Learning to read regular and irregular words: Combining artificial orthography learning with fMRI

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Background

Cognitive models of reading

Dual-route cascaded (Coltheart et al., 2001) and Triangle model (Plaut et al., 1996; Harm & Seidenberg, 2004)
Letter-sound knowledge (rules or statistics) – necessary for pseudoword reading
Item-specific knowledge (lexical and/or semantic) – important for irregular word reading
Pathways resolved in phonological output system

Neuroimaging data (Taylor, Rastle, & Davis, 2012)

Dorsal stream - posterior occipitotemporal and parietal cortex: more active for pseudowords (letter-sounds)
Ventral stream - anterior occipitotemporal and middle temporal cortex: more active for words (whole-items)
Inferior frontal gyrus - resolves phonological information from the two streams

How do these different neural systems contribute to learning regular vs. irregular words?

Method and Behavioural Data

Participants: 22 adults (11 females), aged 18-40

Stimuli: 24 CVC pseudowords written in novel symbols

Procedure: Learn to read novel words whilst in MRI scanner

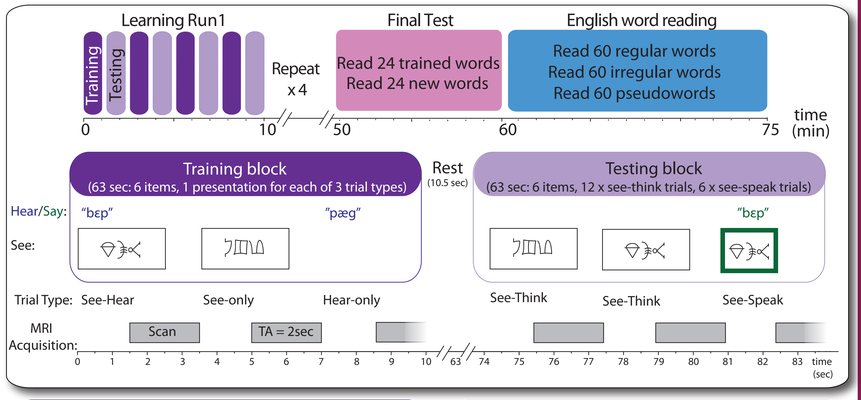
Learning Runs x 5 - alternating training-testing blocks
Training = see novel words - hear pronunciations
Testing = read aloud novel words just learned

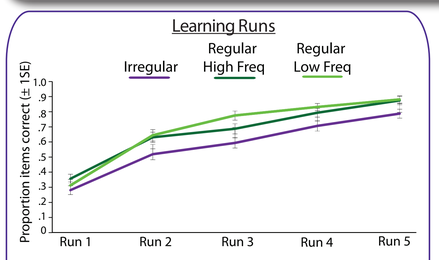
Final test - read aloud trained + untrained words

English word reading - read aloud regular, irregular, and pseudowords written in Latin alphabet

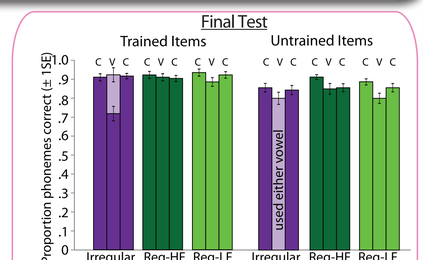
Regularity manipulation

Irregular	Regular High Freq	Regular Low Freq
dæf	dʌs	bɛz
fæm	fʌt	gɛf
gæb	nʌd	mɛp
kæz	pʌm	vɛk
nɒs	sʌg	bɪk
pɒb	sʌt	kɪg
tɒn	tʌv	mɪv
zɒp	vʌk	zɪn



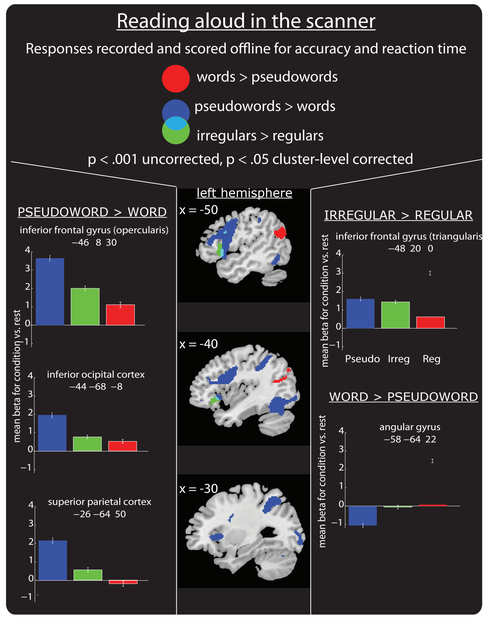


Learned to read regular and irregular words
Simulated typical regularity effect



Learned correct vowel sounds for irregular items
Could generalize and read untrained items

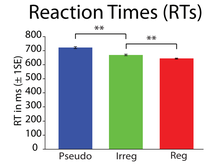
Brain regions involved in English word reading



