The role of morphology in phoneme prediction: Evidence from MEG

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Introduction

- Recent studies of spoken word recognition suggest that listeners predict upcoming phonemes using phoneme probability estimates derived from the frequencies of words in the language (Gagnepain et al. 2012)
- Are these phoneme predictions based solely on the relative frequencies of full word forms, or are they enhanced by morphological structure, in line with word prediction effects observed in sentence processing? (Kutas and Hillyard 1984, Levy 2008)

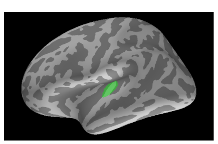
Design

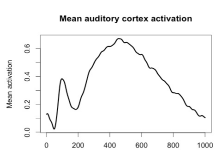
- Auditory lexical decision with concurrent MEG recording
- 356 bisyllabic words: 89 words per condition

	Expected	Unexpected
Monomorphemic	bourbon	burble
Bimorphemic	bruises	bruiser

Analysis

- Data from 13 right-handed native English speakers
- MNE used for calculating distributed source solutions
- Region-of-interest analysis of activity in the left transverse temporal auditory cortex area
- Factorial analysis of the 200 ms period after word offset
- Timepoint-by-timepoint correlational analysis between neural activity and:
  - **Surprisal**: the amount of information conveyed by the current phoneme (Hale 2001)
  - **Cohort entropy**: the degree of competition between forms compatible with the beginning of the word (Marslen-Wilson 1987)

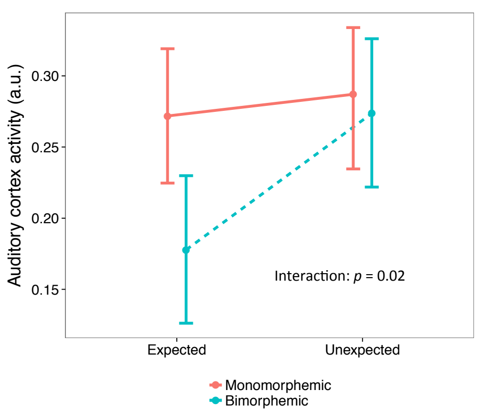




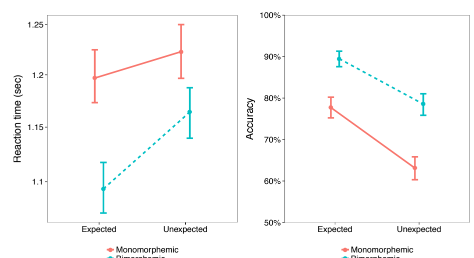
References: [1] Gagnepain, P. et al. (2012). *Current Biology* 22. [2] Kutas, M., & Hillyard, S. A. (1984). *Nature* 307 [3] Levy, R. (2008). *Cognition* 106. [4] Hale, J. (2001). *Proceedings of the Second Meeting of HLT-NAACL*. [5] Marslen-Wilson, W. D. (1987). *Cognition* 25. [6] Todorovic, A. & de Lange, F. P. (2012). *Journal of Neuroscience* 32.

Results

Neural results: factorial design



Behavioral results



Interactions: n.s.

(Bootstrapped 95% confidence intervals)

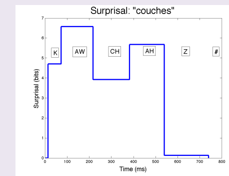
Calculation of surprisal and cohort entropy

The **surprisal** of the i-th phoneme p_i:

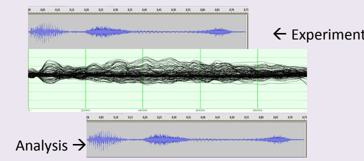
$$I = -\log P(p_i | p_1 \dots p_{i-1})$$

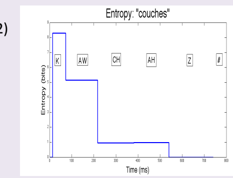
The **cohort entropy** at p_i is the entropy of the distribution of the words $\{w_1, \dots, w_n\}$ that start with the phoneme sequence $p_1 \dots p_i$:

$$H = -\sum_{k=1}^{n} w_k \log P(w_k)$$

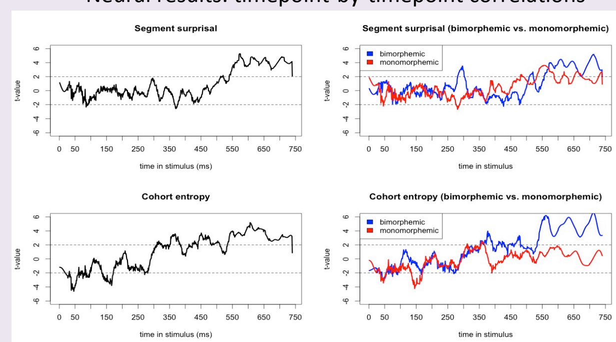


Lag: We assume that phoneme variables affect neural activity 200 ms after phoneme onset (cf. Todorovic and de Lange 2012)





Neural results: timepoint-by-timepoint correlations



Results of linear mixed effects models fitted to neural activity at each timepoint, with subjects and items as random effects (200 ms lag)

Conclusions

- Morphological structure enhances phoneme prediction, over and above the the distributional properties of the phonemes alone
- These results support the viability of millisecond-by-millisecond analysis of MEG data using continuous stimulus variables such as surprisal and cohort entropy
- High phoneme surprisal causes more auditory cortex activity—mostly at the end of the word, and possibly also at morpheme boundaries
- Higher cohort entropy reduces activity in the beginning of the word, but increases it toward the end, especially for bimorphemic words

This work is supported by the National Science Foundation under Grant No. BCS-0843969 and by the NYU Abu Dhabi Research Council under grant G1001 from the NYUAD Institute, New York University Abu Dhabi.