

How does the Brain Solve the Problem of Reading?

Professor Kathy Rastle
Royal Holloway, University of London
www.rastlelab.com
@Kathy_Rastle

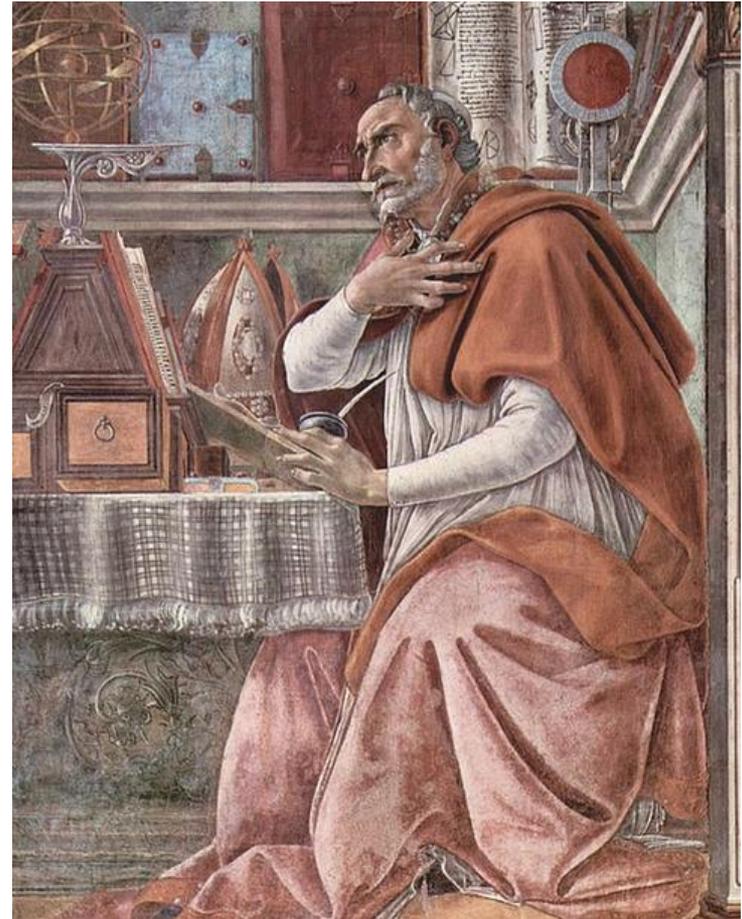


The Leverhulme Trust

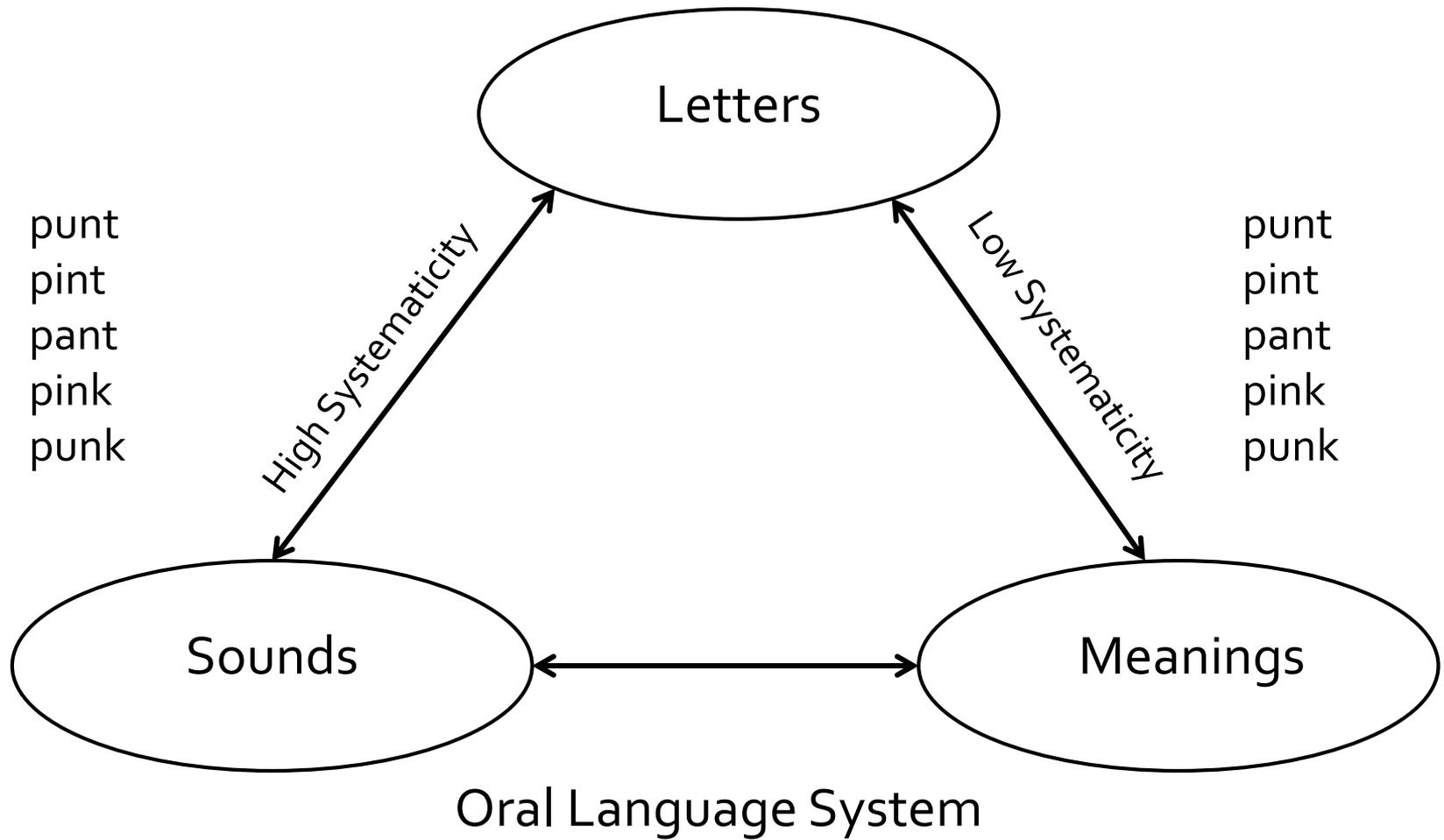


We are not *Meant* to Read

- Unlike spoken language, reading is a cultural invention and a learned skill.
- Evidence for silent reading in antiquity, but reading became an activity enjoyed by the mass public only in the 1800s.
- We are not born with dedicated neural hardware to support reading.
