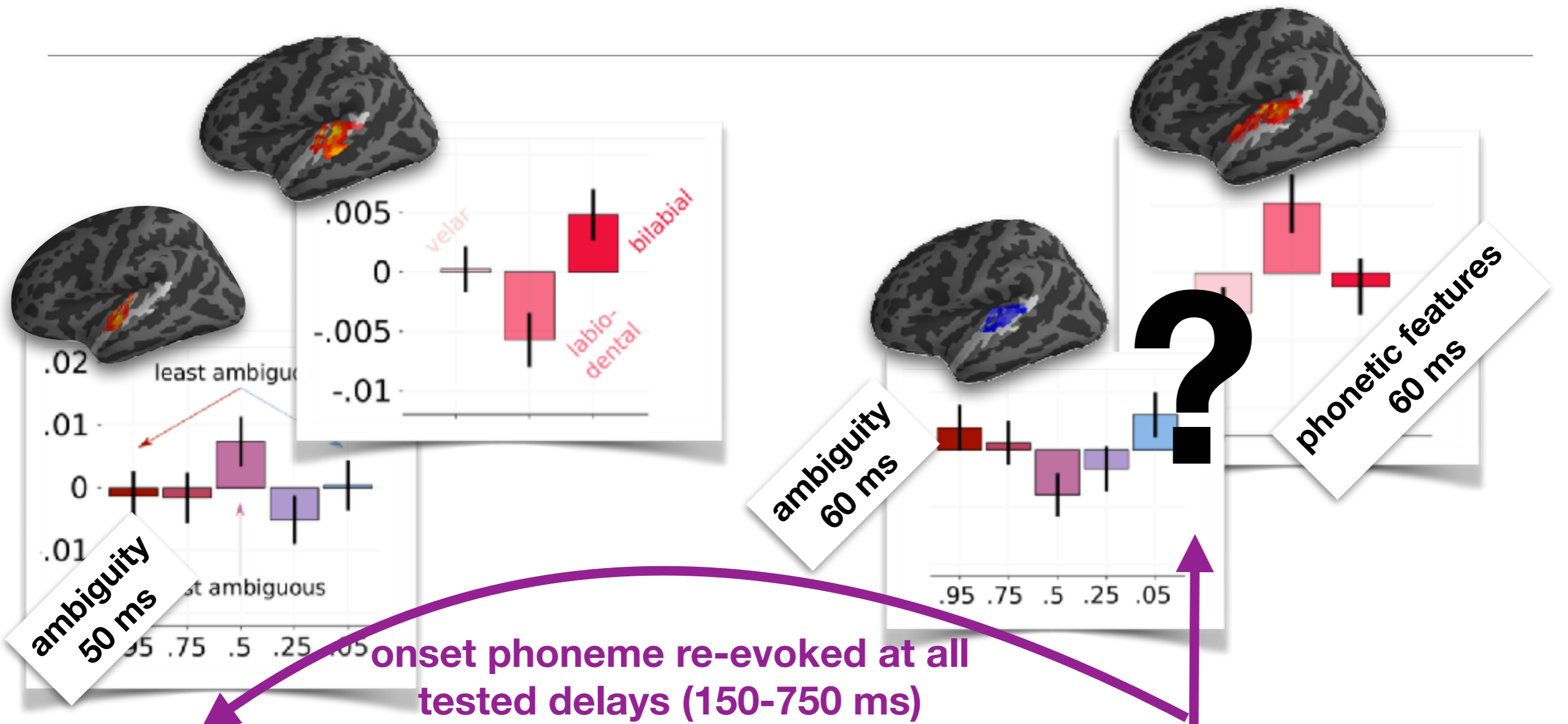


p a r a k e e t

Ambiguity at POD

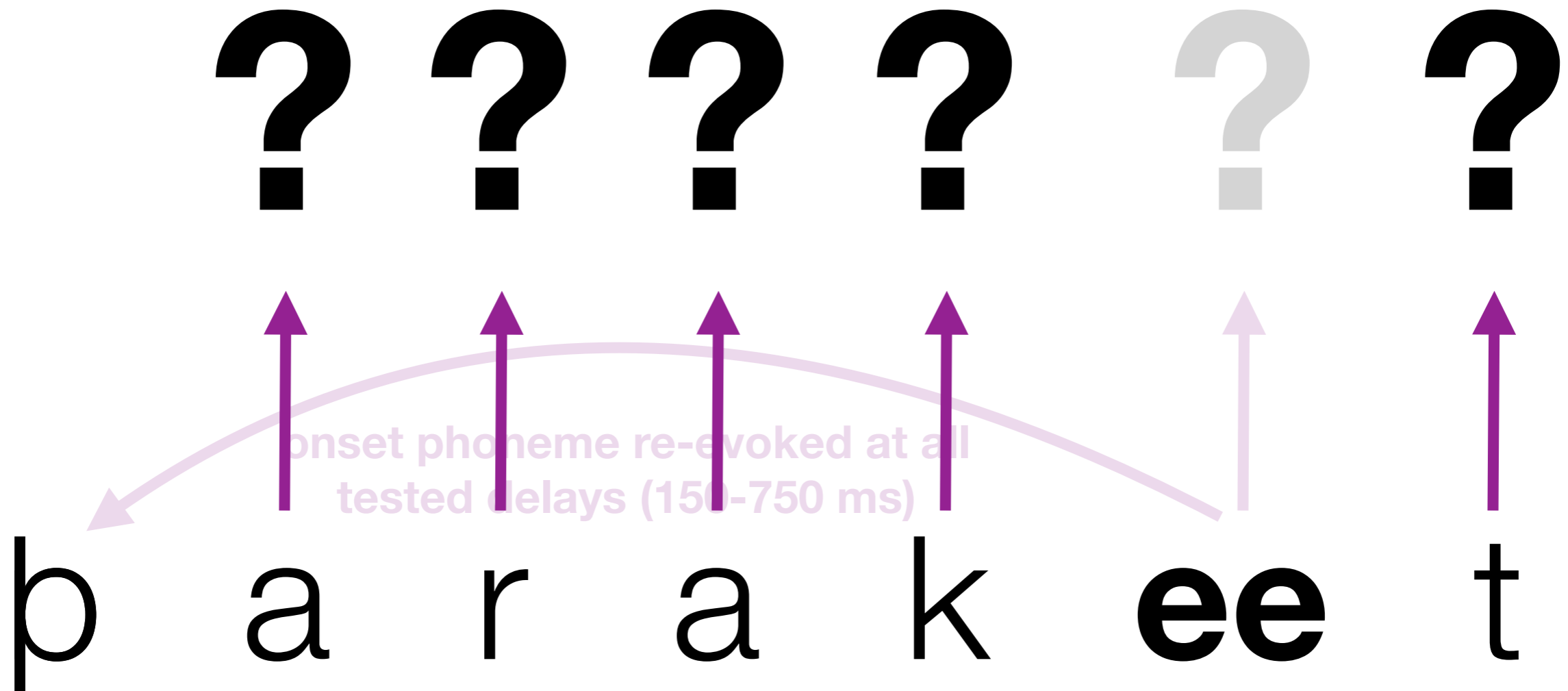


Interim Conclusion

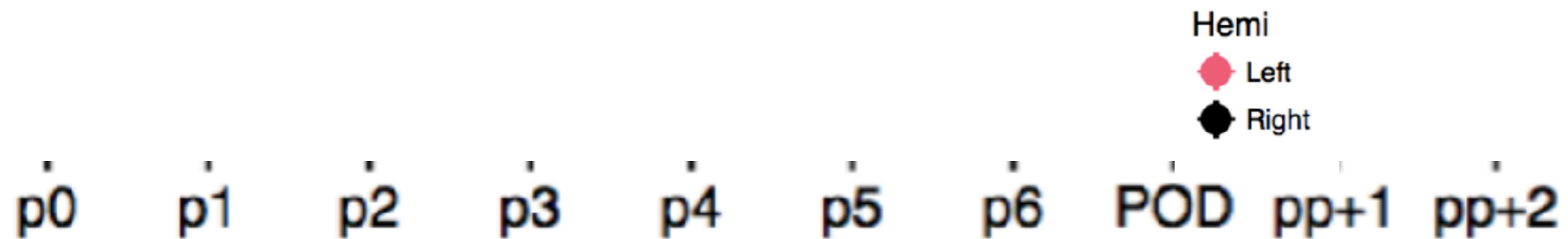


b a r a k e e t

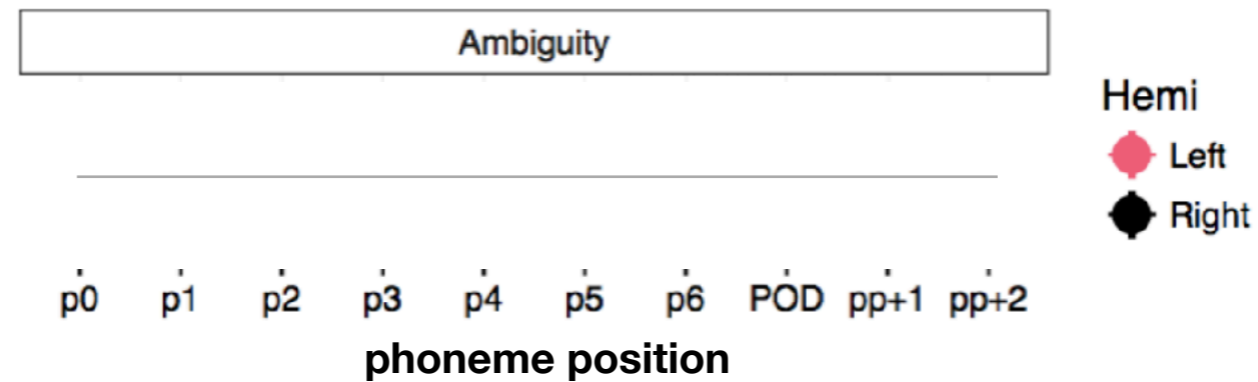
Interim Conclusion



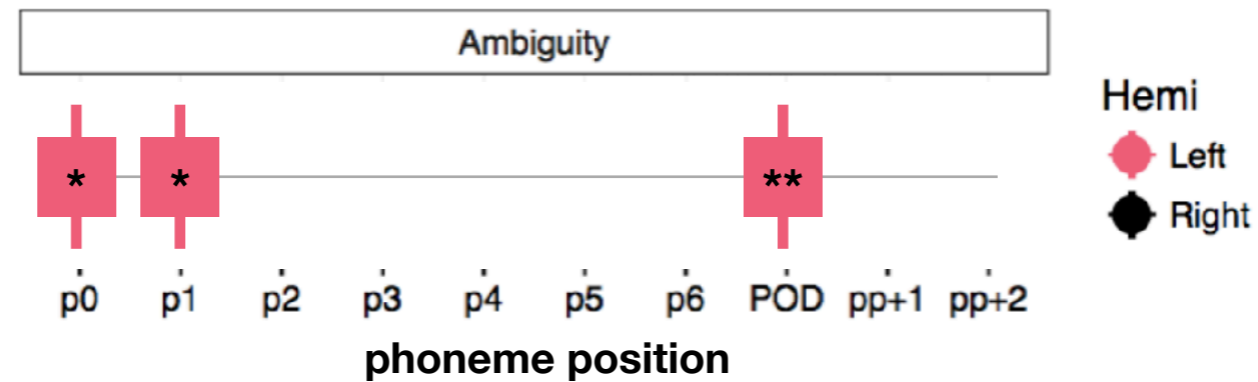
Reactivation in Intermediate Positions



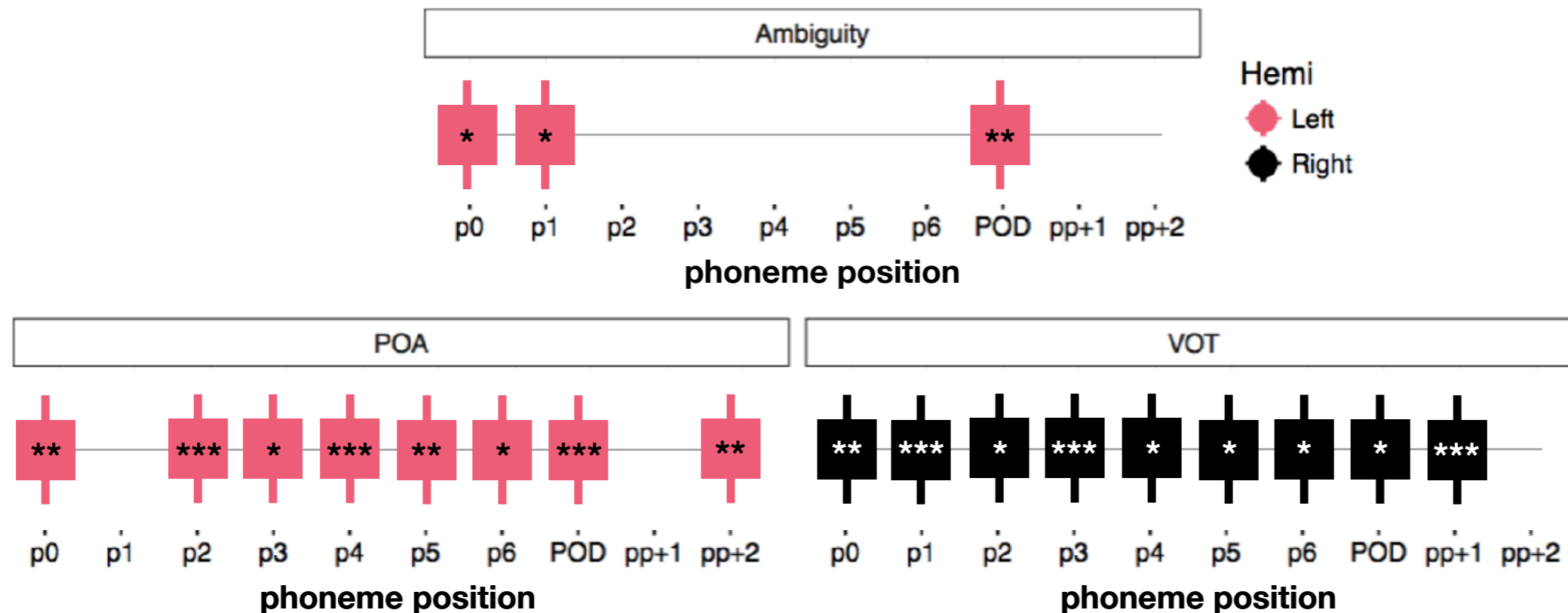
