Neural dynamics of top-down contextual effects in visual word recognition

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Introduction

Behavioral and neuroimaging evidence suggests that an early stage in visual word recognition is the strictly bottom-up segmentation of the visual input into candidate linguistic substrings (words and morphemes), where this process is blind to the lexical properties of the strings being generated [1,2,3].

The goal of this combined electro- and magneto-encephalography (EMEG) study was to investigate whether these early segmentation processes could be modulated by top-down semantic constraints. Participants saw morphologically complex words (containing a root and suffix; e.g. *farmer*) and simple words preceded by a semantically related or unrelated word.

We asked where and when contextual constraints would affect processing of the different word types, and, in particular, if these effects would be seen in the earliest stages of visual word recognition and localise to posterior occipito-temporal areas. This would allow us to assess whether semantic context plays a role in early orthographic processing or later stages involved in lexical access.

Methods

Stimuli

Three test conditions were included that contrasted the presence/absence of a potential suffix in the target:

CONDITION	PRIME	TARGET
real suffix	crop	farmer
pseudo-suffix	cousin	brother
no suffix	sand	pebble

Semantic primes were matched based on co-occurrence using Latent Semantic Analysis.

Subjects

Sixteen right-handed native English speakers took part in the experiment. They performed an occasional one-back memory task on 10% of targets.

MEG/EEG Acquisition and Source Reconstruction

Concurrent MEG-EEG data were acquired from a 306-channel Vectorview system with a 70-channel EEG cap. Raw data were ICA de-noised (blinks removed), and epochs were generated from -100 to 500 ms from word onset. A three-layer boundary element model was created using FreeSurfer from individual structural MRIs. L2 minimum norm estimation (MNE) was used to compute EMEG solutions.

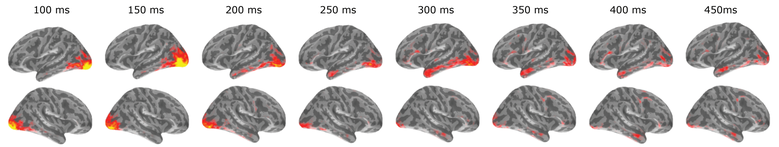
Statistical Analysis

Sensor and source analyses were performed using cluster-based permutation statistics [4] across space and time as implemented in MNE Python [5].

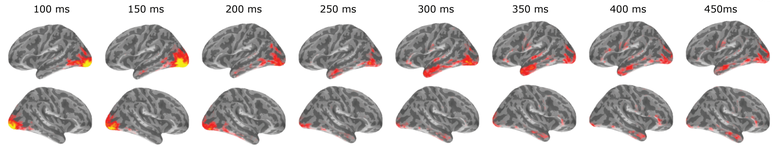
Combined MEG+EEG Data

Grand Average - Related vs. Unrelated Prime

RELATED PRIME



UNRELATED PRIME

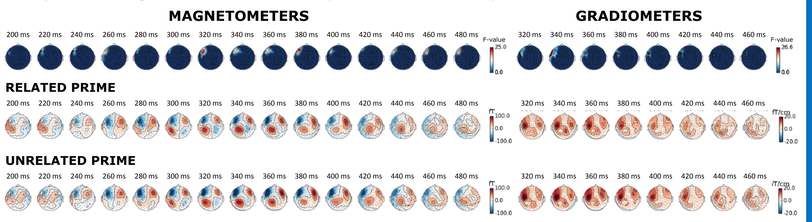


Grand average across subjects at the source level (EMEG) collapsed across all related prime and all unrelated prime conditions, showing neural activity starting in bilateral occipital cortex and moving anteriorly to temporal and frontal areas, primarily on the left.

