Time-course of processing for syntactic properties in spoken word recognition

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Introduction

- A fundamental issue in spoken language comprehension involves understanding the interaction of linguistic representations across different levels of organization (e.g., phonological, lexical, syntactic, and semantic; Folk, 2017; Trueswell et al., 1994)
- There is debate about when different levels are accessed during spoken word recognition
- Serial processing models predict that comprehension is sequential

Acoustic Cue Encoding → Phonological Processing → Lexical Access → Syntactic/Semantic Procesisng

- Parallel processing models predict simultaneous activation of representations at multiple levels
- Current study isolated neural responses to one type of higher-order information—syntactic class of a word (nouns vs. adjectives)—from low-level acoustic and phonological responses using a component-independent event-related potential (ERP) design
- We predicted that parallel procesing would be revealed by overlap in the time-course across different levels of linguistic organization
  - Previous work has demonstrated that acoustic cue encoding occurs 100-200 ms post-stimulus onset (Toscano et al., 2018)
  - Simultaneous processing of syntactic class information would be observed as differences between nouns and adjectives within 200 ms after the point of disambiguation (POD)

Method

Participants: N=26 listeners; age range: 18-22 years; 42% female; self-reported normal hearing, normal or corrected-to-normal vision, and English as their native language

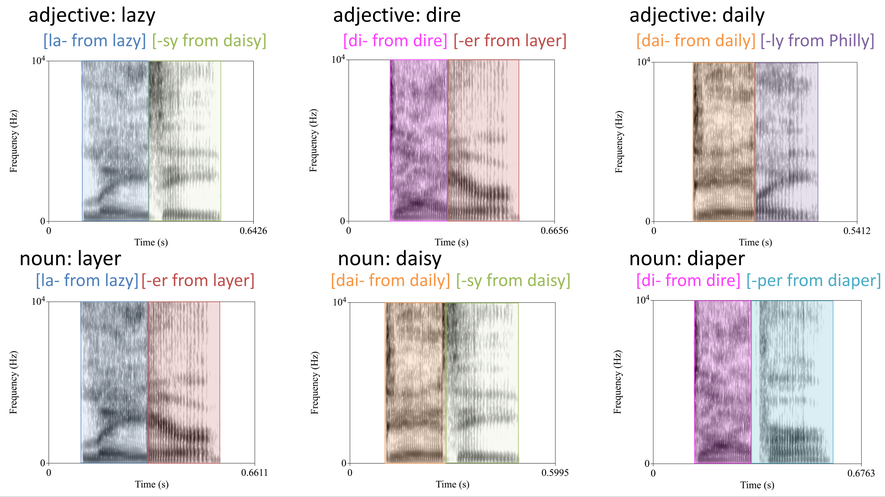
Stimuli
- 20 synthesized disyllabic words (10 nouns and 10 adjectives)
- Noun and adjective lists matched for word frequency, phonological neighborhood density, and biphone probability
- Synthesized using the voice "Samantha" from Apple Text-to-Speech
- Stimuli cross-spliced at syllable boundary (mean POD: 193 ms)

EEG Recording
- 32 electrodes placed at International 10-20 System sites
- Electrode impedances less than 10 kΩ
- Data recorded at a sampling rate of 500 Hz, referenced online to the left mastoid, and re-referenced offline to average mastoids

Procedure
- On each trial, participants heard a spoken word and then saw a visually presented word 500±150 ms later
- Participants indicated whether the auditory and visual words shared the same syntactic class (match vs. mismatch)
- Each combination of 20 auditory and 20 visual items was included, except when the two words were the same, for a total of 380 trials