- Immersed in a library of books, a child will not learn to read; reading requires ~10 years of dedication, instruction, and practice.



The Challenge of Reading

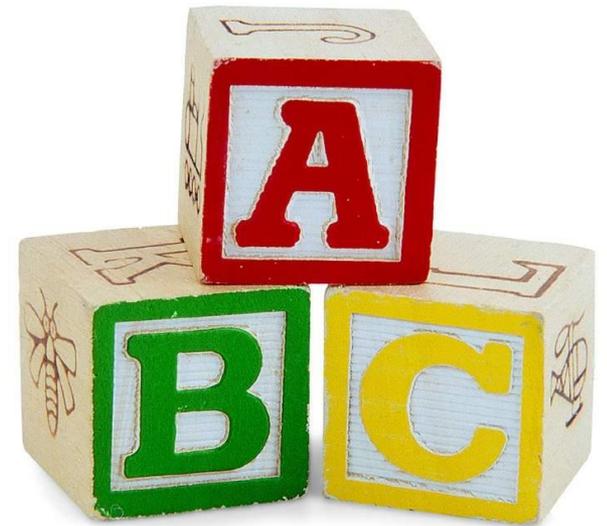


The Challenge of Reading



Cracking the Alphabetic Code - Phonics

- Mastery of the alphabetic principle critical for reading development
- Very strong scientific consensus that methods that teach this principle explicitly are most effective
- English spelling-sound relations can be described with a simple set of rules; irregular words rarely deviate by more than one letter-sound combination
- Focus on sounds *enables* access to meaning; it does not discourage it



