The ventral visual stream represents abstract orthographic and phonological form in an artificial orthography

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J. S. H. Taylor[1], Matthew H. Davis[2], and Kathleen Rastle[1]

[1]Royal Holloway, University of London, UK
[2]MRC Cognition and Brain Sciences Unit, Cambridge, UK

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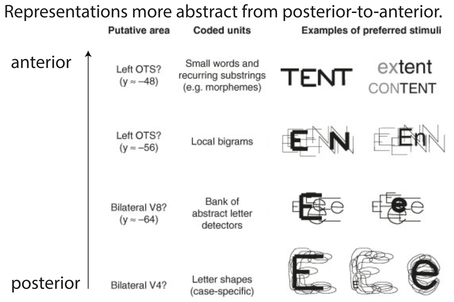
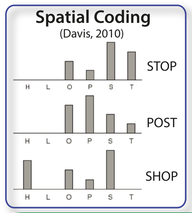
1. Background

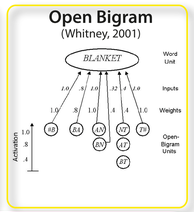
Proposal from Dehaene et al. (2005)

Left occipitotemporal cortex (vOT) represents orthography. Representations more abstract from posterior-to-anterior.



What is the form of this abstraction?





Phonological

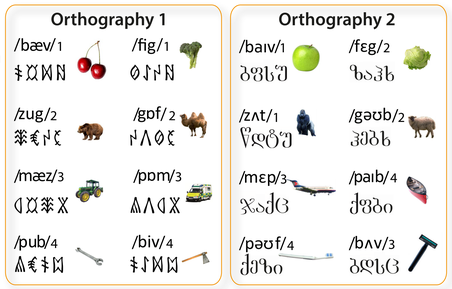
e.g., same representation for a word written in two japanese scripts (Pylkkanen & Okana, 2010)

piman (pepper) — hiragana ぴーまん = katakana ピーマン

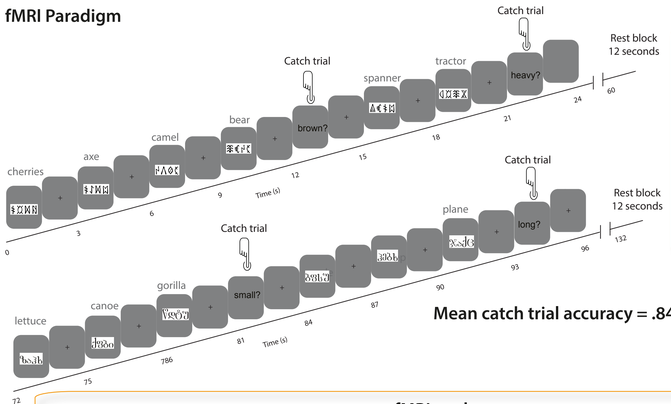
2. Training paradigm and imaging methods

Stimuli and Training Paradigm

- 24 native English speaking adults (18-30 yrs) learn to read two different artificial orthographies.
- Each orthography comprised 24 pseudowords, assigned English meanings.
- In each word, first 3 letters have one-to-one mapping with spoken form. Final letter is silent.
- Learn to read aloud the words and say their meanings over 8 days.



fMRI Paradigm



Scanning Parameters

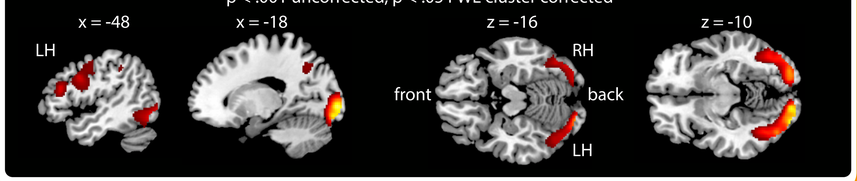
- 4 runs
- 192 standard trials / run
- 48 catch trials / run
- 2500ms trial, 500ms ISI
- TA and TR = 2000ms
- 3T Siemens scanner
- 3mm³ voxels