Behavioural Data

All item types > 98% accuracy

Reaction Times (RTs)



fMRI Data

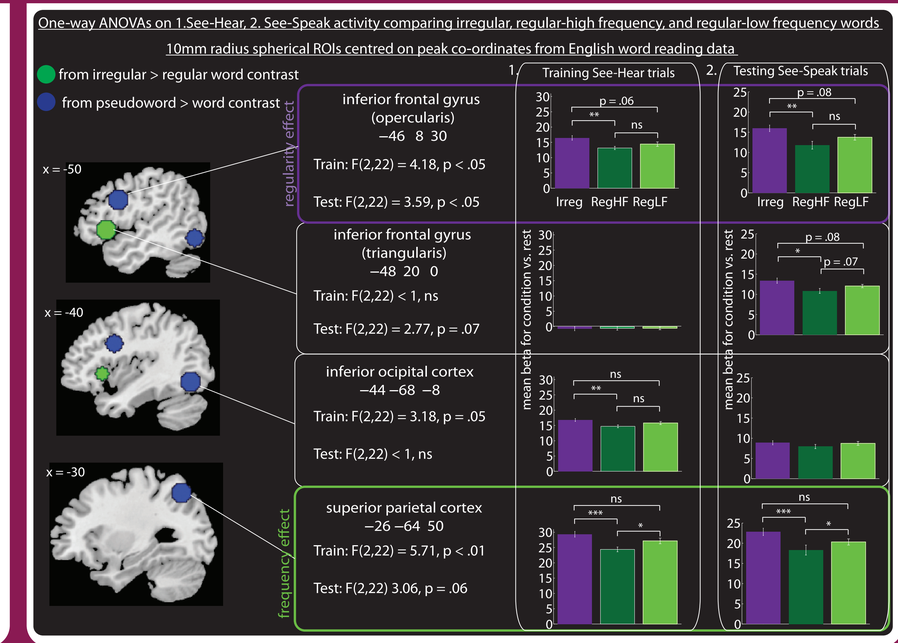
Pseudoword > Word:
Bilateral inferior frontal gyrus
Bilateral inferior parietal cortices
Left occipitotemporal cortex
Bilateral cerebellum

Word > Pseudoword:
Bilateral middle temporal and angular gyri
Anterior cingulate

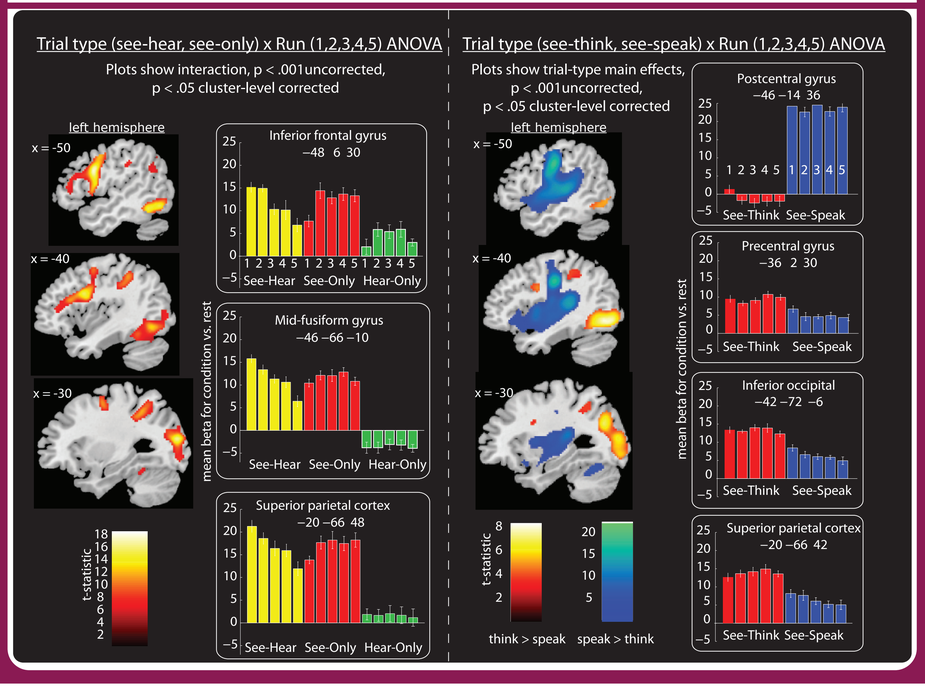
Irregular > Regular:
Left inferior frontal gyrus

Brain regions involved in learning irregularities

One-way ANOVAs on 1.See-Hear, 2. See-Speak activity comparing irregular, regular-high frequency, and regular-low frequency words
10mm radius spherical ROIs centred on peak co-ordinates from English word reading data



Brain regions involved in learning to read



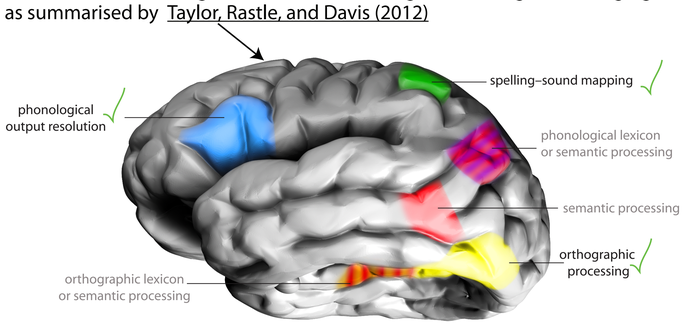
Discussion

- Adults can learn to read an artificial orthography in 1hr whilst in an MRI scanner
- They can learn *irregular* as well as *regular* spelling-sound mappings
- They can *generalize* their spelling-sound knowledge to read untrained items

- Learning to read an artificial orthography activates the *typical reading network*
- Brain regions involved in *encoding* are also involved in *retrieval*

- Left inferior frontal gyrus activity is modulated by spelling-sound regularity
- Left superior parietal cortex activity is sensitive to spelling-sound frequency
- No evidence that occipitotemporal cortex develops item-specific representations

- Results fit well with cognitive models of reading and existing neuroimaging data, as summarised by Taylor, Rastle, and Davis (2012)



References

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