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

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Introduction

- Speech is inherently noisy and ambiguous
- Comprehension fluency is achieved by integrating top-down information with bottom-up acoustic input

i) Sensitivity to phonological categories found ~100 ms after onset for unambiguous tokens, but not yet uncovered responses to ambiguous sounds

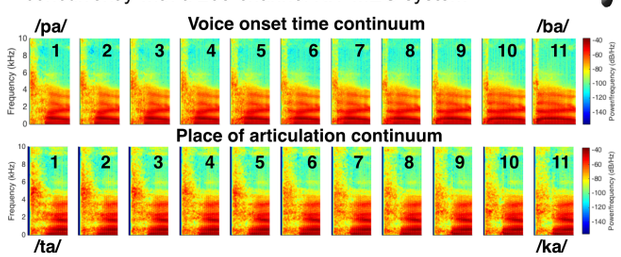
ii) Behavioural studies have used sensitivity to subphonemic variation to approximate the size of the integration window, with inconclusive results

How does the auditory system reflect and resolve phoneme ambiguity?

Methods

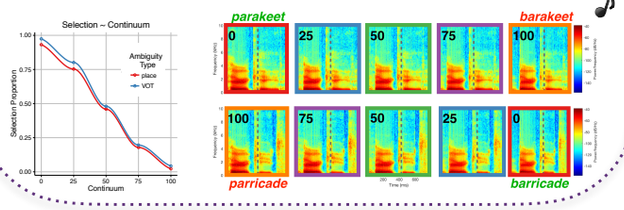
Experiment 1: Syllable Continua

- Extracted the first syllable from natural spoken words
- Eleven-step continua of syllables between two unambiguous end-points. Voice onset time (VOT): t-d, p-b, k-g; place of articulation (PoA): t-p, p-k
- 2AFC task: choice between two letters presented on-screen
- Neurophysiological responses of 24 participants measured concurrently with a 208-channel KIT-MEG system



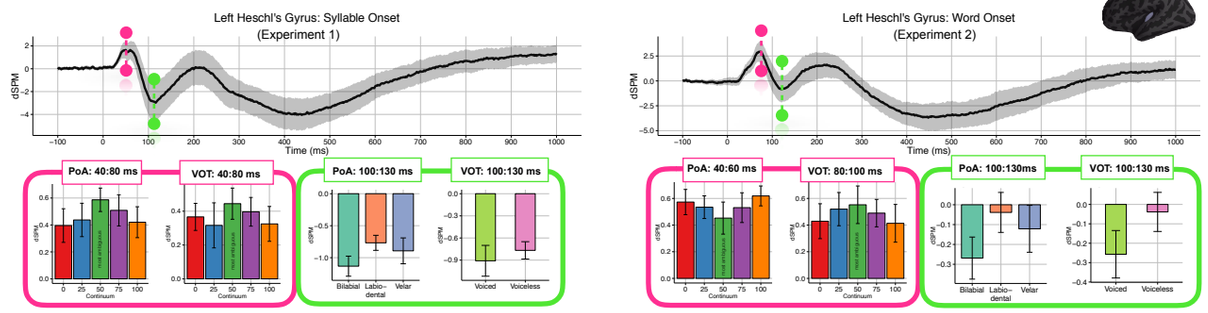
Experiment 2: Lexical Garden Paths

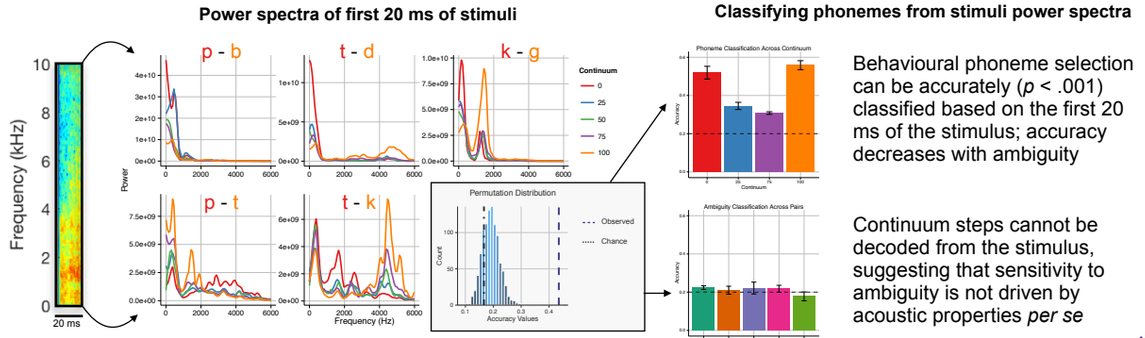
- Selected 5 continua steps of spoken words, based on the psychometric functions of Experiment 1
- 65 word pairs, with identical speech stream until divergence point (also see McMurray et al., 2009)
- Match/mismatch task: written words presented 500 ms after speech offset; 22 participants' responses measured with MEG