Mean catch trial accuracy = .84 (SD = .13)

fMRI analyses

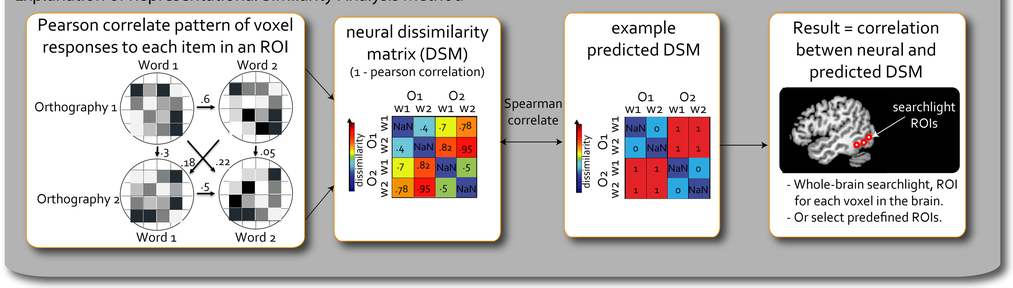
Analyses conducted using SPM8 and the CoSMoMVPA toolbox (Oosterhof, Connelly, & Haxby, 2016).
Univariate analyses: realigned, slice-time corrected, normalised (2mm³ voxels), smoothed.
Representational Similarty Analyes: realigned, slice-time corrected (no normalisation or smoothing).
Whole brain searchlight (3voxel radius sphere). vOT regions of interest (ROIs) from Vinckier et al. (2007).

Univariate analysis: All visual trials vs. resting baseline
p < .001 uncorrected, p < .05 FWE cluster corrected

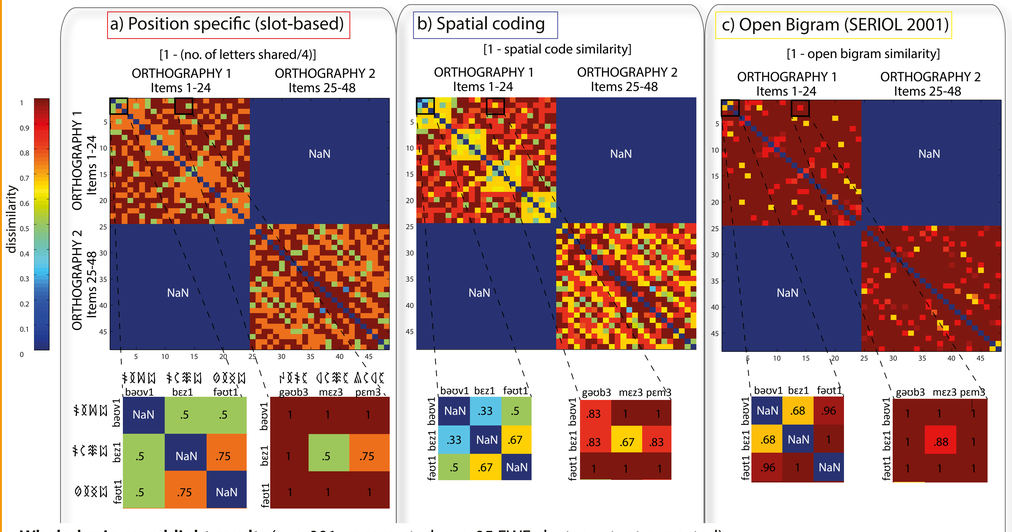


3. RSA reveals orthographic abstraction in the ventral visual stream

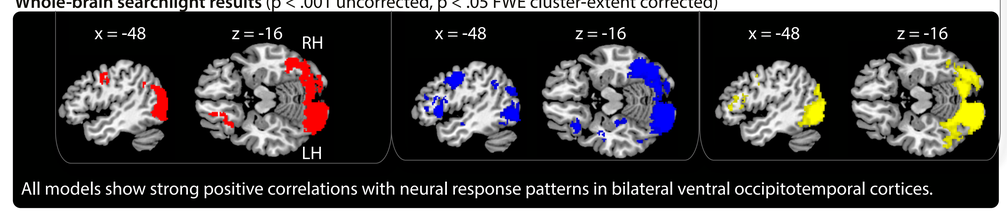
Explanation of Representational Similarity Analysis Method



