Letter position sensitivity in the VWFA: Evidence from multivariate searchlight analyses in MEG-EEG source space

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Introduction

Human left ventral occipitotemporal (VOT) cortex shows functional specialisation for the processing of orthographic features (letters, bigrams) required for skilled reading, with the "visual word form area" (VWFA) claimed to play a critical role [1]. It remains unclear, however, what are the specific computational functions subserved by the VWFA and the precise time-course of these contributions. This largely reflects the use of fMRI techniques with poor temporal resolution.

Here we present source-localised combined MEG + EEG (EMEG) data, providing millisecond temporal resolution and fine-grained spatial resolution, and use Representational Similarity Analysis (RSA) to ask three basic questions about VWFA function during visual word perception:

- Does orthographic processing in VWFA abstract away from low-level visual detail?
- If VWFA is sensitive to abstract letter identities, are these computed in a word-level position-sensitive format?
- Does the lexical status of potential word forms affect processing in the VWFA?

To test these questions we construct three sets of RSA model, manipulating pixel-level overlap between letter strings, position specificity, and lexical status.

Methods

Stimuli

- visually-presented words and pseudowords (100 ms), all 4 letters in length and morphologically simple
- occasional lexical decision on 10 % of items

Acquisition and Source Reconstruction

- concurrent MEG-EEG data acquired with 306-channel Vectorview system and 70-channel EEG cap
- epochs from -100 to 500 ms from word onset
- three-layer boundary element model using FreeSurfer from individual structural MRIs
- L2 minimum norm estimation (MNE) for source reconstruction
- regions of interest (ROIs) defined anatomically in FreeSurfer, one functional ROI - visual word form area (VWFA) - defined using Talairach coordinates (-43, -54, -12 [1]) with radius ten vertices

Multivariate pattern analysis

- searchlight-based Representational Similarity Analysis (RSA) in source space [2, 3]
- analysis extracts pattern of neural activity across voxels, and correlates pattern at each source location to theoretical models
- cluster-based permutation statistics used to reveal significant spatio-temporal clusters

Representational Similarity Analysis (RSA) models

a) visual model based on pixel-level overlap between word images

e.g. pill / plum

b) orthographic models based on the number of shared letters:

i) position-specific models **bake beak** **1 shared letter**
ii) position-nonspecific models **bake beak** **4 shared letters**

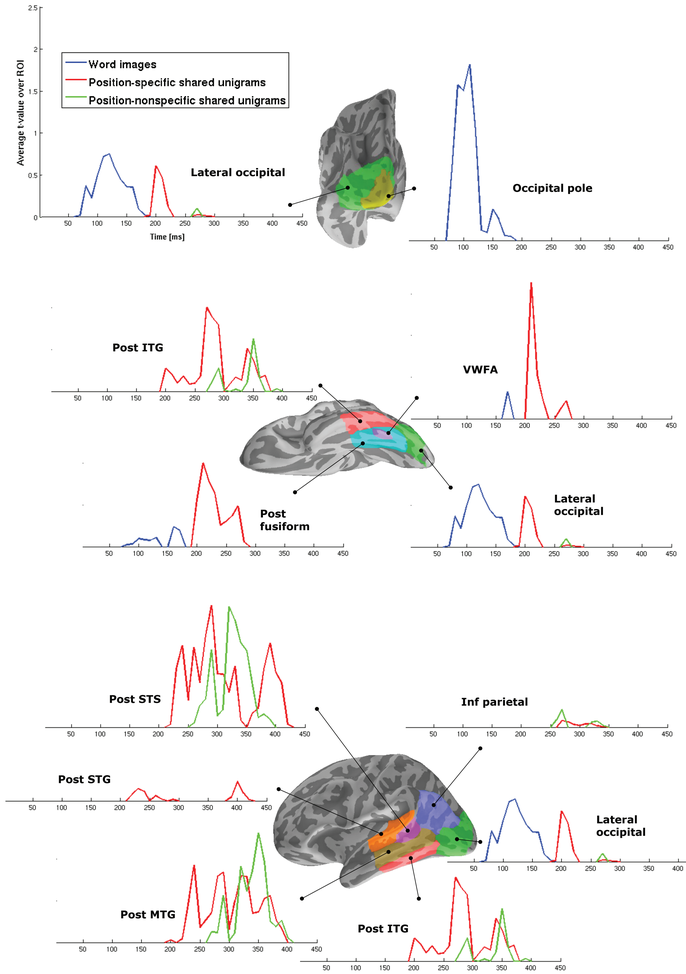
Results - Visual and Orthographic Models

