How does the brain learn to read words and name objects? fMRI investigations of artificial language learning

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How does reading differ from object naming?

In alphabetic/syllabic orthographies, systematic spelling-sound mappings enable generalization

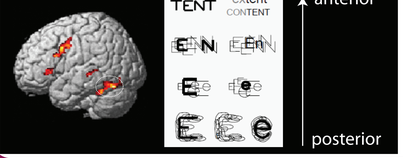
Contrasts with vocabulary/object naming where form-sound mappings arbitrary

Can have specific problems with reading - developmental/acquired dyslexia

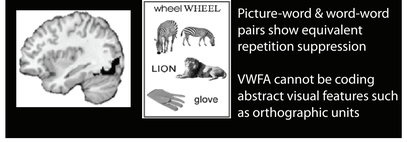
Are the neural mechanisms for reading and object naming distinct?

VISUAL WORD FORM AREA (VWFA) in the left fusiform gyrus

Dehaene and colleagues
Represents sublexical orthographic units



Price and colleagues
Visual form processing influenced by interactions with phonology and semantics



Picture-word & word-word pairs show equivalent repetition suppression

VWFA cannot be coding abstract visual features such as orthographic units

Artificial language learning paradigm

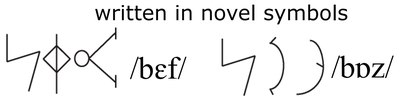
Contrast brain activity during....
Orthographic learning - read new words written in novel symbols
Object-label learning - new names for novel objects

Examining learning maximises task differences:
Orthography - decode words by extracting systematic symbol-sound rules
Object-label - objects must be arbitrarily associated with their names

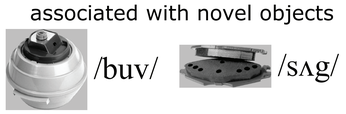
Complete control over statistics of the language:
a)match phonological forms of written words and objects, b)all novel - no previous experience, c)visual to spoken form mappings are entirely regular

Stimuli:

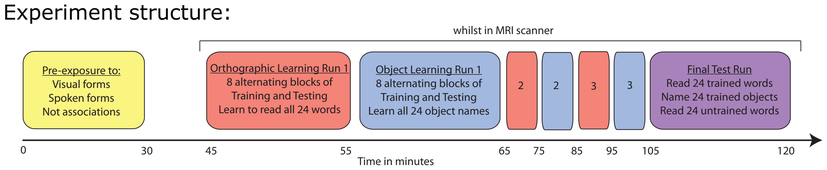
24 novel spoken words written in novel symbols



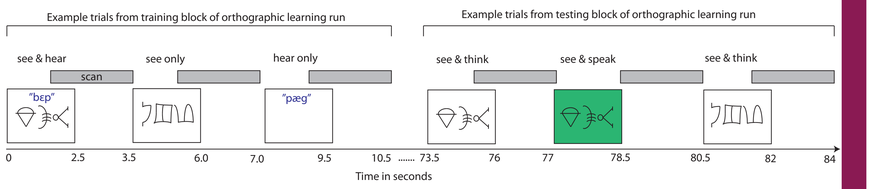
24 novel spoken words associated with novel objects



Experiment structure:



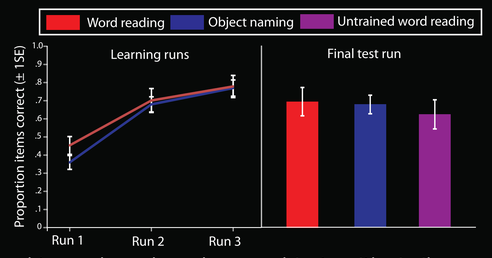
Trial structure:



fMRI data from 20 right-handed native English speakers aged 18 - 40 using a fast sparse-imaging protocol (TR=3.5s, TA=2.0s). Each learning run comprised 169 EPI volumes (32 x 3+0.75mm slices, 3x3mm in-plane). Analyses used SPM8, standard preprocessing and the canonical HRF. Results from group analysis thresholded at p<.05 FWE cluster corrected.

Results

Behavioural performance

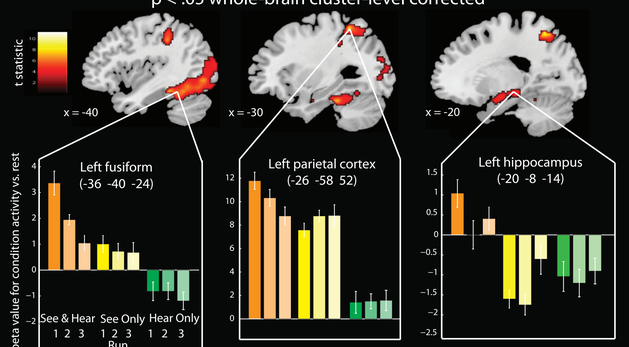


Adults learned to read words and name objects with similar accuracy.