Reactivation in Intermediate Positions



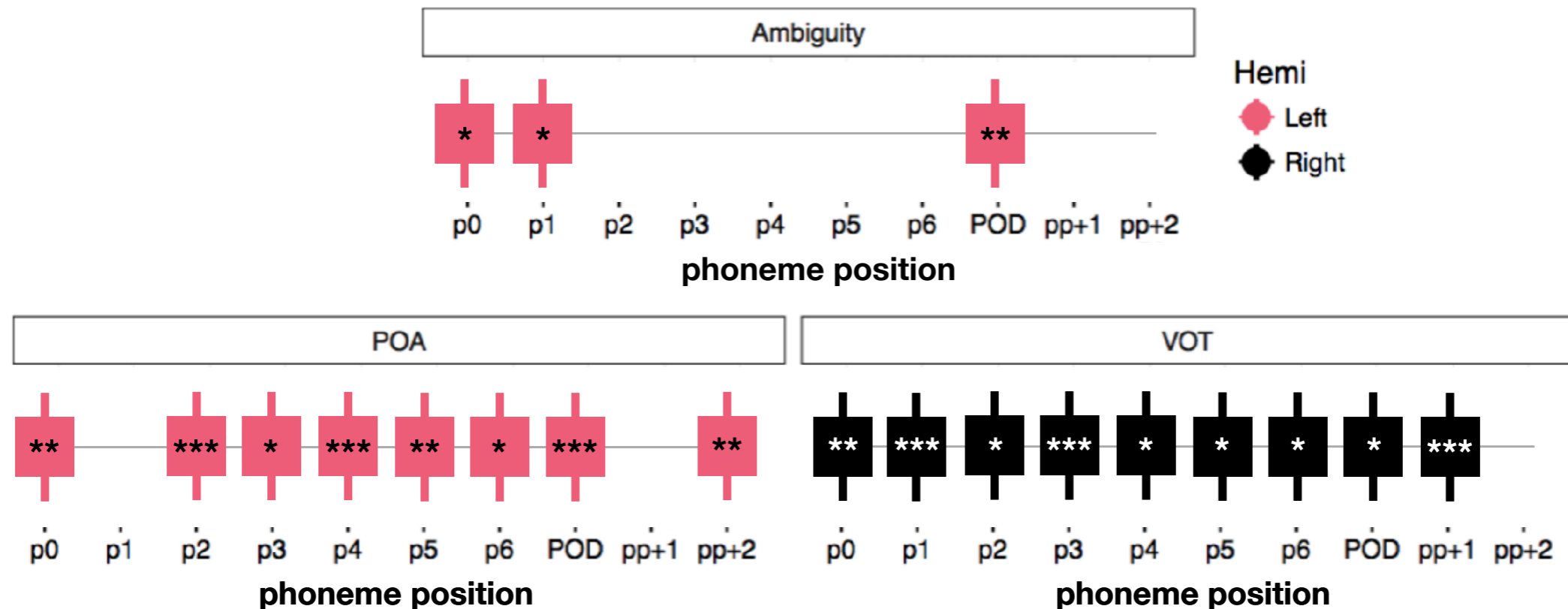
Reactivation in Intermediate Positions



Reactivation in Intermediate Positions

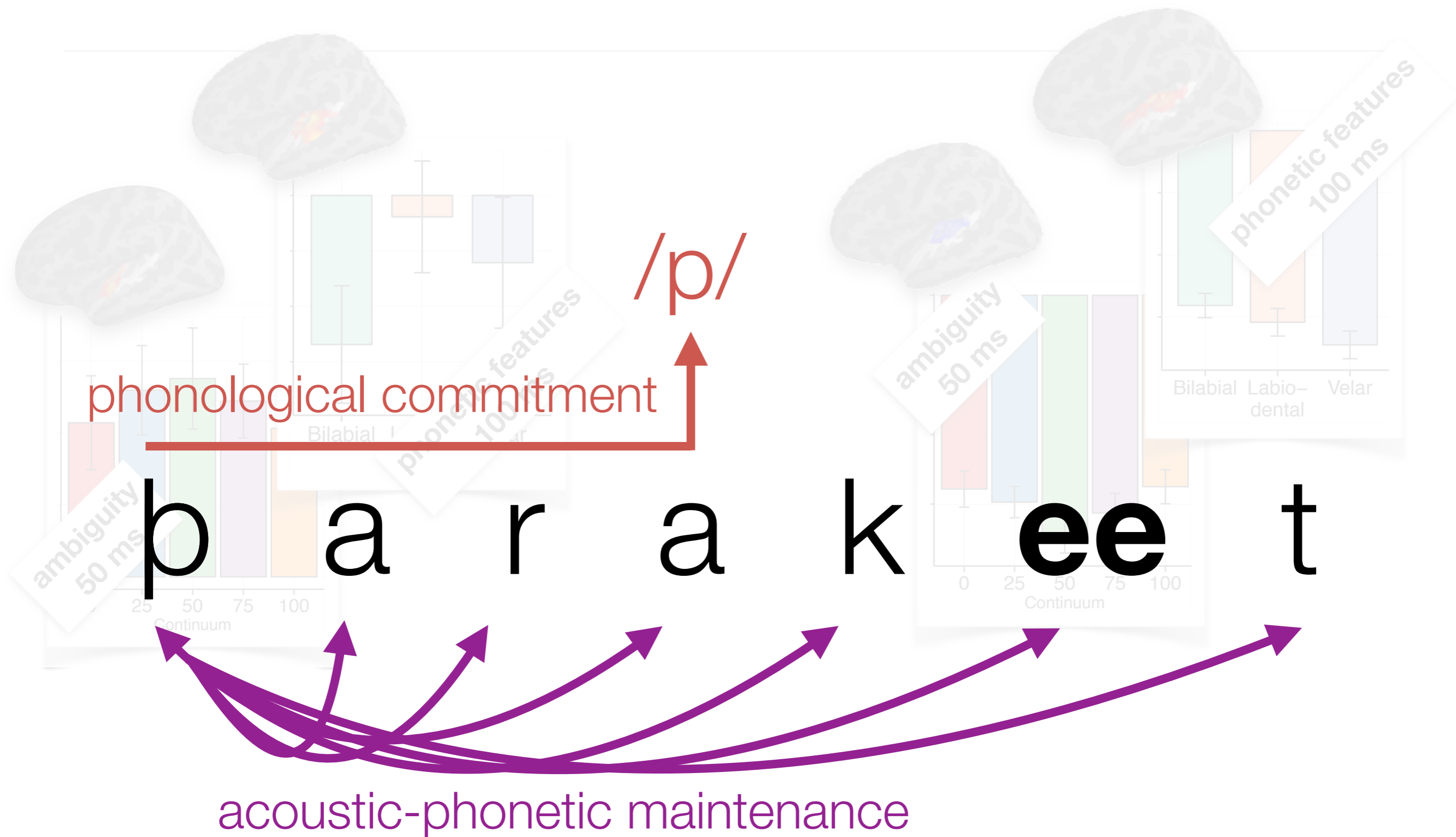


Reactivation in Intermediate Positions



- Information is re-evoked in auditory cortex
- Specifically time-locked to the onset of subsequent phonemes