Phonic Knowledge is Central to *Skilled* Reading

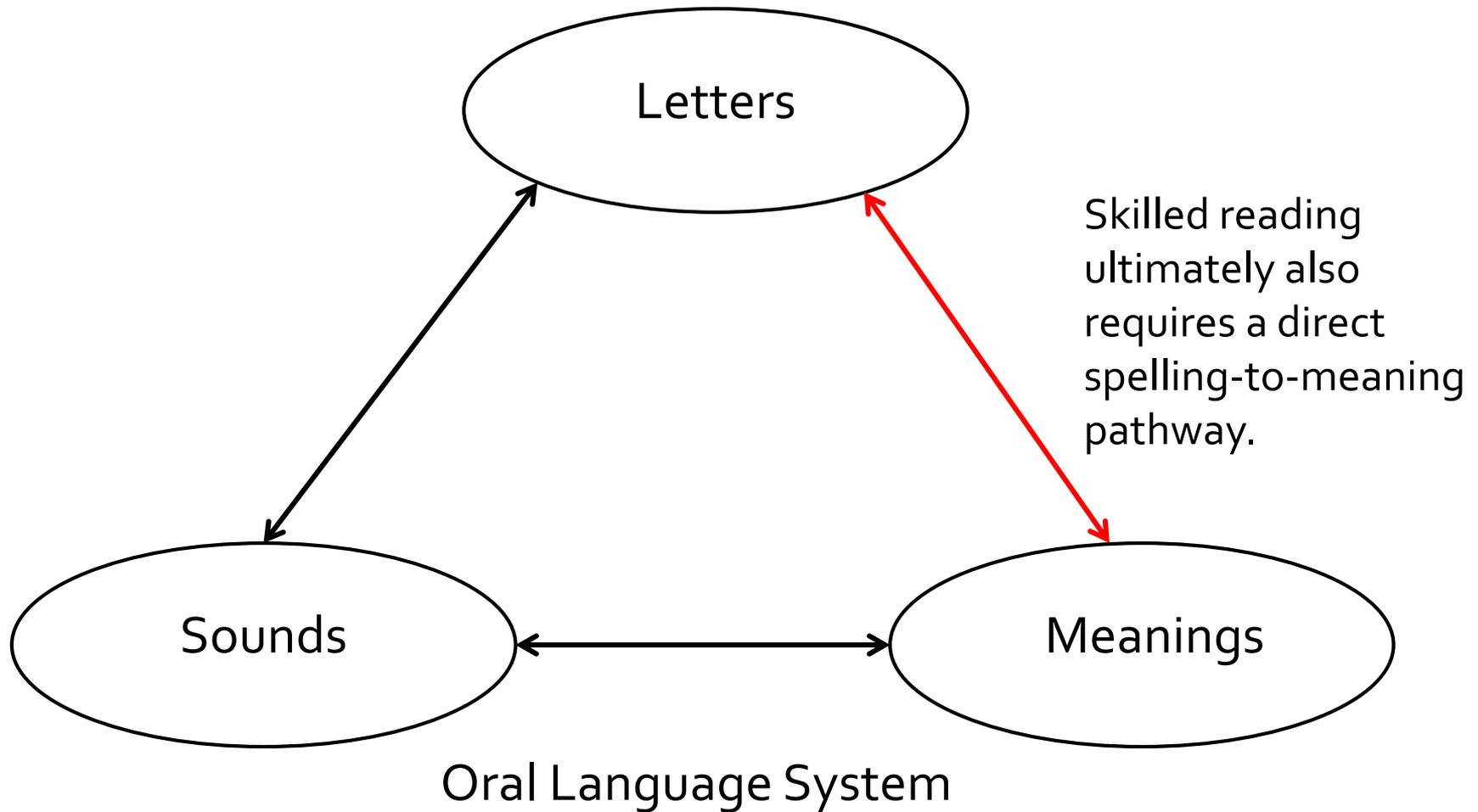


Phonic Knowledge is Central to Skilled Reading

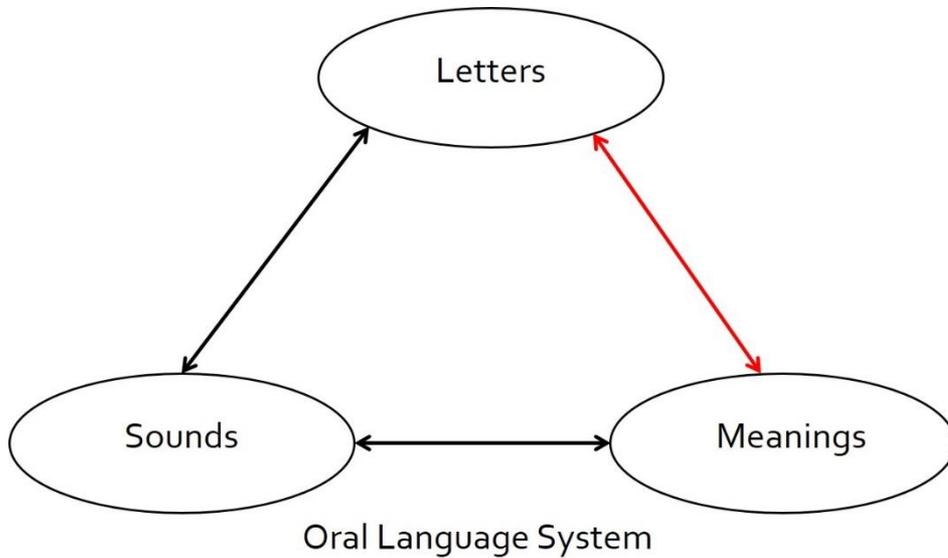
- Skilled readers translate printed words (and nonwords) to sound-based codes as a matter of routine.
- This computation is rapid, and can arise before a reader is even conscious of the stimulus (or when the stimulus is in the visual periphery during text reading).
- Even for skilled readers, using phonic knowledge is necessary for rapid computation of meaning.



