

How Science Informs the Teaching of Reading

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What is science?

“Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence”

The Science Council (www.sciencecouncil.org)

- Science as a body of knowledge
- Science as a process

Why is science needed?

- Individual observations might not be reliable, and might not generalize
 - Taking notes in class
 - Smoking grandmothers
 -“the plural of anecdote is not data”
- The scientific method allows us to move beyond single observation or anecdote to reduce uncertainty and accrue knowledge and understanding

Key properties of the scientific method

- Empirical
- Systematic
- Objective
- Controlled
- Testable and falsifiable
- Replicable
- Tentative and self-correcting
- Logical and rational

- Culture of transparency and openness
- Clearly set out procedures and methods
- Appropriate statistical analysis
- Peer review

- Knowledge base that is systematic, formal, reliable, and supported by evidence
- Conclusions from evidence are trustworthy but open to question and revision, if warranted by further evidence



An example from science and medicine

- Basic: studying how cells divide
- Applied: using cell biology knowledge to develop cancer treatment
- Implementation: studying how to successfully implement treatment packages in a hospital



Science and education

- Basic: studying how reading happens
- Applied: using this knowledge to build and test instruction
- Implementation: studying how to successfully implement instructional approaches in the classroom

Challenges in communicating and applying scientific findings about reading

- Reading is complex and multi-faceted. It means different things to different people
- Anecdotes and introspection rather than evidence
- Not all science is relevant to the classroom – some overreach from researchers
- Quick-fix treatments that promise much but do not work
- Ideological positions in educational pedagogy: the reading wars
 - Strong commercial interests in educational publishing
 - Political associations aligned with educational positions

Ending the Reading Wars: Reading Acquisition From Novice to Expert

Anne Castles^{1,2}, Kathleen Rastle³, and Kate Nation^{2,4}

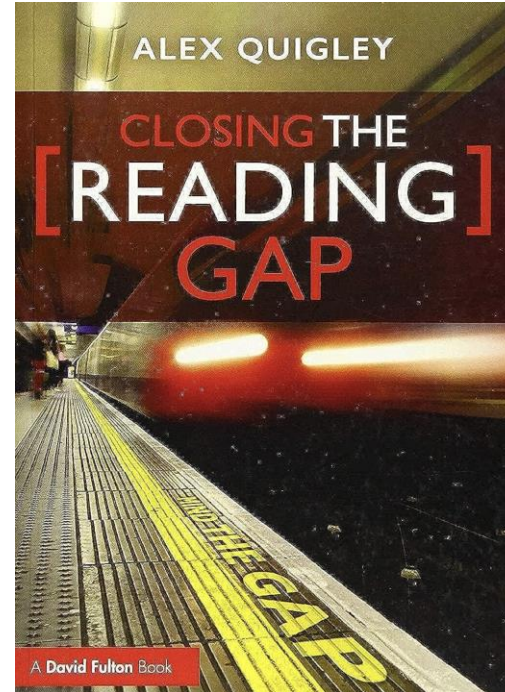
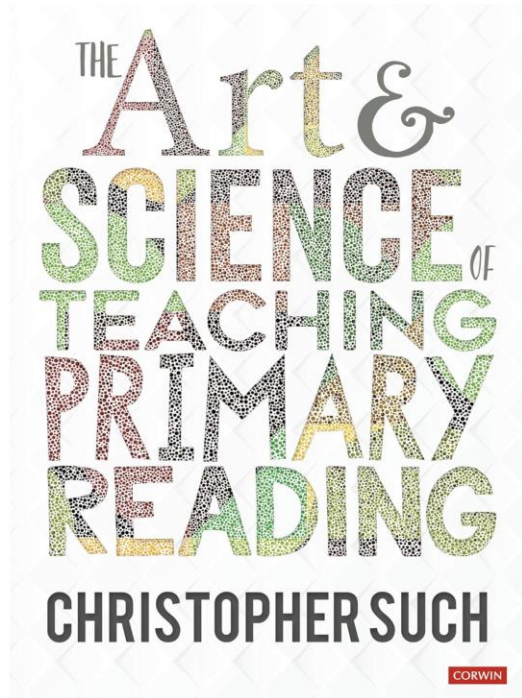
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www.psychologicalscience.org/PSPJ