- Not specific to the ambiguous tokens — general to language processing

Interim Conclusion

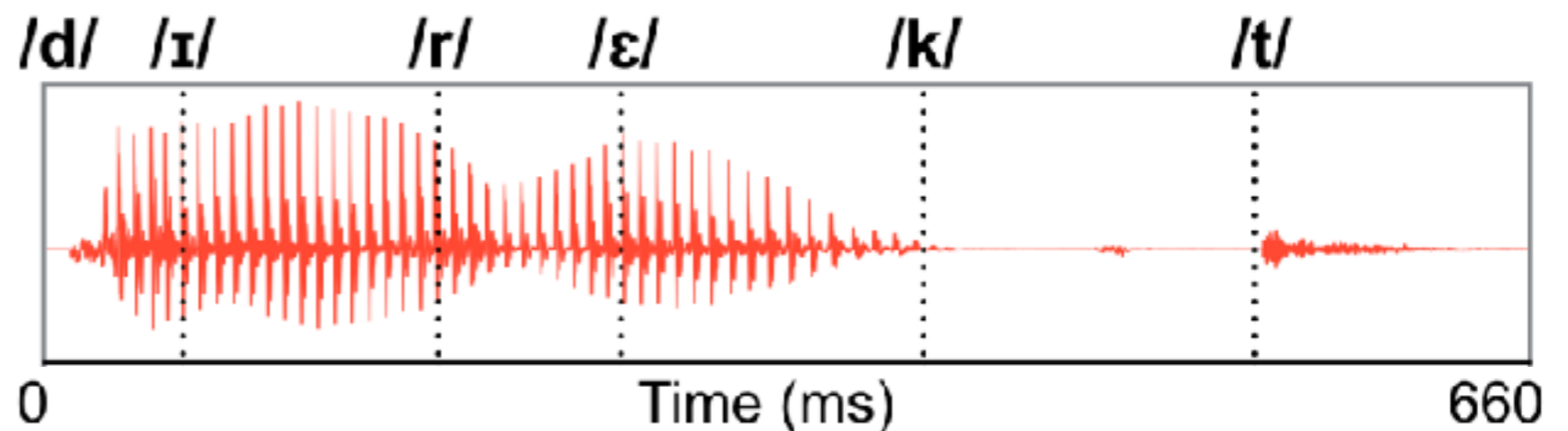


Testing for phonological commitment

- **Surprisal:**

No commitment
Commitment

$$-\log_2 \left(P(\varphi_a | A) \frac{f(\varphi_a, \varphi_2, \dots, \varphi_t)}{f(\varphi_a, \varphi_2, \dots, \varphi_{t-1})} Q_a^t + \dots \right)$$



