Word and pseudoword processing in the ventral stream

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Introduction

Neural representations of pseudowords have been studied extensively ([1], [2], [3]), but questions remain about their interaction with the mental lexicon and the degree to which they share or diverge from pathways activated by real words.

Study questions

1. Are differences between word and pseudoword listening observable in temporal lobe activity, and what are the temporal dynamics of those differences?

2. Does the structure of the lexicon mediate word and pseudoword responses along the ventral stream ([4], [5])? As speech unfolds, how does the set of possible lexical forms constrain activity?

Methods

Data: ECoG recordings (high-γ band) from temporal lobe electrodes. 4 subjects; 3 left-hemisphere, 1 right-hemisphere (all language- dominant).

Task: Listening task with long words and phonologically-matched pseudowords (Wilson and Gorno-Tempini), e.g.:

ceremony [sɛɹəmoʊni] **moanaserry** [moʊnəsɛɹi]

repetition [ɹɛpətɪʃən] **piteretion** [pɪtəɛʃən]

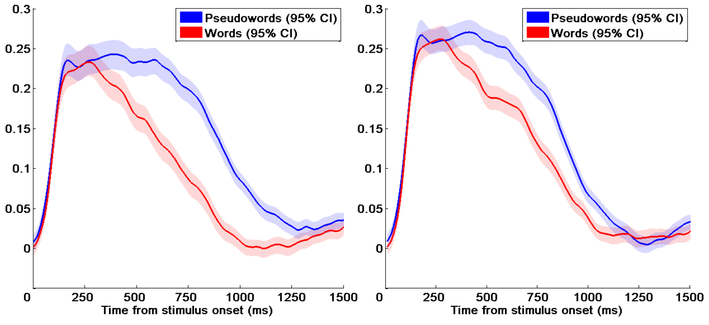
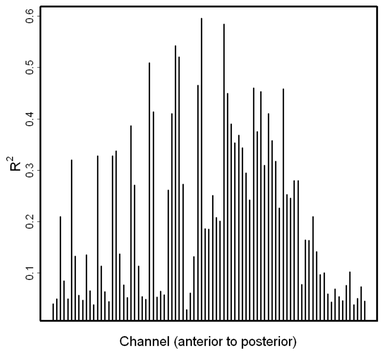


Figure 1. Average response across subjects and all temporal lobe electrodes (left); average response after controlling for acoustic tuning with STRF models (right).

Analysis

- **Spectrotemporal receptive fields (STRFs): model acoustic tuning**
- **Linear mixed-effects models using growth curve analysis (GCA, [6]) fit to difference of high-γ activity – STRF prediction in each electrode**
- **GCA predictors: Lexicality, cohort size, cohort frequency (residualized by lexicality), 1st - 4th order time terms; interaction of lexical predictors * time terms, interaction of lexicality * cohort size, lexicality * cohort frequency; random effect of stimulus identity**



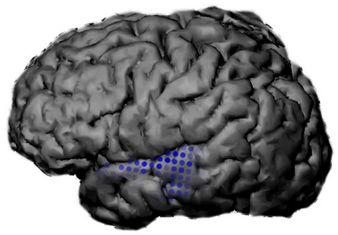


Figure 2. R^2 values for GCA electrode models in subject 1, from anterior to posterior (left) and mapped onto their position on the cortex (above), with greater saturation indicating higher R^2 values.

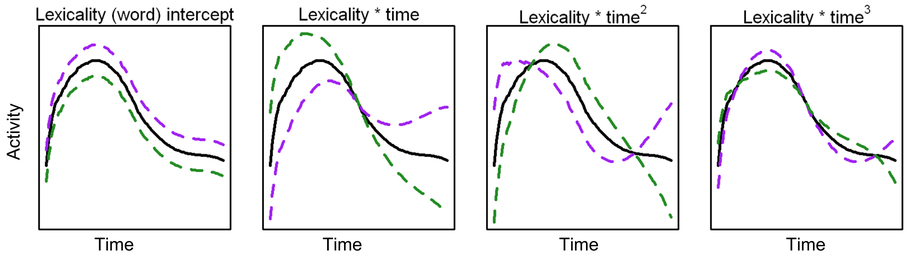


*Figure 3. Schematic GCA model fits with manipulation of lexicality * time coefficient magnitudes. Black lines show model predictions for words in one electrode. Purple and green lines show a 50% increase and decrease, respectively, of each coefficient, holding all others constant. Quartic term effects are subtle and not shown.*

Summary of GCA models

Across GCA models, responses to words and pseudowords interacted with time terms, with a trend of steeper curves and later peaks for pseudowords as compared to words. Cohort size and frequency made significant contributions to the model, as did their interactions with lexicality and time terms. Coefficients of lexical parameters showed patterns in magnitude and directionality by temporal lobe location.