Explain reading science to communicate how reading works in an accessible form, and give pointers for instruction and enable translation to practice

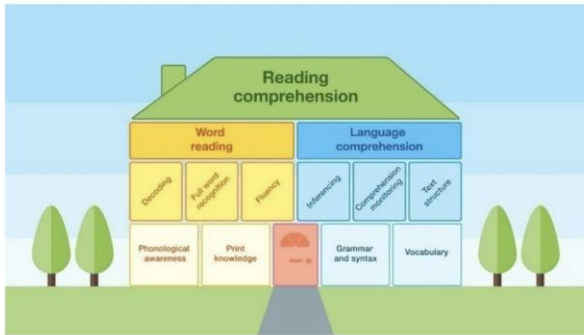
“We call for an end to the Reading Wars and recommend an agenda for instruction and research in reading acquisition that is balanced, developmentally informed, and based on a deep understanding of how language and writing systems work”



$$\text{WR} \times \text{LC} = \text{RC}$$

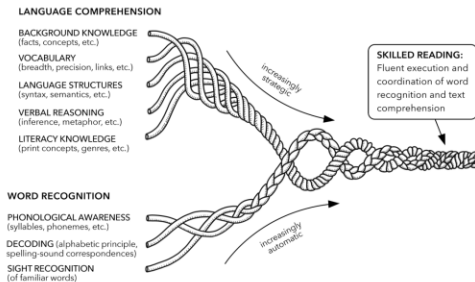
The Simple View of Reading (Gough & Tunmer, 1986)

Figure 2: Reading comprehension—the sum of many parts
Adapted from Hogan, Bridges, Justice, and Cain (2011)



Useful in highlighting the components of reading, and making the broad distinction between word reading and language comprehension
(both necessary, neither sufficient)

But limited utility beyond that as they don't address the *what*, *when* and *how* (and there is a danger of misleading impressions)



Reading Rope (Scarborough, 2001)

Three sections

1. Cracking the alphabetic code
2. Becoming a skilled word reader
3. Learning to comprehend text

Importance of understanding the writing system and taking a developmental approach to understand how learning happens and how expertise emerges

I. Cracking the alphabetic code

- The nature of the writing system
- The development of alphabetic decoding skills

The Alphabetic Principle

The fundamental understanding that the letters of the alphabet work together in systematic ways to represent the sounds of the language

Foundation to decoding: establishing mappings from print to meaning via sound

All alphabet, no principle....



Not easy!

1. Segmentation problem – the need to ‘hear’ words within sentences and sounds within words
2. Ambiguity problem – speech is ambiguous, within and between speakers
3. The mapping problem – systematic and predictable, but (in some languages) quasi-regular



Figure 2.9. First grade reading proficiency in European countries. The numbers are the average percentages of one-syllable words that children could read correctly at the end of first grade. Portuguese, French, and Danish, like English, have less consistent mappings between sounds and letters than other languages do. Map of Europe: modified, original © hektoR, Shutterstock; data from Seymour, Aro, & Erskine, 2003

From Willingham, 2017

‘Phonic knowledge’ is a critical part of learning to read words

- Phonics is a method to teach phonic knowledge in ways that are direct, explicit and systematic
- Teaching the relationships between letters and sounds, and how to use this knowledge to ‘decode’ words

CAT → “c-a-t” → “cat”

opportunities for learning about how
different letters represent sound
(generalizable)

and word specific orthographic
information about cat

achieved via direct and systematic
instruction plus opportunities for
practice (phonically-controlled books)



establish a
‘habit of decoding’



A case study from England

Government review established systematic phonics as the primary approach to initial word reading instruction (Rose, 2006)

Government distributed resources and training (Letters & Sounds, 2007; and issued further validated programmes and guidance in 2021)

Introduction of the Phonics Screen (2012) for Year 1 children

Despite initial concerns, now implemented in England schools and core to early years education

Scientific questions remain – as they should!