Learning the Spelling-Meaning Mapping



Learning the Spelling-Meaning Mapping



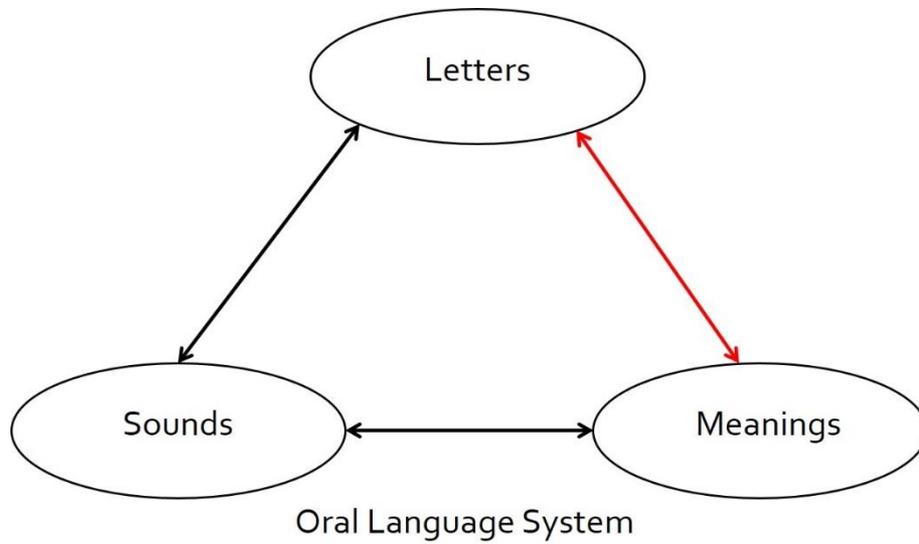
English spelling provides very strong cue to morphological structure (e.g. -ed, -s, -ous)

Morphology provides systematicity in the letter-to-meaning mapping

<u>clean</u>	<u>redo</u>
<u>unclean</u>	<u>repaint</u>
<u>cleaner</u>	<u>rewire</u>
<u>cleanliness</u>	<u>remake</u>
<u>cleanly</u>	<u>reheat</u>
<u>preclean</u>	<u>reprint</u>
<u>cleaning</u>	<u>recreate</u>
<u>reclean</u>	<u>reuse</u>