Significant clusters (p<.05 cluster level) for visual and orthographic models - maximum fit of each model and timecourses of model fit in ROIs.

Visual model:
70 - 180 ms
p = .041
fit at 110 ms

Position-specific model:
190 - 420 ms
p = .001
fit at 210 ms

Position-nonspecific model:
260 - 400 ms
p = .032
fit at 350 ms

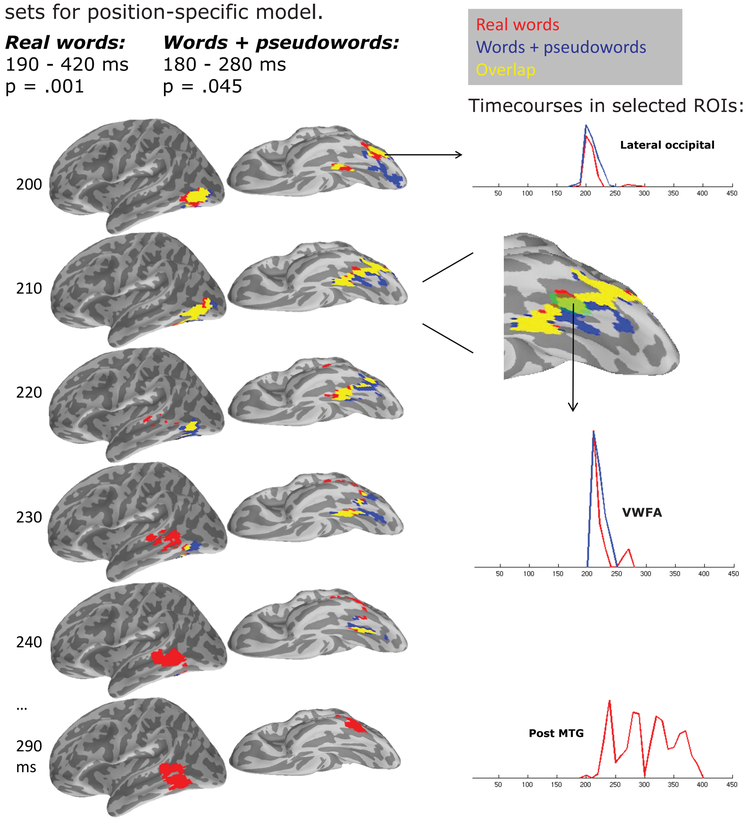


Results - Words and Pseudowords

Dissociating lexical and non-lexical effects: word and word+pseudoword data-sets for position-specific model.

Real words:
190 - 420 ms
p = .001

Words + pseudowords:
180 - 280 ms
p = .045



Conclusions

- RSA successfully delineates regions in the ventral stream sensitive to visual word form properties captured by the proposed models, and dissociates activity in VWFA from **simple visual** feature processing, which emerges earlier in time (70–180 ms) and in occipital cortex.
- Processes in VWFA are transiently sensitive (200-250 ms) to abstract letter identities in a **position-specific word-level** format but not to the lexical status of these strings.
- Lexical effects are seen 50 ms later, in left inferior and middle temporal areas, where we also see apparently lexically dependent **position-nonspecific** effects.
- These data confirm the role of VWFA in processing **abstract word-form representations**, transiently activated as feed-forward orthographic processes sweep through the fusiform gyrus to lexical destinations in posterior temporal cortex.

References

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