- Science is rarely settled, and knowledge is never fully complete; new evidence might bring about further recommendations for teaching
- How much to teach explicitly? Which GPCs are most useful?
- How long to stick with phonically-controlled books before introducing less-controlled texts?
 - Decodables important for practice, and to experience success
 - But restricted, by definition, cf. ‘authentic’ texts
- What’s the ideal ‘starter kit’ that gets children reading independently?
- And what next: phonics necessary but not sufficient

2. Becoming a skilled word reader



*"I'm wondering what to read next," Matilda said.
'I've finished all the children's books.'"*

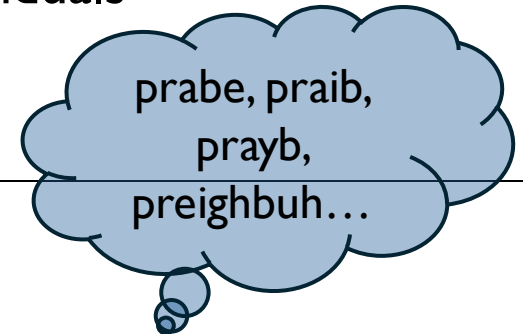
- **Reading experience** to practice and hone basic skills and develop fluency
- **Reading experience** to discover and ‘internalize’ systematic regularities in the writing system—the importance of learning (implicit/statistical)

Example 1: refining and enriching orthographic mappings

Is *spook* an exception because of *book* and *look*, or rule-governed because of *spook* and *spool*?

Consider the *ea* grapheme, as in *beat*, *head*, *steak*

- “ee” most common pronunciation
- but, conditioned by final letter: if T, “ee” most common; if D, “e” most common
- Not absolute, and variation within and between individuals
- How would you pronounce *steat* and *gread*??
- How would you spell a new phonological form?



Example 2: building print-meaning connections

morphological regularities are an important feature of the English writing system: systematic links between written (and spoken) form and meaning

lock
unlock
locked
lockable

teacher
farmer
reader



magic



magician

adjectives
nervous
advantageous
dangerous

nouns
bonus
genius
focus

Ulicheva et al. (2020)

Skilled visual word recognition highly sensitive to morphological regularities
(Rastle, 2022)

Learning about these regularities through reading experience may assist in the transition from novice to expert

- Language is complex, but has structure via a multitude of probabilistic relationship between multiple correlated features
- Language development is the product of general learning mechanisms operating across this rich input
- Transition to expertise is gradual, reflecting accumulation of experience with sounds, words, sentences and their contexts over years

REVIEW ARTICLE OPEN

Nurturing a lexical legacy: reading experience is critical for the development of word reading skill

Kate Nation¹

The scientific study of reading has taught us much about the beginnings of reading in childhood, with clear evidence that the gateway to reading opens when children are able to decode, or 'sound out' written words. Similarly, there is a large evidence base charting the cognitive processes that characterise skilled word recognition in adults. Less understood is how children develop word reading expertise. Once basic reading skills are in place, what factors are critical for children to move from novice to expert? This paper outlines the role of reading experience in this transition. Encountering individual words in text provides opportunities for children to refine their knowledge about how spelling represents spoken language. Alongside this, however, reading experience provides much more than repeated exposure to individual words in isolation. According to the lexical legacy perspective, outlined in this paper, experiencing words in diverse and meaningful language environments is critical for the development of word reading skill. At its heart is the idea that reading provides exposure to words in many different contexts, episodes and experiences which, over time, sum to a rich and nuanced database about their lexical history within an individual's experience. These rich and diverse encounters bring about local variation at the word level: a lexical legacy that is measurable during word reading behaviour, even in skilled adults.

npj Science of Learning (2017)2:3 | doi:10.1038/s41539-017-0004-7

Top Lang Disorders
Vol. 38, No. 1, pp. 66–83
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The Impact of Language Experience on Language and Reading