magician, health, two

Learning the Spelling-Meaning Mapping

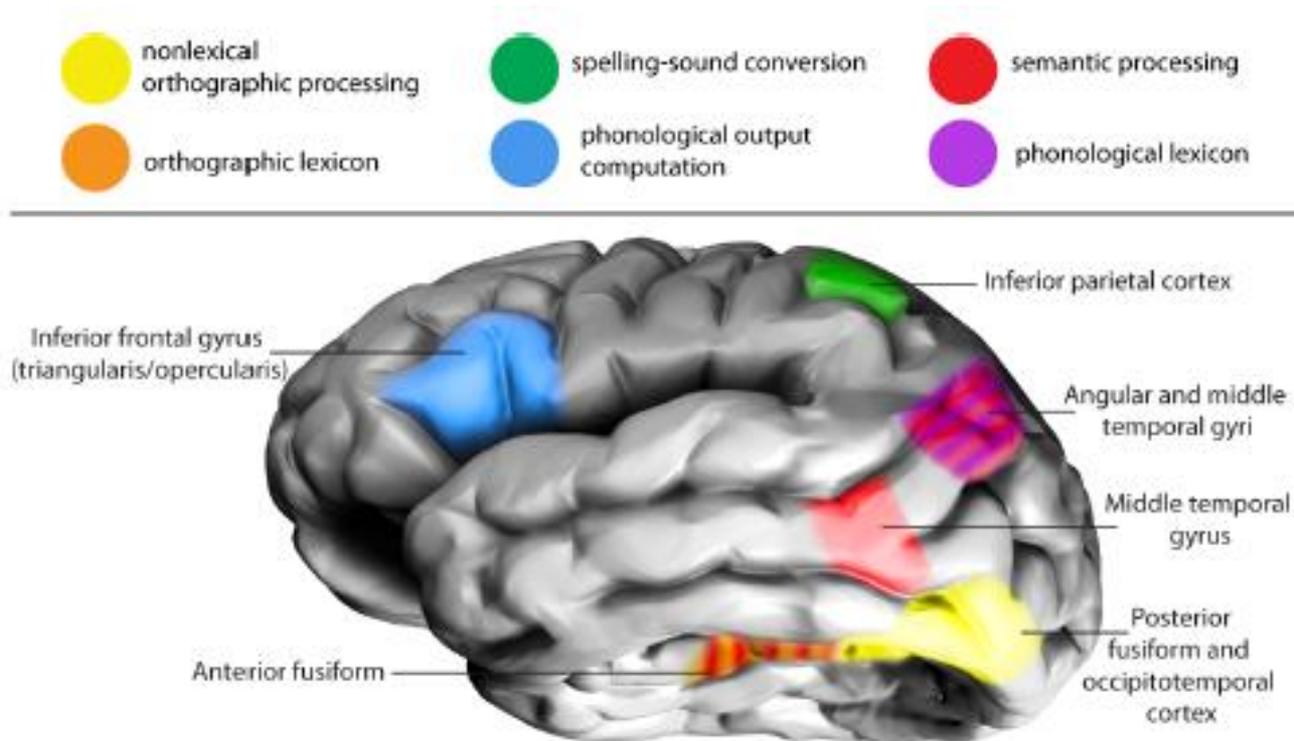


- Skilled readers segment printed words into their morphemes
- This segmentation is rapid, arising before conscious awareness (or when the stimulus is in the visual periphery in text reading).
- No evidence that English readers up to the age of 10 show this rapid segmentation.



*"Actually, I'm not even a real
Modo. I'm only a Quasimodo."*

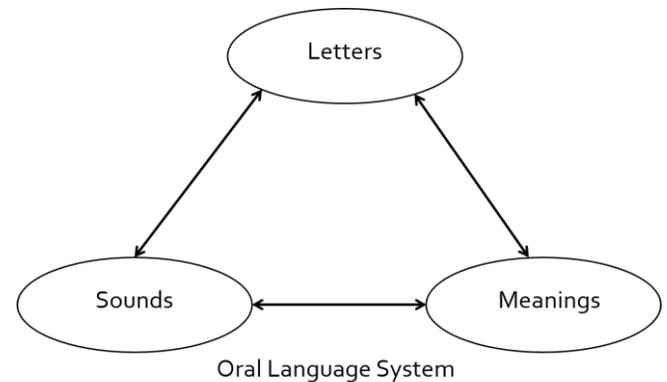
Pathways to Reading in the Brain



- Meta-analysis of 36 neuroimaging studies
- Dorsal (letters-to-sounds) and ventral (letters-to-meanings) pathways
- Evidence that ventral pathway still developing into early adolescence

A Word on Interventions and Treatments

- RCTs aren't always available, and it is challenging for non-experts to evaluate the evidence.
- But reading is simple.
- It should be clear what aspect of the reading system an intervention is affecting.
- If it is not clear, or if complicated language is used to mask the lack of clarity, then that should raise questions; proximal and distal causes.
- e.g. intensive phonics training, intensive balance and coordination exercises, intensive speech and language therapy, playing action video games, wearing coloured glasses ??