- **Entropy:**

No commitment
Commitment

$$P(w | C, A) = P(w | C_a) P(\varphi_a | A) + P(w | C_b) P(\varphi_b | A)$$

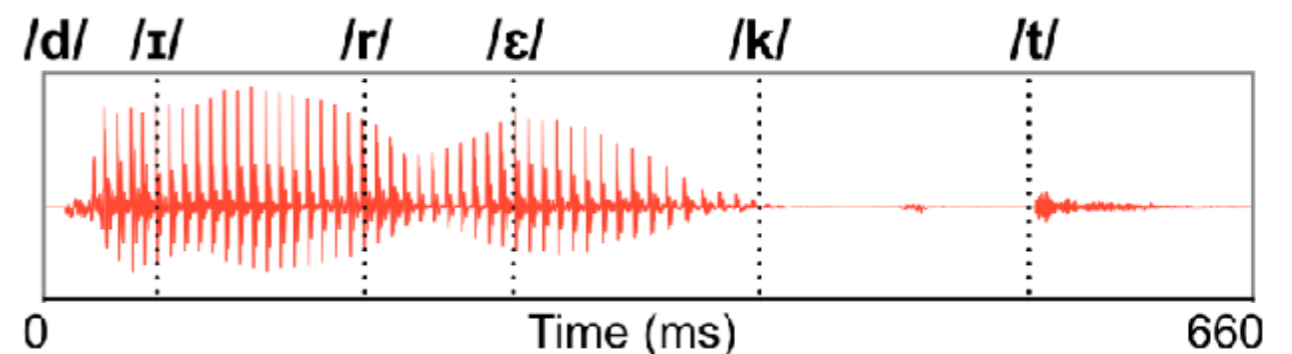
Model Setup

- **Critical variables:**

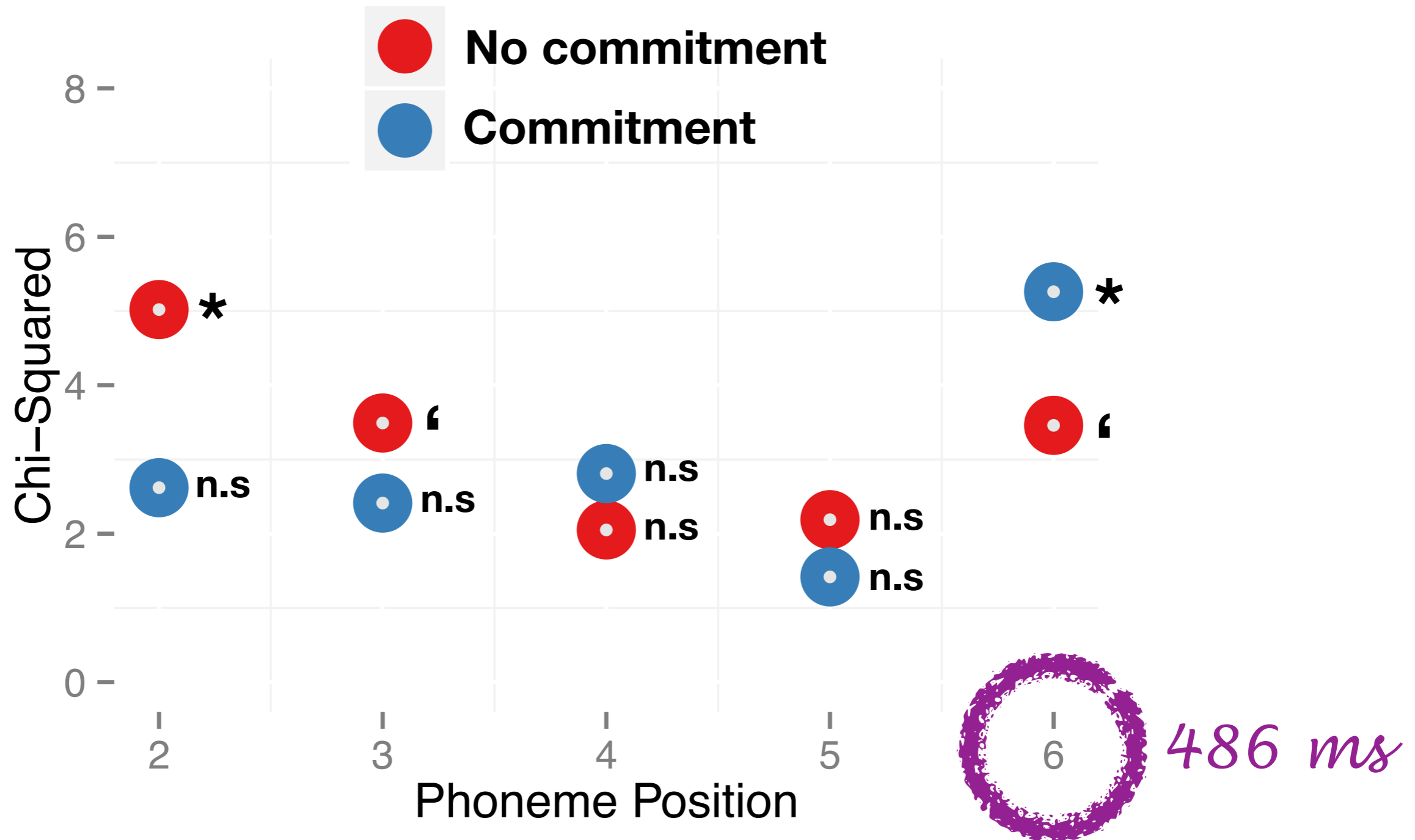
no commitment entropy
no commitment surprisal
commitment entropy
commitment surprisal

- **Control variables:**

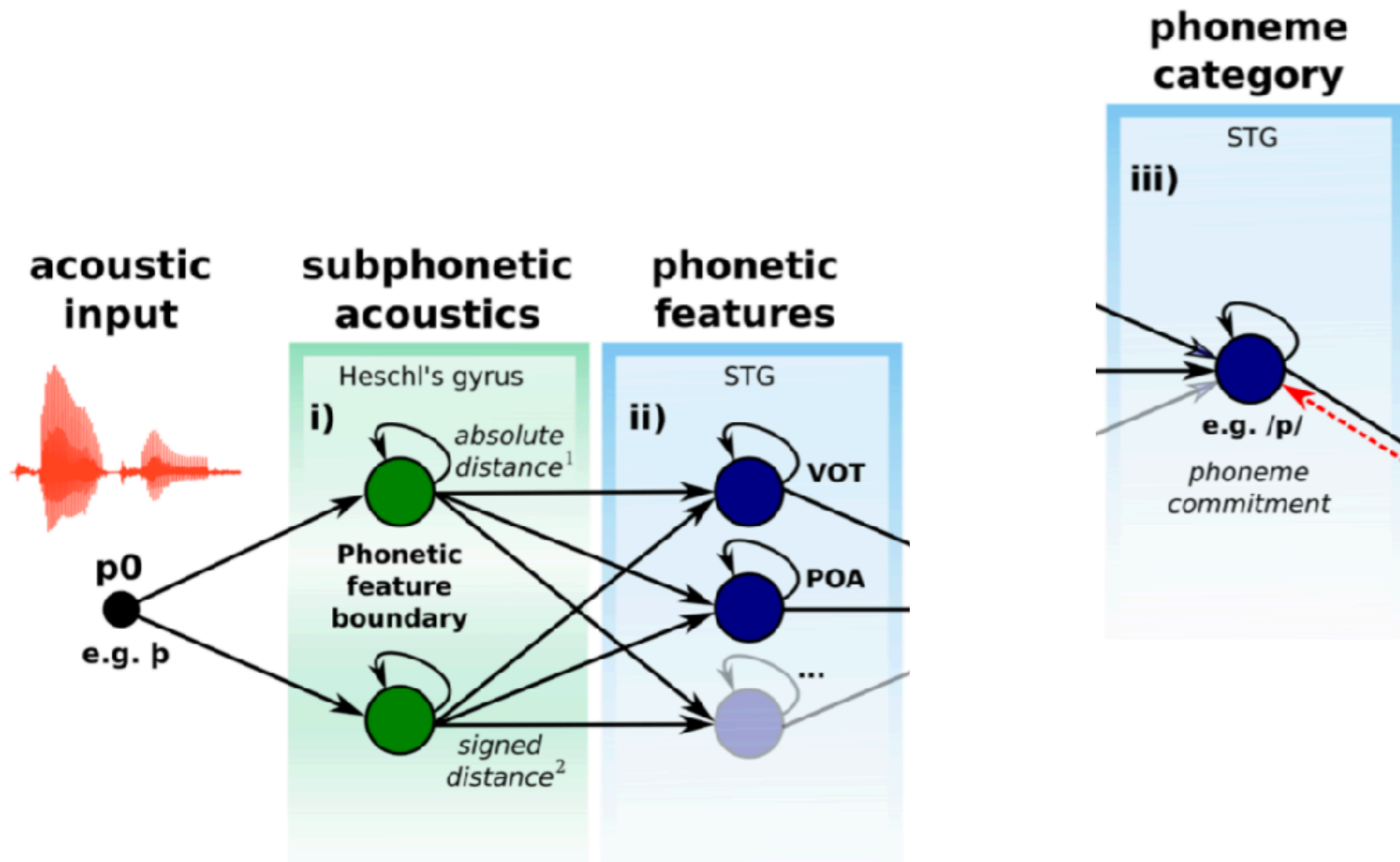
phoneme latency (ms)
phoneme latency (number of phonemes)
trial number
block number
stimulus amplitude
phoneme pair
ambiguity