A Statistical Learning Approach

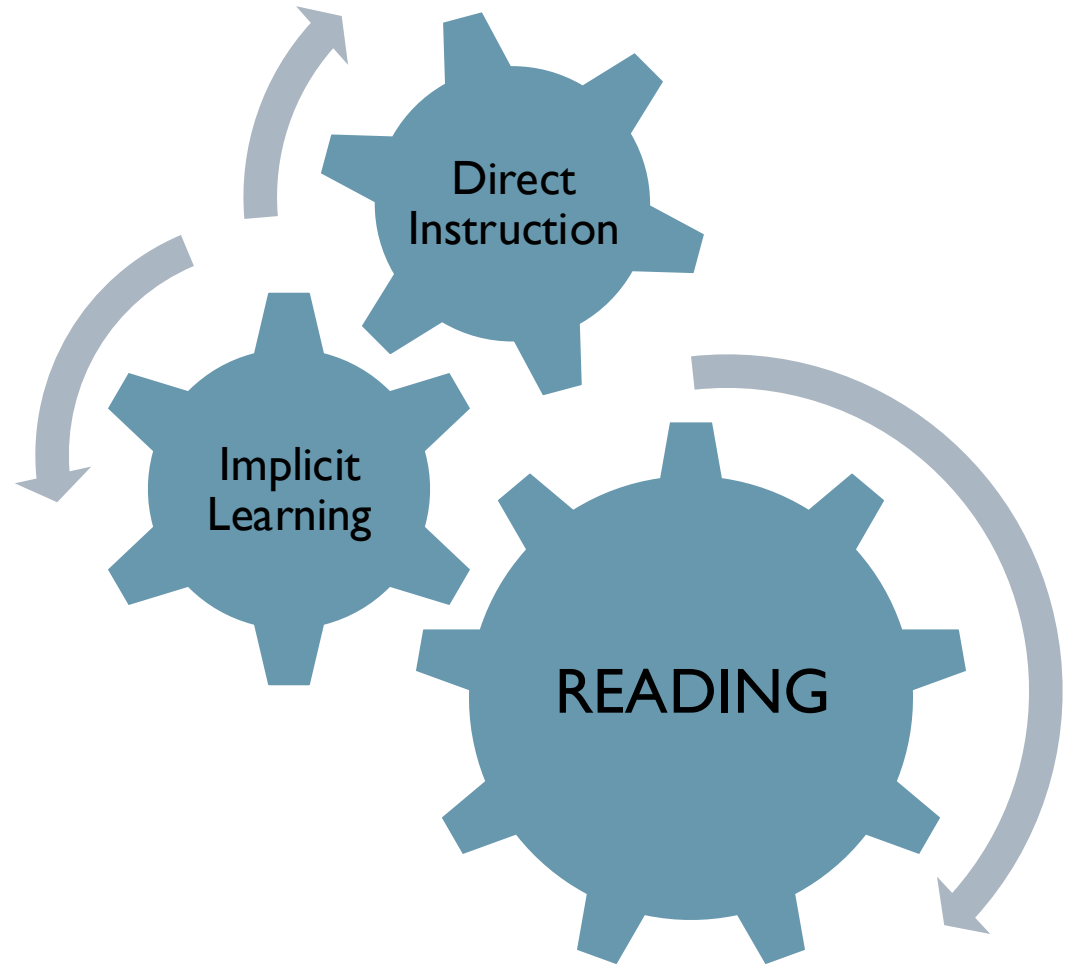
Mark S. Seidenberg and Maryellen C. MacDonald