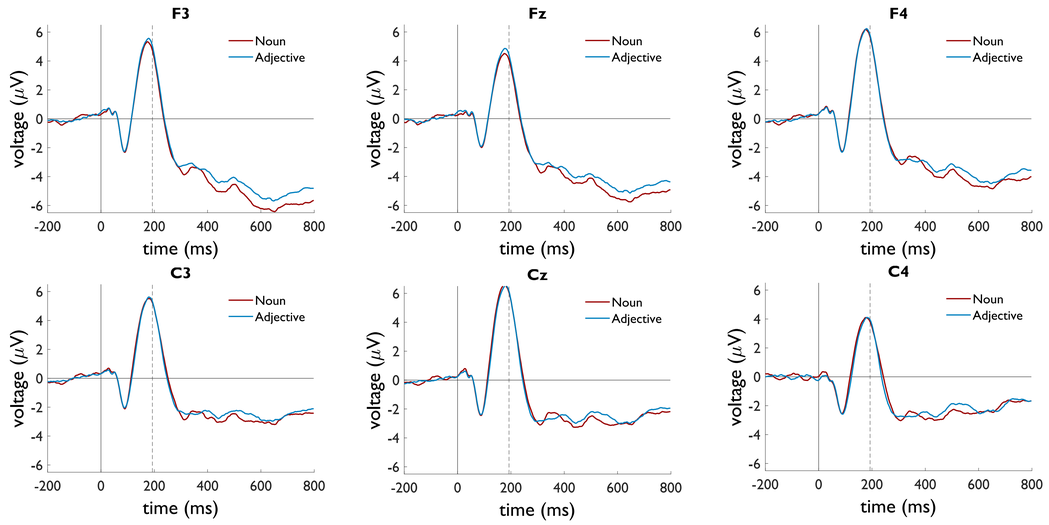
Stimuli

- Examples of stimuli spliced at syllable boundary
- Onset and offset segments matched across the set of nouns and adjectives, canceling out low-level acoustic differences between the two sets of stimuli (see Baart & Samuel, 2015, for a similar approach)

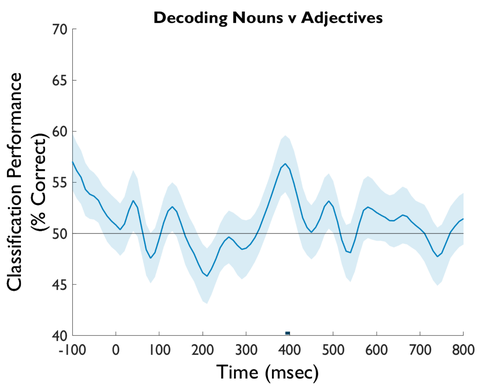


Results

Grand average ERP waveforms at F3, Fz, F4, C3, Cz, and C4; dotted lines represent POD



Decoding Analysis
- Support-vector machine (SVM) trained on two-alternative forced choice classification job (noun vs. adjective)
- Input to SVM was the averaged mean voltage in a 10-ms time window
- Cross validation was performed using a 3 k-fold procedure
- Free parameters of the SVM (*C* and *γ*) optimized at 350 ms post-target word onset
- SVM was run from -100 to 800 ms in 10-ms intervals
- Data smoothed with a 50-ms triangular window



Discussion

- ***Mean Amplitude Analysis:*** Difference between noun and adjective waveforms at 400-450 ms post-target word onset (207-257 ms post-POD) at Fz ($t(25) = -2.14$, $p = 0.04$)
- ***Decoding Analysis:***
  - Statistical significance evaluated with t-tests against numerical chance (Sarrett & Toscano, submitted), using Bootstrapped Difference of Timeseries (bdots) to correct for multiple comparisons (Seedorff et al., 2018); autocorrelation of the test statistic was 0.90, and new alpha level was 0.0074
  - Above chance performance seen at 390 ms post-target word onset (197 ms post-POD)
- ***Conclusions:*** Results provide preliminary support for parallel processing models of spoken word recognition in which higher-level information is accessed while early acoustic analysis is still occurring
- ***Future Directions***
  - Examine processing of semantic class based on cosine similarity between items in a word embedding model
  - Is there evidence of early processing of semantic effects and is the timing similar to timing for syntactic properties of words?

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