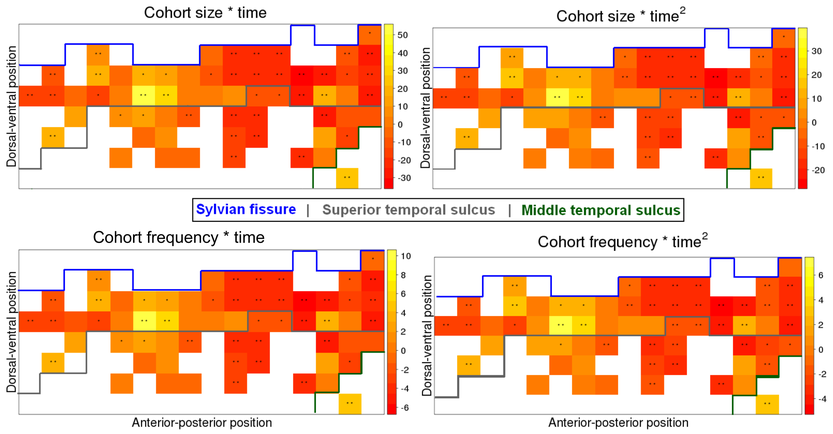


Figure 4. Coefficient weights for linear and quadratic terms of cohort size and cohort frequency for GCA models at each active temporal lobe electrode, subject 4. (*) indicates significance at $p < 0.05$, (**) significance at $p < 0.01$.

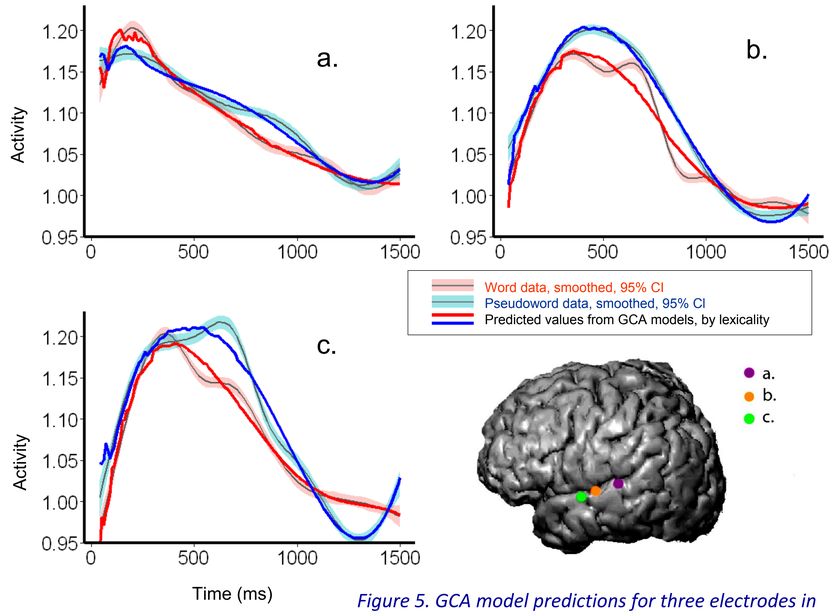


Figure 5. GCA model predictions for three electrodes in subject 1 ($R^2.a = 0.317$, $R^2.b = 0.542$, $R^2.c = 0.509$). Location shown on brain map.

Discussion

1. The timing of differences in response to words and pseudowords varies across the course of listening, as well as across temporal lobe sites. (figures 1, 2, 5) Observed magnitude differences between words and pseudowords depend both on cortical location and on time in the trial.

2. Stored information from the lexicon – cohort size and cohort frequency – mediates responses in the ventral stream, with varying effects at posterior and anterior sites. (figures 2, 4)

3. This data suggests that ventral stream processing relies on stored lexical information, not just sequential phonemic recognition, both for stored lexical items and phonotactically-legal novel wordforms.

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