2. Becoming a skilled word reader

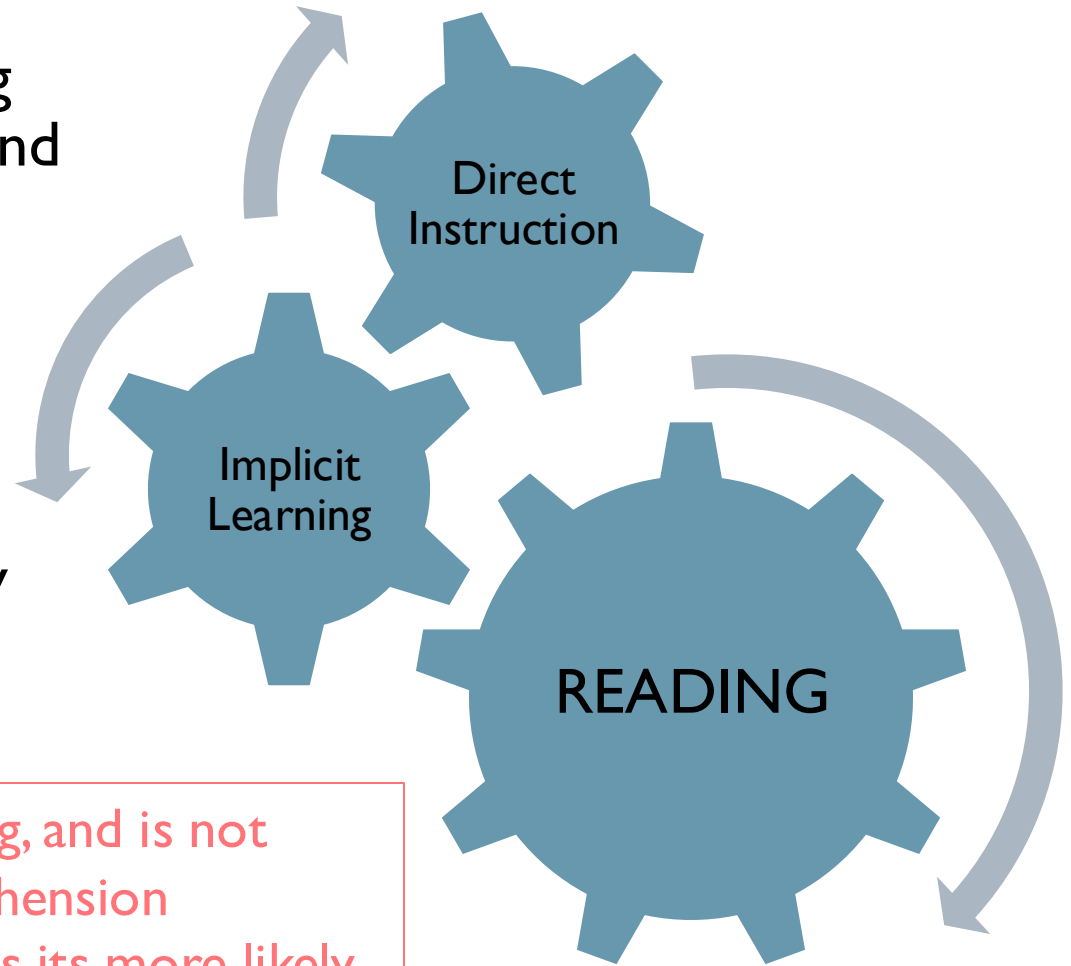


*"I'm wondering what to read next," Matilda said.
'I've finished all the children's books.'"*

- **Reading experience** to practice and hone basic skills and develop fluency
- **Reading experience** to discover and ‘internalize’ systematic regularities in the writing system—the importance of learning (implicit/statistical)
 - Between spellings and sounds
 - Between spellings and meanings
- **Reading experience** to encounter words and syntactic structures in language-rich context



- Reading experience to bring about fluency at the word and sentence level
- Repeated oral reading
- Modelling and scaffolding
- Challenging texts
- Vocabulary and morphology
- And more reading!



Fluency builds from decoding, and is not independent of comprehension (understanding a sentence means its more likely to be read fluently)

3. Learning to comprehend text

reading comprehension: the act of constructing meaning from print – transforming symbols on the page to the message intended by the writer – everything from recognizing the identity of a letter to inferring the mental state of a character described in a story

“The orchestrated product of a set of cognitive and linguistic processes operating on a text and interacting with background knowledge, features of the text, and the purpose and goals of the reading situation”

(Castles, Rastle & Nation, 2018)

Reading comprehension is complex!

- Reading words, accurately and fluently
- Vocabulary knowledge, and ready access to meanings in context
- Understanding of syntax to build connections between ideas, events and characters in the text
- Background knowledge and ‘world knowledge’
- Constant monitoring, updating, predicting and *inferencing*

Grasping his CV, Diego looked through the window at the growing puddles and searched for his umbrella. It was only after a minute of ransacking his house that he remembered that he had lent it to his sister. There was no other option; he would have to go by car.

1. Deigo's CV suggests he is on his way to something like a job interview.
2. The 'growing puddles' show its raining.
3. Diego does not wish to get wet.
4. 'he' refers to Diego.
5. 'it' refers to the umbrella. (but 'It' doesn't)
6. Diego's sister has not returned his umbrella.
7. Going by car is an alternative means of travel that will keep him dry.