Prediction DSMs



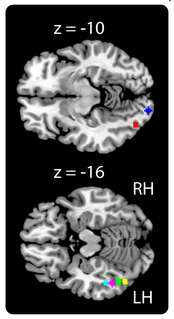
Whole-brain searchlight results (p < .001 uncorrected, p < .05 FWE cluster-extent corrected)

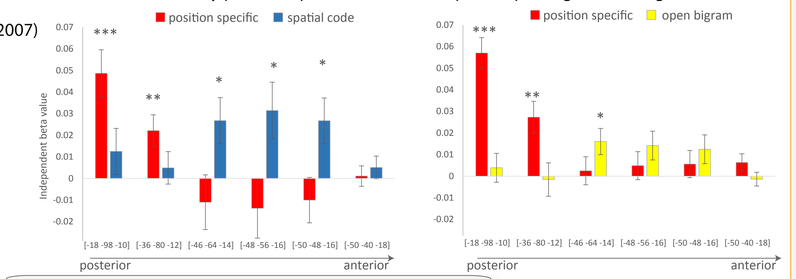


Multiple regression analyses in ventral occipitotemporal ROIs

Independent variance in neural DSM accounted for by position-specific vs. abstract (spatial/open bigram) coding models.

ROIs from Vinckier et al. (2007)





Region (1 to 6) x Model (position-specific vs. spatial/open bigram) ANOVAs
Interaction between region and model:
Position-specific vs. spatial code: F(1,23) = 5.66, p < .05, partial eta-squared = .20
Position-specific vs. open bigram: F(1,23) = 8.16, p < .001, partial eta-squared = .26

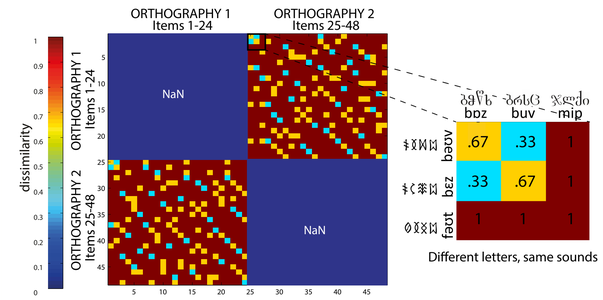
Direct comparison between spatial code and open bigram models non-significant in mid-to-anterior ROIs.

4. Phonological abstraction in left ITG and MTG

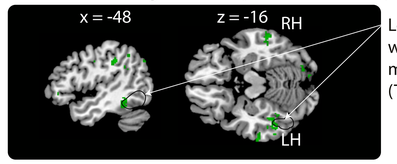
Is left vOT sensitive to phonological similarity?
In a natural language this is usually confounded with orthographic similarity, but our two artificial orthographies share no letters but do share sounds.

Position specific phonological similarity prediction DSM

[1 - (no. of sounds shared/3)]

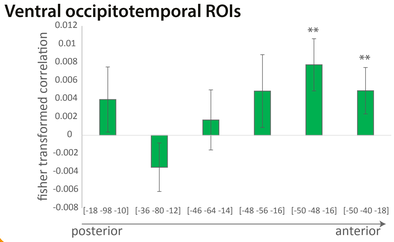


Whole-brain searchlight results *(p < .01 uncorrected)*



Left ITG cluster overlaps with [pseudoword > word] meta-analysis cluster (Taylor et al., 2013).

Ventral occipitotemporal ROIs



Left ITG and MTG sensitive to phonological similarity, in the absence of visual similarity.

5. Conclusions

Left vOT represents orthographic form for a recently learned script.

Posterior vOT is sensitive to basic visual similarity, as captured by a position specific coding model.

Orthographic representations in anterior vOT are more abstract, as captured by relative position coding models.

Further research is needed to adjudicate between spatial coding and open bigram models of orthographic abstraction.

Anterior left vOT (ITG/MTG) is also sensitive to phonological similiarity, in the total absence of orthographic similarity (i.e., different scripts).

This demonstrates that left vOT representations are influenced by phonology, as suggested by Price & Devlin (2011).

Artificial orthographies are a powerful tool for investigating these questions as they provide total control over orthographic, phonological, and semantic similarity.

6. References

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