Results: Time-locked to Syllable/Word Onset

1. *Responses in left (but not right) Heschl's Gyrus are modulated by phoneme ambiguity ~50 ms after onset.*
2. *Sensitivity to PoA and VOT is bilateral at 100 ms. Replicated across syllable and word contexts.*



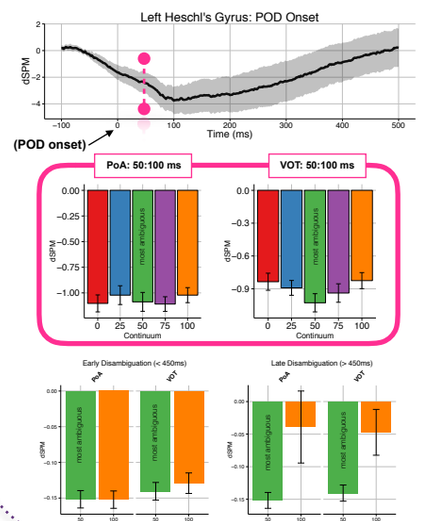


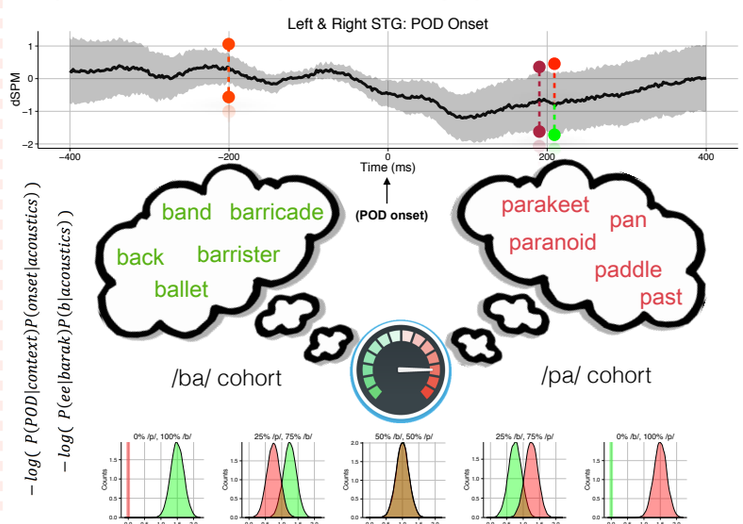
Behavioural phoneme selection can be accurately ($p < .001$) classified based on the first 20 ms of the stimulus; accuracy decreases with ambiguity

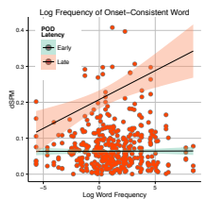
Continuum steps cannot be decoded from the stimulus, suggesting that sensitivity to ambiguity is not driven by acoustic properties *per se*

Results: Time-Locked to Point of Disambiguation (POD)

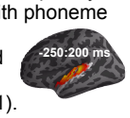
3. *Ambiguity effect re-surfaces at POD, regardless of latency.*
4. *Cohort activation is weighted by subphonemic detail until the system commits to a phoneme category ~450 ms.*



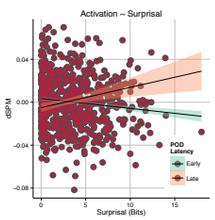


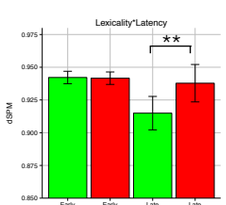


In late disambiguation, responses before the POD are modulated by the frequency of the word most consistent with phoneme onset; this variable does not modulate early disambiguated responses, revealing a significant interaction ($p < .001$).

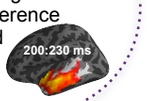


Predictions of upcoming sounds are weighted by subphonemic detail of the onset phoneme when POD is earlier than ~450 ms; late responses are not modulated by this variable, revealing a significant interaction ($p = .03$).





If disambiguation comes late, there is an error response when the POD reveals a non-word ($p = .01$); if disambiguation comes early, there is no difference between word and non-word responses, suggesting that reanalysis is not necessary.



Conclusion

- Sensitivity to phoneme categories is apparent from ~50 ms after onset: Tracks difficulty of classification and is not driven by acoustic properties
- If disambiguation comes too late (> 450 ms after word onset), listeners preemptively commit to a phonological interpretation
- Subphonemic detail is maintained across long time-scales in Heschl's Gyrus; phonological commitment resolves earlier in superior temporal gyrus
- Acoustic-phonetic and phonological processing are independent and computed in parallel

References

McMurray, B., Tanenhaus, M. K., & Aslin, R. N. (2009). Within-category VOT affects recovery from "lexical" garden-paths: Evidence against phoneme-level inhibition. Journal of memory and language, 60(1), 65-91.

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