They retained knowledge of trained items and could generalize and read untrained words.

Cross-modal activity related to learning visual-verbal associations

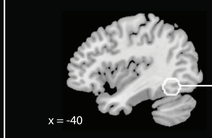
See & Hear > Max (See Only, Hear Only)
p < .05 whole-brain cluster-level corrected



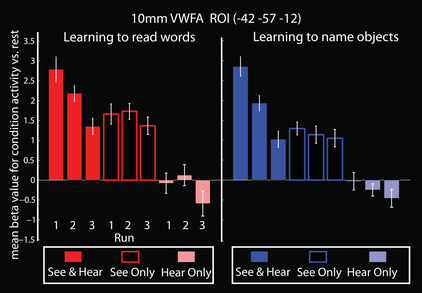
Activity in bilateral occipitotemporal and parietal cortices and left hippocampus was greater for cross-modal than uni-modal trials.

An ANOVA of Run (1,2,3) x Task (objects,words) found a decrease in the cross-modal benefit over runs in bilateral occipitotemporal cortex and pre-central gyrus and left superior parietal cortex and inferior frontal gyrus.

Activity in the VWFA when learning to read words and learning to name objects



-42 -57 -12
10mm³ VWFA ROI

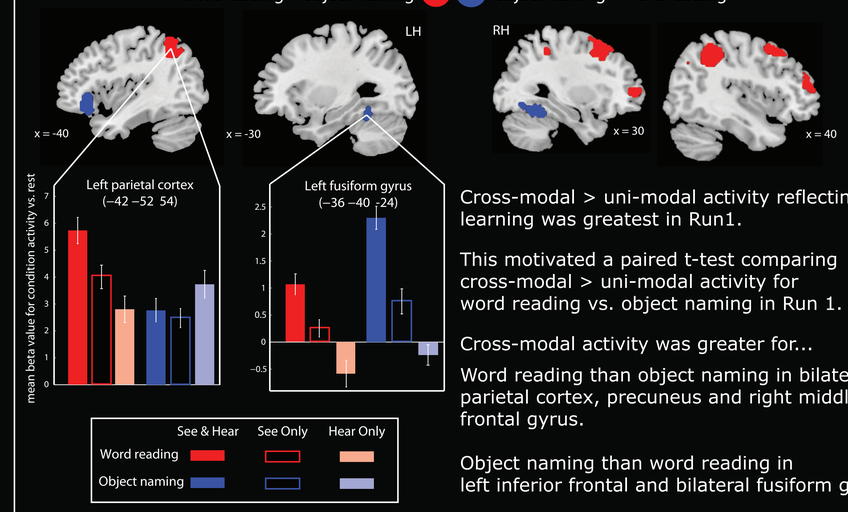


Run x Task ANOVA
Cross-modal > uni-modal activity, VWFA ROI
No difference between word reading and object naming in any of the learning runs

Differences in cross-modal activity in Run1 for learning to read words vs. name objects

See & Hear > Max (See Only, Hear Only)
p < .05 whole-brain cluster-level corrected

word reading > object naming
object naming > word reading



Cross-modal > uni-modal activity reflecting learning was greatest in Run1.

This motivated a paired t-test comparing cross-modal > uni-modal activity for word reading vs. object naming in Run 1.

Cross-modal activity was greater for...

Word reading than object naming in bilateral parietal cortex, precuneus and right middle frontal gyrus.

Object naming than word reading in left inferior frontal and bilateral fusiform gyri.

Discussion

Our innovative method enabled us to examine the brain mechanisms that are activated when people learn systematic symbol-sound rules.

The VWFA in the left fusiform gyrus showed equivalent activity when learning a new orthography and when learning new names for novel objects.

Bilateral fusiform gyri and the left inferior frontal gyrus (orbitalis) were more active when learning object names than when learning to read words.

These results question the specialisation of the VWFA for reading and are in line with the suggestion that this region is influenced by semantic processing in the inferior frontal gyrus (Mechelli et al., 2005).

Parietal cortices and right middle frontal gyrus were more active when learning to read words than when learning object names.

This is in line with Wilson et al. (2009) who suggested a role for left parietal cortex in spelling-sound conversion as this region showed greater activity in surface dyslexics relative to controls during irregular word reading.

Future analyses will determine whether activity in occipitotemporal and parietal cortices and inferior frontal and hippocampal regions predicts behavioural performance and how these regions contribute to generalization to untrained words.

Future research will use artificial language learning paradigms to explore:

a) whether occipitotemporal specialisation for orthographic processing develops over a longer time frame (weeks/months)

b) the neural systems involved in learning regular vs. irregular words

c) how semantic knowledge influences orthographic learning.

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