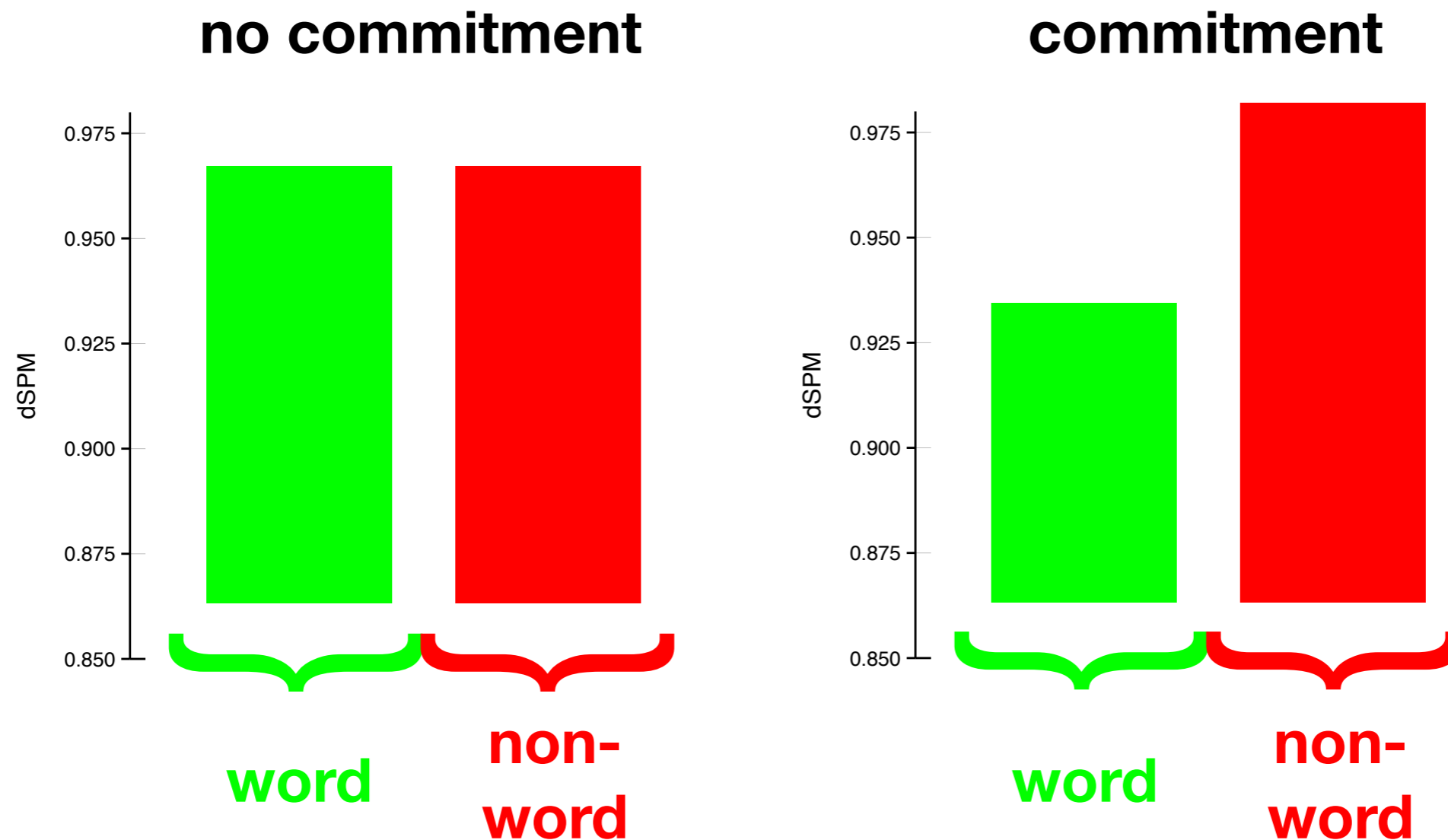
Results



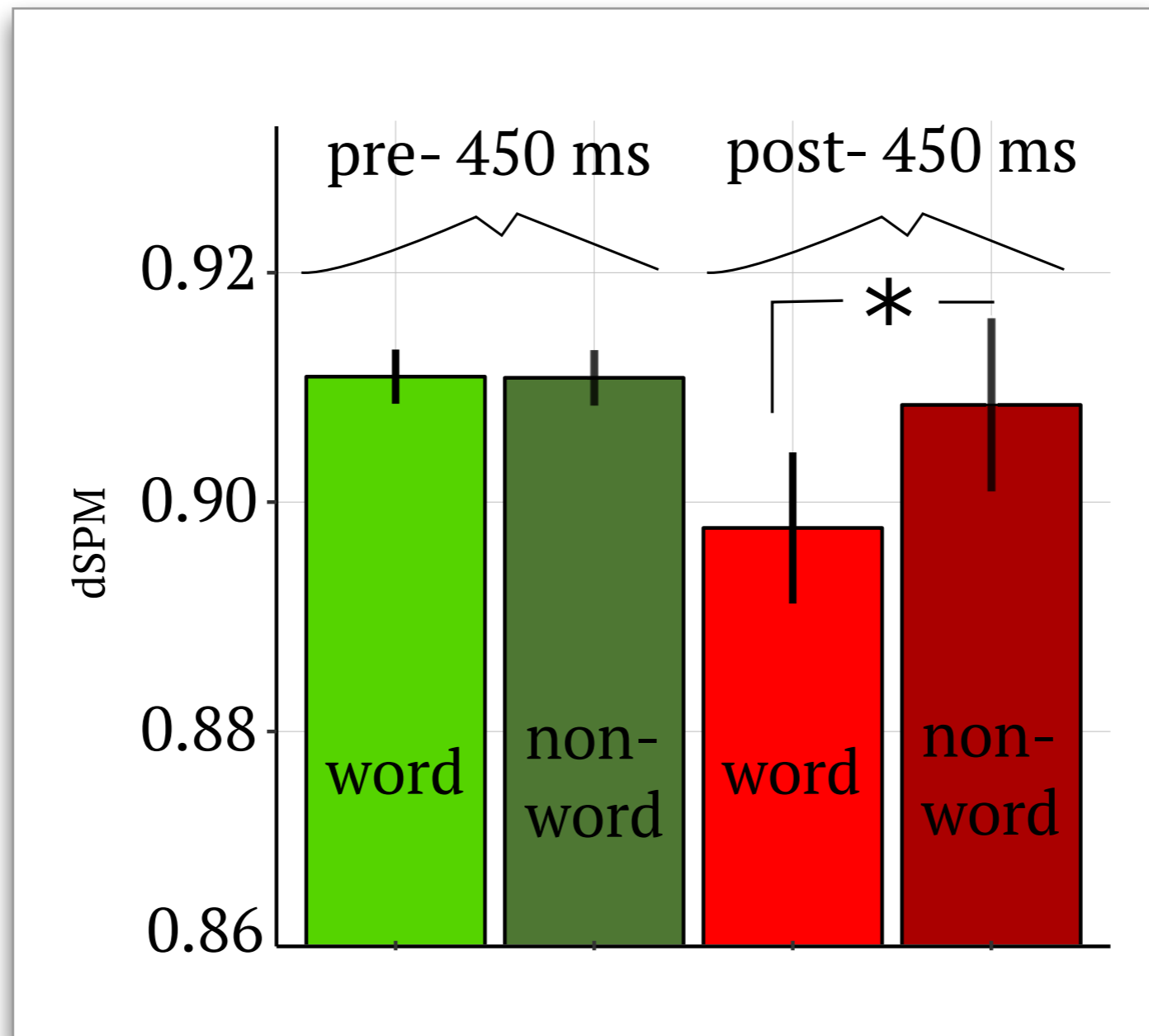
Putting together the processing pieces



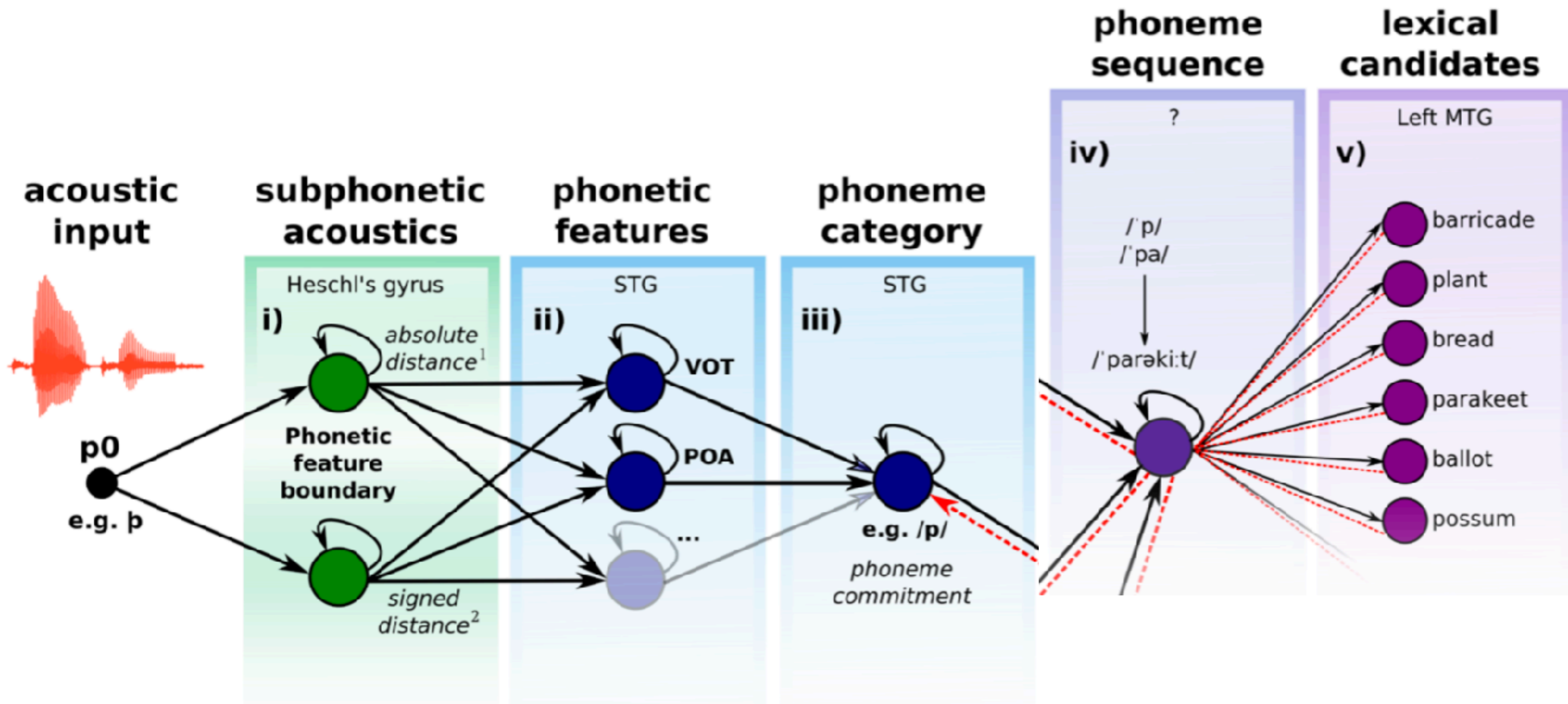
Further test of commitment



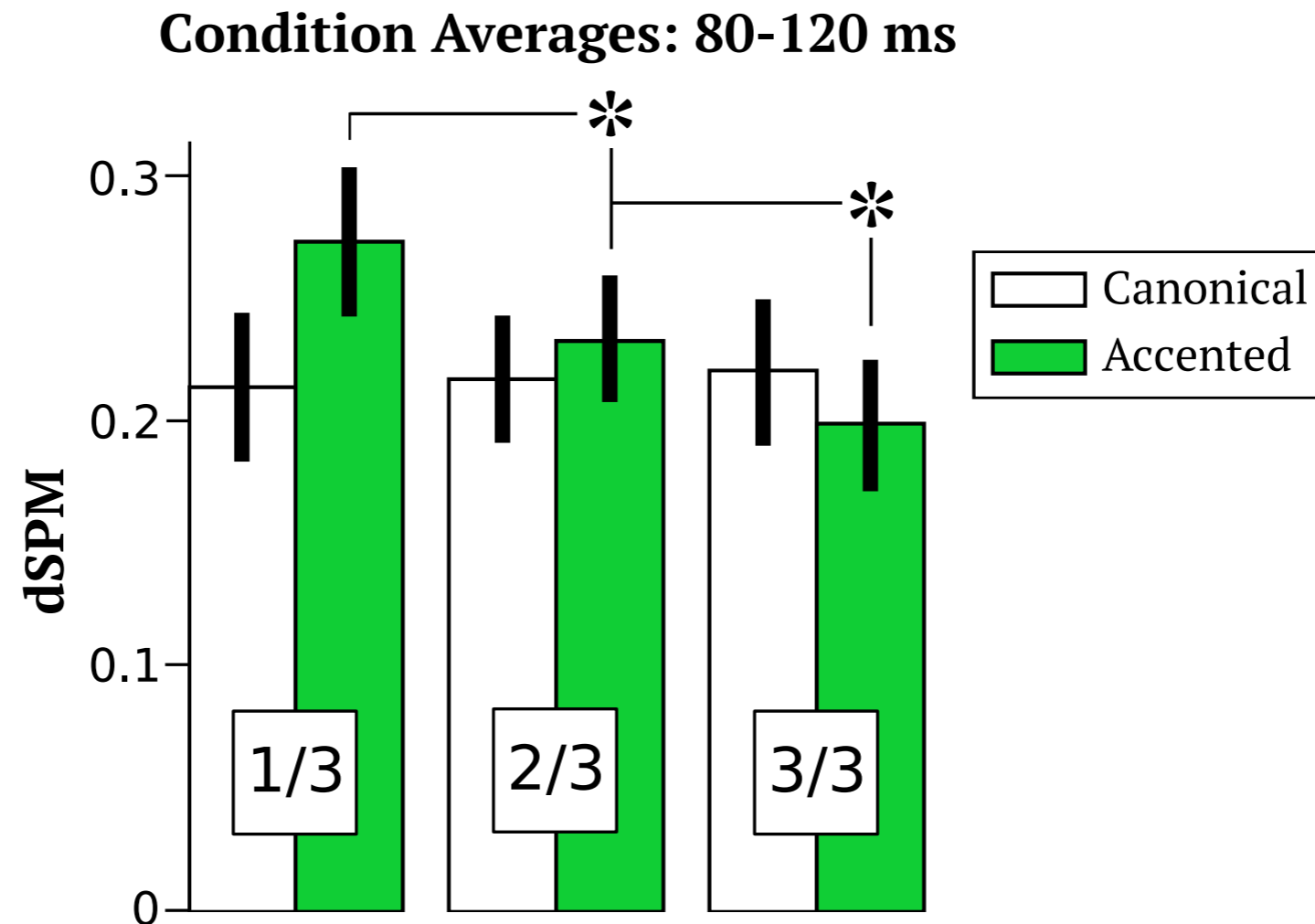
Further test of commitment



Putting together the processing pieces



Lexical influence



- Attunement is proposed to involve **re-tuning perceptual boundaries** between phonological categories (Norris et al., 2003; Kraljic and Samuel, 2005, 2006, 2007; Maye et al., 2008; see Samuel & Kraljic, 2009 for a review)

Interpretation

Processing hierarchy: Scott and Johnsrude, 2003; Hickock and Poeppel, 2004; Liebenthal et al., 2005; Rauschecker and Scott, 2009

lexical access

phonological commitment

/p/



acoustic-phonetic maintenance

Interpretation

Processing is not purely feedforward, or feed “up”: TRACE model: McClelland and Elman, 1986; McMurray et al. 2009. cf. MERGE: Norris et al. 2000