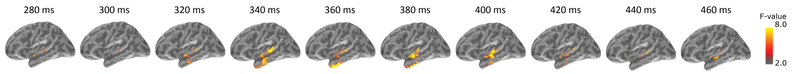
Results

Main Effect of Priming

- Sensor-level: main effect of priming from 200-500 ms in magnetometers (cluster-level p < .05) and 320-500 ms in gradiometers (cluster-level p < .05), showing decreased activity with a related prime in left anterior sensors

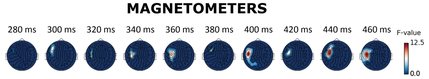


- Source-level: main effect of priming from 240-500 ms (cluster-level p < .05), confirming the sensor-level results, showing decreased activity with a related prime in left temporal regions (ITG, MTG, STG)



Interaction of Condition and Priming

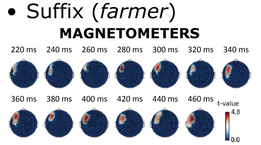
- Sensor-level: interaction between condition and priming from 280-500 ms in left anterior magnetometers (cluster-level p < .05)

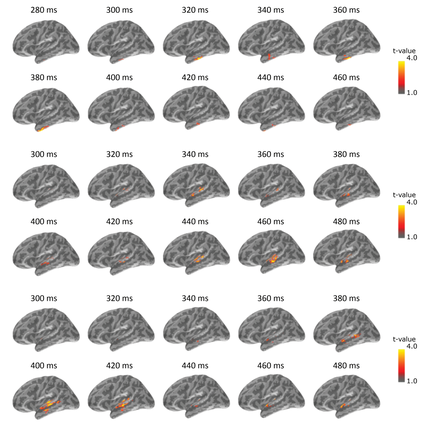


Results

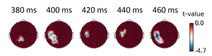
Priming in Separate Conditions

- Suffix (*farmer*)



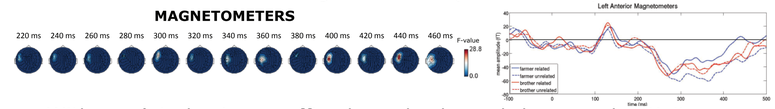


- Pseudo-Suffix (*brother*)

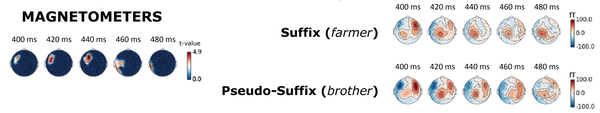


- No Suffix (*pebble*)

- We then directly tested the suffixed and pseudo-suffixed words (2 x 2; *farmer*/*brother* x related/unrelated) to ask whether there was modulation of bottom-up segmentation with the presence of a semantic context
- Sensor-level results: interaction between condition and priming from 220-500 ms in left anterior magnetometers (cluster-level p < .05)



- With a related prime, suffixed words showed decreased activity compared to pseudo-suffixed words from 400-500 ms (cluster-level p < .05). With an unrelated prime, there were no significant clusters.



Conclusions

- Semantic priming effects emerged late (peak at 300-400 ms) and in anterior/dorsal regions associated with accessing lexical representations
- Processing of real suffixed and pseudo-suffixed words diverged in the context of a semantically-related prime at 400 ms
- Semantic priming for real suffixed words localised to left anterior temporal cortex; priming for pseudo-suffixed and no suffix words localised to left posterior middle/superior temporal cortex
- Overall, these results support claims for automatic, blind morphological processing based on the presence of morphological structure, with contextual constraints modulating later access to word meaning

References

1. Rastle, K., Davis, M.H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review, 11(6)*, 1090-1098.
2. Marslen-Wilson, W.D. & Tyler, L.K. (2007). Morphology, language and the brain: the decompositional substrate for language comprehension. *Phil. Trans. R. Soc. B, 362*, 823-836.
3. Whiting, C., Shtyrov, Y., & Marslen-Wilson, W.D. (2014). Real-time functional architecture of visual word recognition. *Journal of Cognitive Neuroscience*, *27*(2), 246-265.
4. Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG-and MEG-data. *Journal of Neuroscience Methods*, *164*(1), 177-190.
5. Gramfort, A., Luessi, M., Larson, E., Engemann, D.A., Strohmeier, D., Brodbeck, C., ... & Hämäläinen, M. (2013). MEG and EEG data analysis with MNE-Python. *Frontiers in Neuroscience*, 7, 267. doi:10.3389/fnins.2013.00267

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