Effects of phonetic category structure on brain activity during word recognition

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Introduction

- Listeners are sensitive to **within-category phonetic variability** during lexical access (e.g., Andruski, Blumstein, & Burton, 1994)
  - In a visual world task, listeners given a target word (e.g., *peach*) also look at a voiced minimal pair competitor (e.g., *beach*), with increased phonetic competition yielding more looks to the competitor (McMurray, Tanenhaus, & Aslin, 2002)
- There is debate on the **neural basis of this sensitivity**, particularly on the involvement of (left) inferior frontal regions
  - Studies implicating frontal areas in resolving phonetic competition (Myers, 2007; Minicucci, Guediche & Blumstein, 2013) often involve metalinguistic tasks (but see Myers, Blumstein, Walsh, & Eliassen, 2009)
  - Hickok and Poeppel (2004) posit that inferior frontal involvement is due to metalingustic tasks and limit the processing of phonetic variability to bilateral temporal areas
- In a more naturalistic task (e.g., visual world paradigm), **are listeners sensitive to phonetic and lexical competition? Do inferior frontal regions respond to phonetic competition?**

Methods

- N=18 right-handed, monolingual speakers of American English with no hearing, speech, or neurological impairments
- 3T scanner (Siemens PRISMA) at Brown University
- MRI-compatible eye-tracker (EyeLink 1000+)
- Task: Look at named picture

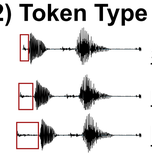
Critical trials manipulated:

(1) Distractor Type presented
voiced onset competitor: *beaker*
unrelated distractor: *sausage*
Note relatively little overlap between beaker and peacock

Display with onset competitor

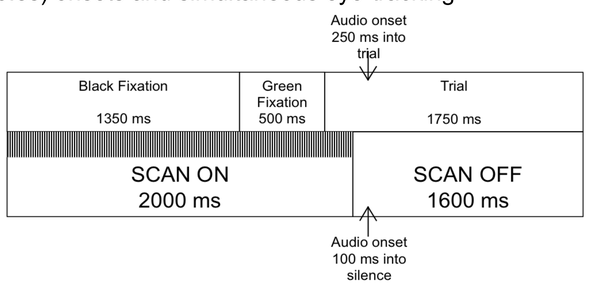
Display with unrelated distractor

(2) Token Type (VOT) of target



shortened: *[p*]eacock*
unaltered: *[p]eacock*
lengthened: *[p^{hh}]eacock*

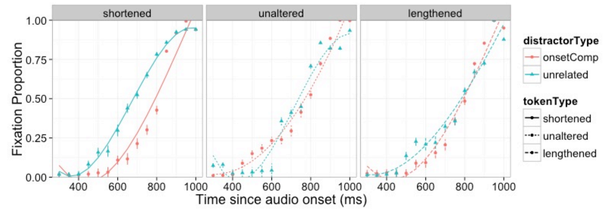
- Sparse sampling, rapid-event design with jittered (3.6s, 7.2s, 10.8s) onsets and simultaneous eye-tracking



Results

Eye Tracking Results

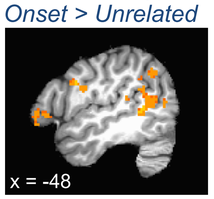
- Growth curve analysis (Mirman, Dixon, & Magnuson, 2008) was used to model the time course of looks to the target and to capture how distractor type and token type affected this time course



- **Effect of distractor type:** Looks to target were slowed when there was an onset competitor in the display ($p < 0.001$)
- **Effects of token type:** Shortened tokens incurred earlier looks to target; lengthened tokens incurred later ones (both $p < 0.01$)
- **Significant distractor type x token type interaction:** As predicted (owing to increased phonetic competition), most pronounced onset competitor effect found for shortened tokens

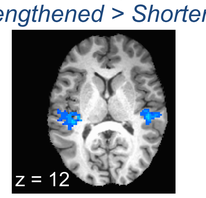
fMRI Results

Distractor Type
Onset > Unrelated



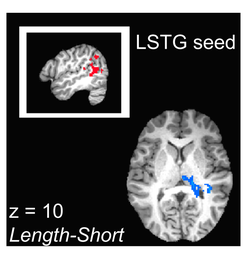
LSTG, BA 44/45, LMFG

Token Type
Lengthened > Shortened

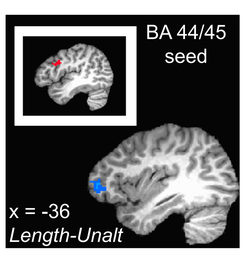


Bilateral Heschl's Gyrus

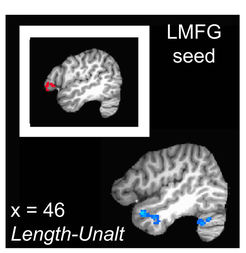
- A 2x3 ANOVA found main effects of distractor type and token type (above) but no significant interaction between these factors. **What is driving the behavioral interaction?**
- *A **gPPI analysis** examines brain activity in a seed region, correlates it with activity elsewhere in the brain, and examines how these correlations are modulated by task*
- We took areas sensitive to distractor type (onset competitor vs unrelated distractor) in the 2x3 ANOVA (shown above left) as our seed regions and asked how functional connectivity differed based on token type (lengthened, unaltered, shortened)



Connectivity between posterior LSTG and R. Heschl's / thalamus is strengthened when the token is lengthened (relative to shortened)



Connectivity between BA 44/45 and LMFG is strengthened when the token is lengthened (relative to unaltered)



Connectivity between LMFG and RSTG/ cerebellum are strengthened when the token is lengthened (relative to unaltered)

Conclusions

- Extending previous work, eye tracking data suggest that listeners **integrate acoustic-phonetic information** during lexical access, even when there is **relatively little lexical competition** (e.g., between *beaker* and *peacock*)
- **Left frontal** (LIFG, LMFG) and **bilateral posterior temporal** areas show sensitivity to the **type of distractor**
- **Bilateral temporal areas** show sensitivity to within-category phonetic variability (main effect of token type)
- Though no clusters showed a distractor type X token type interaction, **regions sensitive to distractor type "talk to" other regions differently depending on token type**
  - Effects on **temporo-temporal** connectivity suggest different engagement of core phonetic processing regions under conditions of phonetic ambiguity
  - **Fronto-frontal** connectivity is modulated by phonetic information, suggesting that phonetic information may reweight interactions between different frontal regions to resolve both phonetic and lexical competition
  - Effects on **fronto-temporal connectivity** suggest that frontal and temporal areas work together to process acoustic-phonetic structure (i.e., that processing is not limited to either frontal regions or temporal regions)
- Inconsistent with Hickok & Poeppel's (2004) proposal, these results suggest that **frontal areas work with temporal areas to process phonetic competition**, even in a task that does not require metalinguistic judgments

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Acknowledgments

Research was supported by NIH grant R01 DC013064 and NIH NIDCD Grant RO1 DC006220. The authors thank Julie Markant, SR Support (particularly Greg Perryman, Marcus Johnson & Dan McEchron) and Brown MRF staff (specifically Michael Worden, Lynn Fanella, Maz DeMayo & Caitlin Melvin) for assistance with the eye tracker and scanner. We thank Corey Cusimano and Pete Molfese for help with growth curve analysis and fMRI analysis, respectively. Finally, we thank both the Blumstein and Myers labs for helpful feedback throughout the project.