Summary

- Reading is a recent invention and a learned skill.
- The brain capitalises on systematicity that exists in the writing system – e.g. phonological and morphological.
- Strong scientific consensus around importance of phonic knowledge in reading acquisition.
- Reading system still developing well into secondary education.
- Interventions should 'make sense' in terms of the theory of reading proposed.

**I'm so smart
because I read!**



Questions?

"The more that you read, the more things you will know. The more that you learn, the more places you'll go." Dr Seuss



History of Reading / Writing

Manguel, A (1996). *A history of reading*. London: HarperCollins

Saenger, J. (1998). *Spaces between words: The origins of silent reading*. Stanford University Press.

Phonic knowledge in reading development / teaching of reading

Rayner et al. (2001). How psychological science informs the teaching of reading. *Psychological Science in the Public Interest*, 2, 31-74.

Hulme, C., Bowyer-Crane, C., Carroll, J., Duff, F., & Snowling, M.J. (2012). The causal role of phoneme awareness and letter-sound knowledge in learning to read: combining intervention studies with mediation analyses. *Psychological Science*, 23, 572 - 577

Rules for Translating Print-to-Sound

Coltheart M et al., (2001). DRC: A dual-route cascaded model of visual word recognition and reading aloud. *Psychological Review*, 108, 204-256.

Phonic Knowledge in Skilled Reading

Rastle, K. & Brysbaert, M (2006). Masked phonological priming effect in English: Are they real? Do they matter? *Cognitive Psychology*, 53, 97-145.

Harm, M. W., & Seidenberg, M. S. (2004). Computing the Meanings of Words in Reading: Cooperative Division of Labor Between Visual and Phonological Processes. *Psychological Review*, 111, 662-720.

Role of Morphology in Writing/Reading

Plaut, DC & Gonnerman, LM (2000). Are non-semantic morphological effects incompatible with a distributed connectionist approach to lexical processing? *Language and Cognitive Processes*, 15, 445-485.

Frost, R. (2012). Towards a universal model of reading. *Behavioral and Brain Sciences*, 35, 263-279.

Rapid Morphological Segmentation in Children and Adults

Beyersmann, E. Castles, A. & Coltheart, M. (2012). Morphological processing during visual word recognition in developing readers: Evidence from masked priming. *Quarterly Journal of Experimental Psychology*, 65, 1306-1326.

Rastle, K & Davis, M (2008). Morphological segmentation based on the analysis of orthography. *Language & Cognitive Processes*, 23, 942-971.

Meta-Analysis of Reading in the Brain

Taylor, J. S. H., Rastle, K. & Davis, M. H. (2013). Can cognitive models explain brain activation during word and pseudoword reading? A meta-analysis of 36 neuroimaging studies. *Psychological Bulletin*, 139, 766-779.

Development of Ventral Reading Pathway

Ben-Shachar, M., Dougherty, RF, Deutsch, GK, Wandell, BA (2011). The development of cortical sensitivity to visual word forms. *Journal of Cognitive Neuroscience*, 23, 2387-2399.

Reading Impairment / Interventions

Jackson, NE & Coltheart, M. (2001). *Routes to reading success and failure*. Psychology Press.

Snowling, M & Hulme, C (2012). Interventions for children's language and literacy difficulties. *Int J Lang Commun Disord*. 2012 Jan; 47(1): 27-34.

Henderson, L. et al. (2014). Treating reading difficulties with colour. *BMJ* 349:g5160 .

Duff, FJ & Clarke, PJ (2011). Practitioner review: Reading disorders: what are the effective interventions and how should they be implemented and evaluated? *Journal of Child Psychology & Psychiatry*, 52, 3-12

www.interventionsforliteracy.org.uk based on Brooks, G. What works for children & young people with literacy difficulties?

Please feel free to email me for any papers that are not openly accessible!