lexical access



phonological commitment

/p/

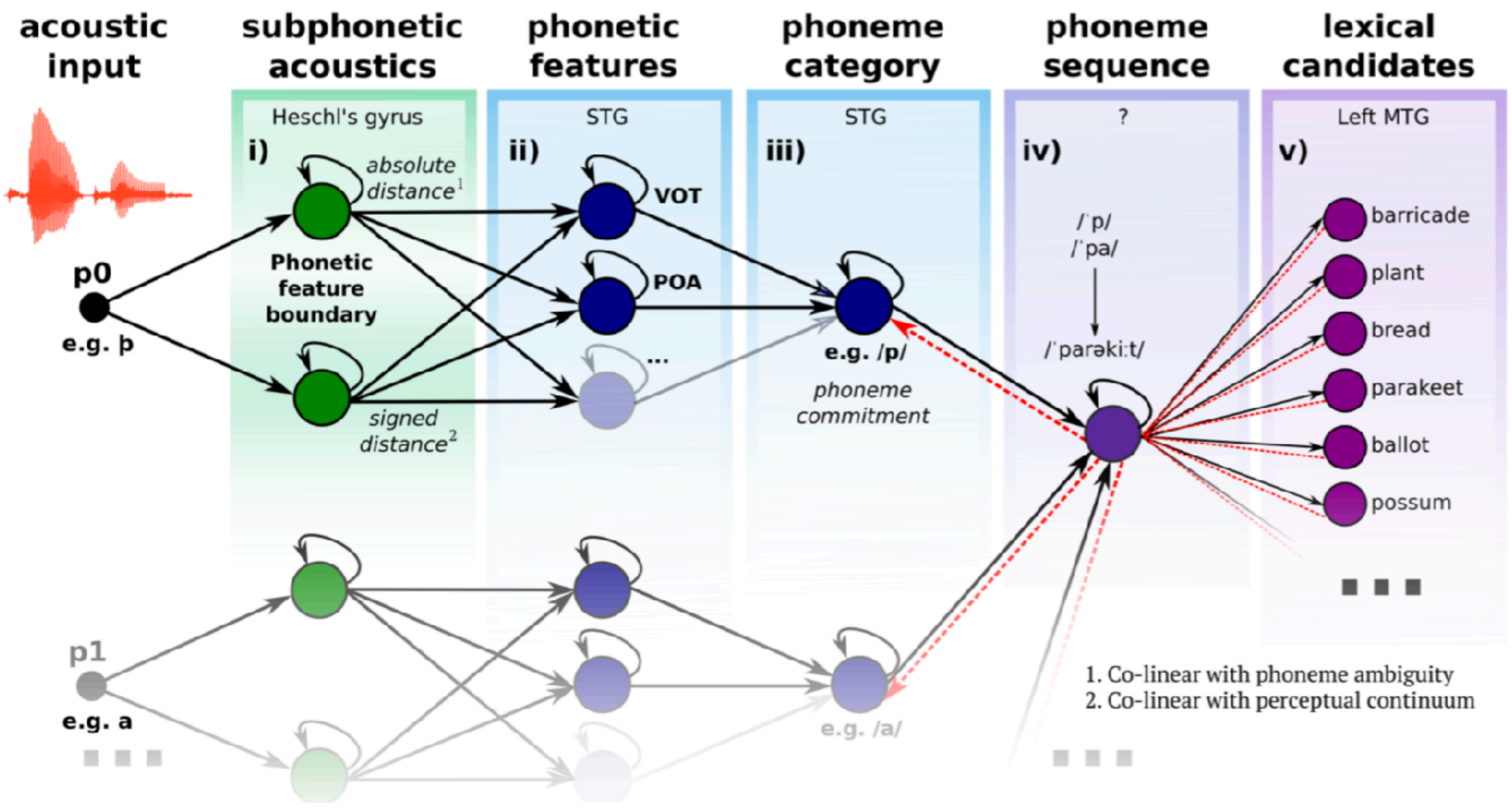
prediction-error learning

b a r a k e e

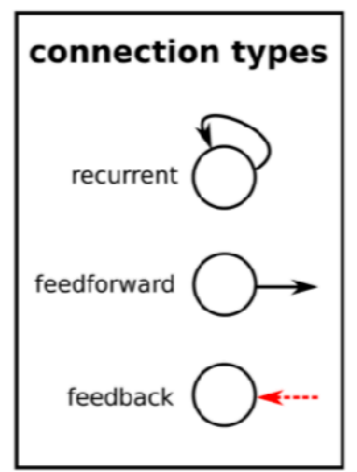
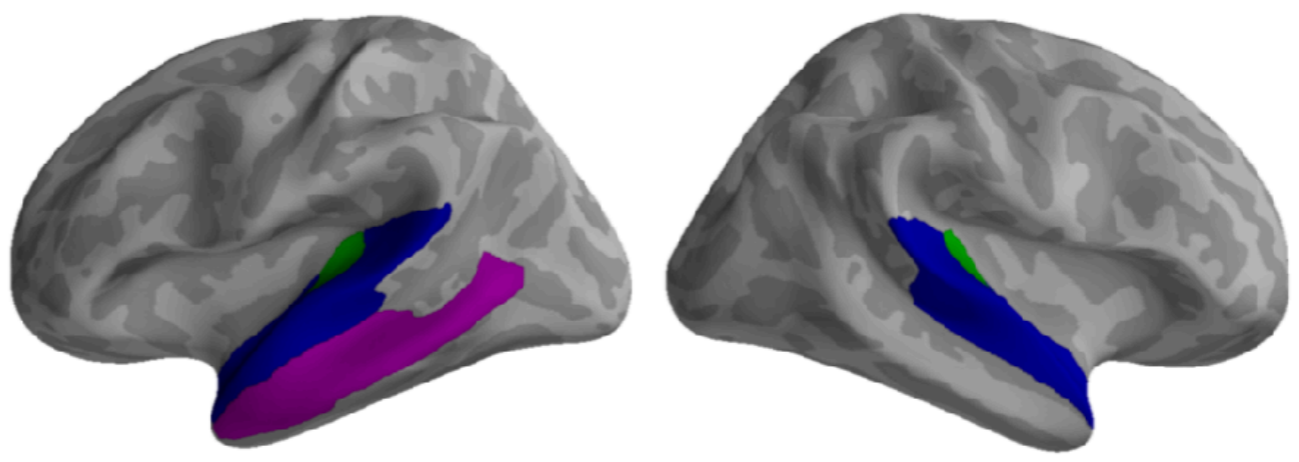
acoustic-phonetic maintenance

making commitment to a category does not cost — the system can flexibly avoid committing to a category; avoiding the function of exposure

but what happens if you continuously jump on a trampoline because you made a wrong choice? well, you fall when talking to someone with a different accent.



↓
phonemes
↓



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🐦 [@GwilliamsL](https://twitter.com/GwilliamsL)

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
Laura Gwilliams | [New York University](https://www.nyu.edu) | [@GwilliamsL](https://twitter.com/GwilliamsL)



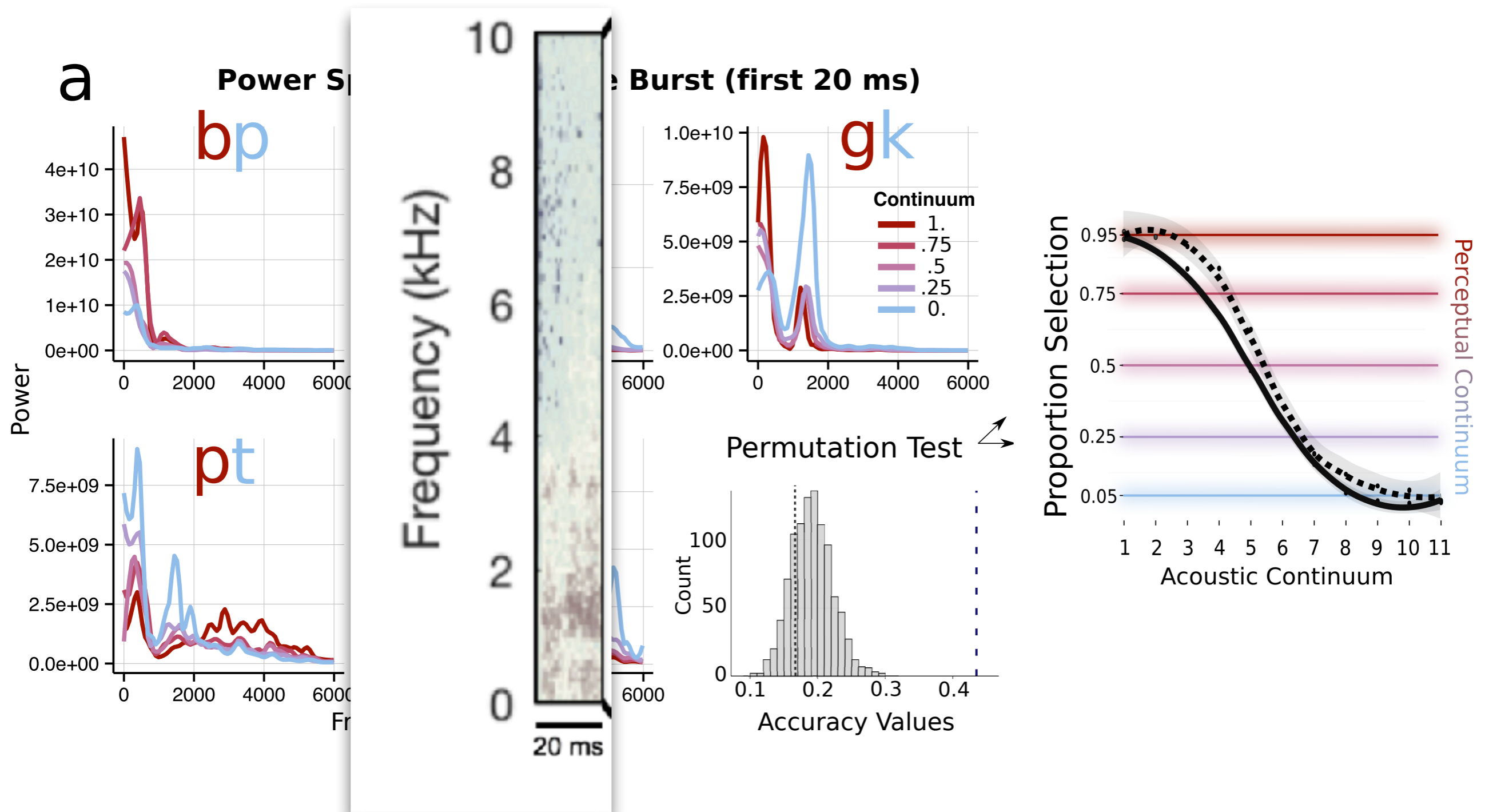
NEW YORK UNIVERSITY

✉ laura.gwilliams@nyu.edu
🐦 [@GwilliamsL](https://twitter.com/GwilliamsL)

Thank you!

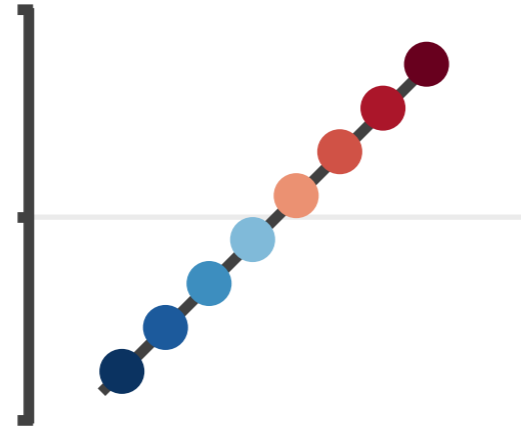


Is ambiguity correlated with acoustic properties?

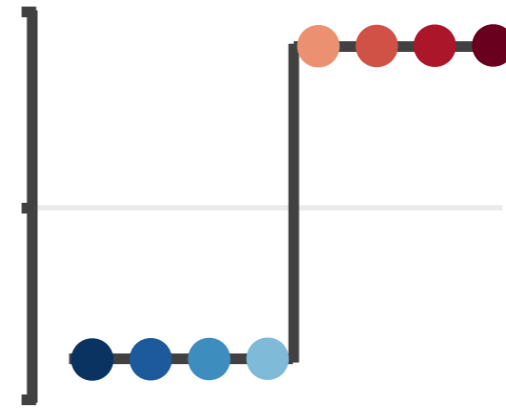


Predictive Coding

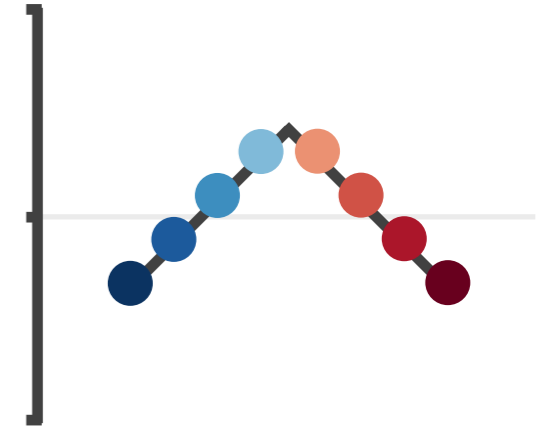
Linear Evidence



Categorical Percept

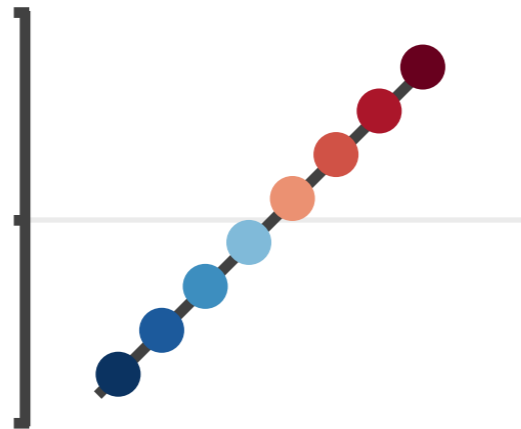


Ambiguity

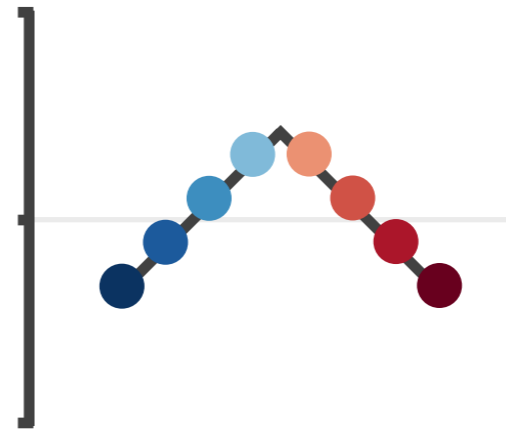


Neutralisation

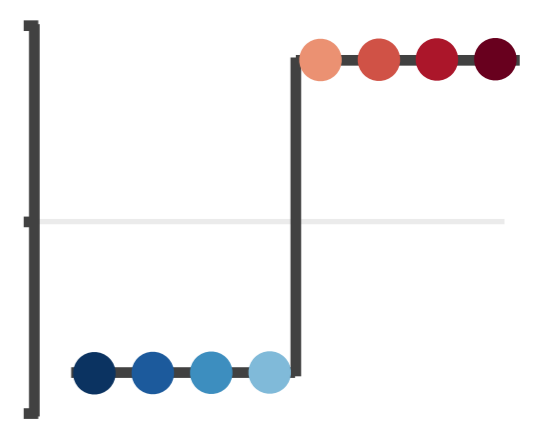
Linear Evidence



Ambiguity

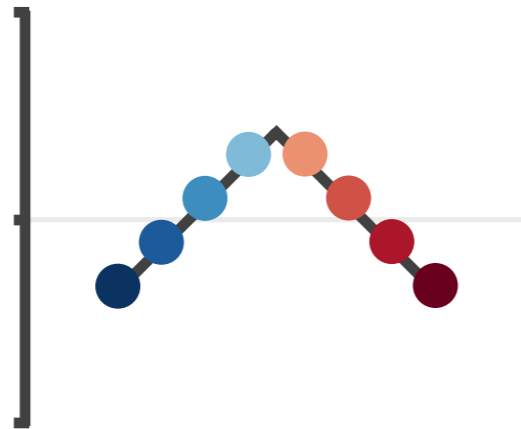


Categorical Percept

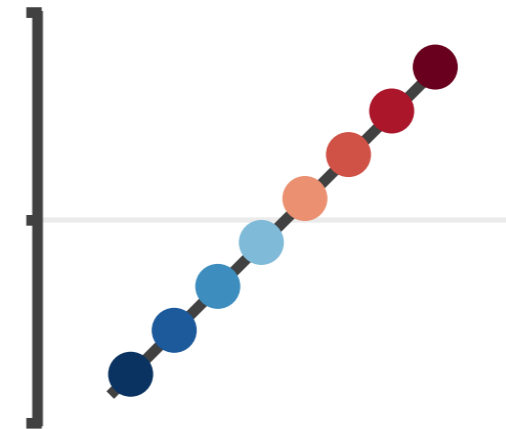


Cut-through connection

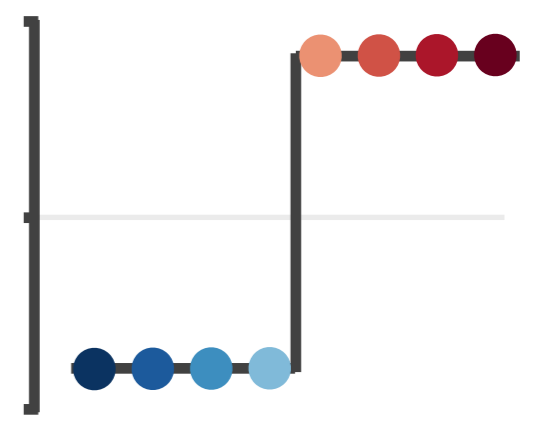
Ambiguity



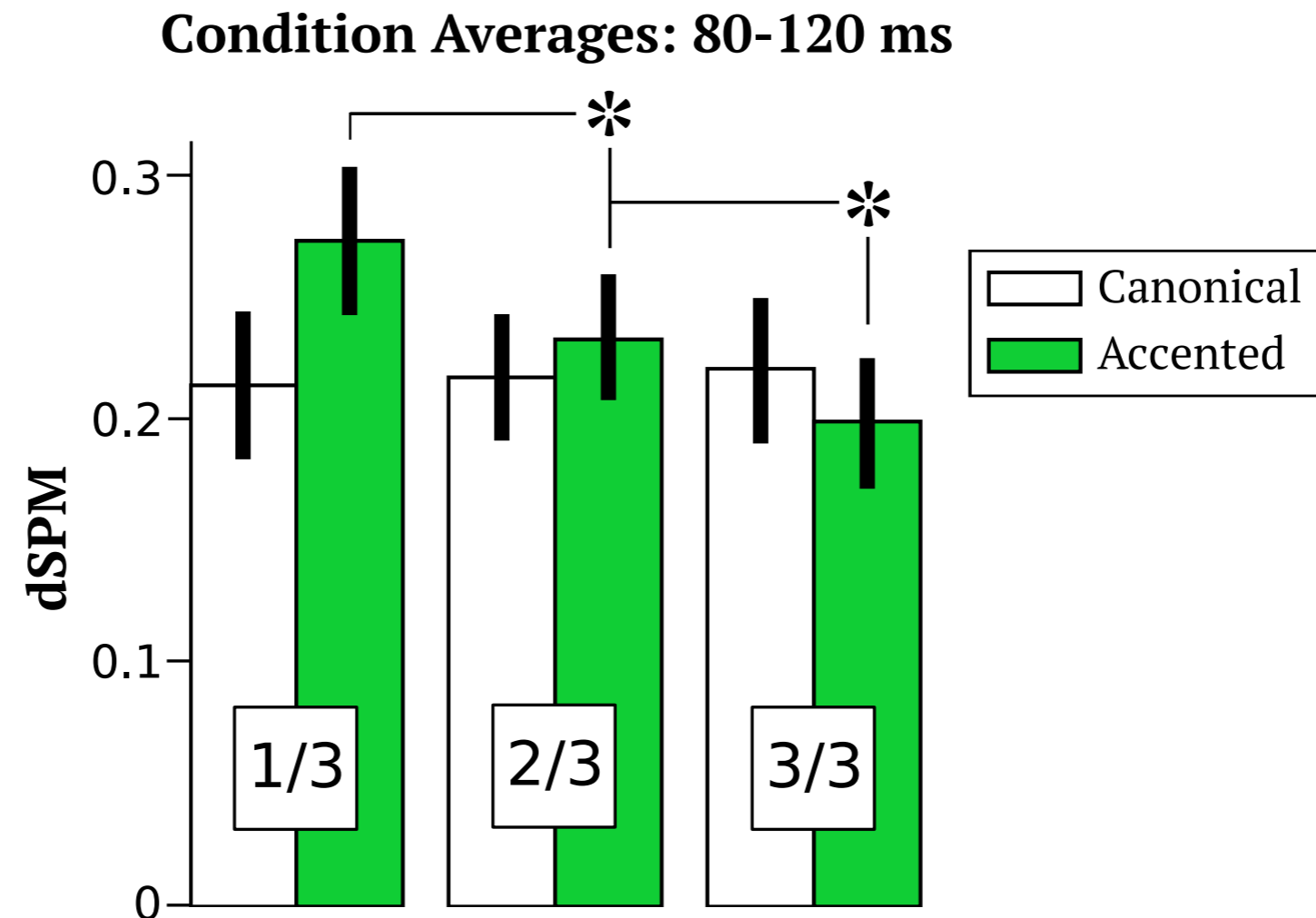
Linear Evidence



Categorical Percept



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