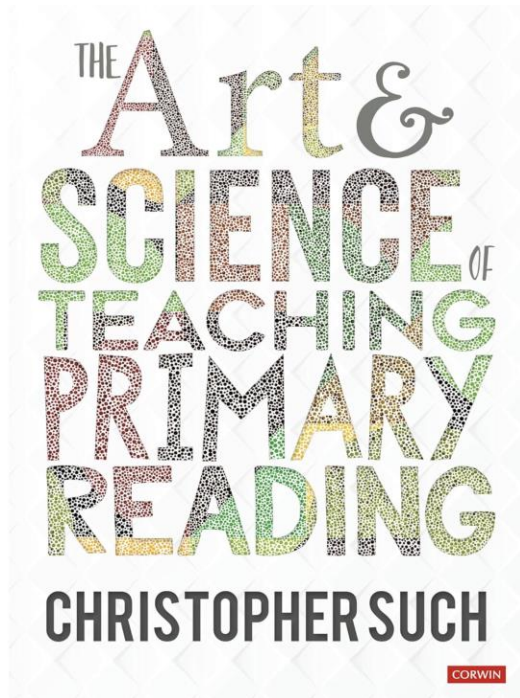
Mixture of local coherence inferences (e.g., 4.) and global coherence inferences (e.g., 1.)
Inferences can be necessary (1-7) or elaborative

Two misunderstandings and an underappreciation

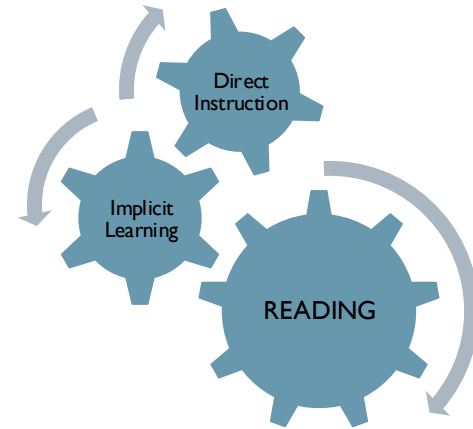
1. Inference making and other strategies as transferrable skills
2. Skills, not knowledge (and equally, knowledge, not skills)
3. Language
 1. Rich and diverse vocabulary that is contextually appropriate
 2. An understanding of sentence and text structure

- Pronouns (he, it, they)
- Nouns preceded by the definite article (*'the cat'* after introducing *'a cat'*)
- Connectives (previously, while, instead, because)
- Missing words (he jumped in the river and his brother *did too*)
- Nouns referred to in a different way (he peered into *the cavern*. The *dark expanse* echoed)

Finding a balance, and a 'reading instruction diet' that is developmentally informed



- Active engagement with stories and other high-quality texts with rich content
- Phonics instruction*
- Fluency practice
- Extended reading
- Close reading
- Vocabulary instruction
- Comprehension strategy instruction



much, much reading

Book Language....

- the substrate across which words (and their contexts) are experienced
- has orthography!
- is more **lexically diverse**



*"I'm wondering what to read next," Matilda said.
"I've finished all the children's books!"*

Some words **most** representative
of book language

stare	deep	shriek
voice	gasp	mutter
begin	whisper	large
horrid	dad	cheer
suddenly	leap	shout
father	sigh	dream
everyone	perfect	each
yell	enormous	towards
world	reply	cave
giant	thought	silence

Some words **least**
representative of book language

yeah	mm	oy
alright	careful	car
darling	shall	yesterday
pardon	poorly	naughty
okay	nursery	yum
whoops	yes	what
oh	penguin	today
hm	want	we
wee	you	doll
jigsaw	whee	oops

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Book Language....



*"I'm wondering what to read next," Matilda said.
"I've finished all the children's books!"*

- the substrate across which words (and their contexts) are experienced
- has orthography!
- is more **lexically diverse**
- carries **denser** information content
- is more **sophisticated**
- contains more **morphologically complex words**
- and words that are more **abstract** and **emotionally arousing**, and **later acquired**
- greater **syntactic complexity** in written language, e.g., relative clauses, passives

children who read more or are read to more (for whatever reason) experience different language, and different opportunities for learning – about language, and the world!

- Lexical features
 - Dawson et al. 2021
- Syntactic complexity
 - Hsiao et al. 2023
- Morphological complexity
 - Dawson et al., 2023
- Emotion words
 - Dong & Nation, 2025
- Children's own writing
 - Hsiao et al., 2024
 - Dong et al., 2024

Book Language and Its Implications for Children's Language, Literacy, and Development

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Department of Experimental Psychology, University of Oxford

Current Directions in Psychological Science

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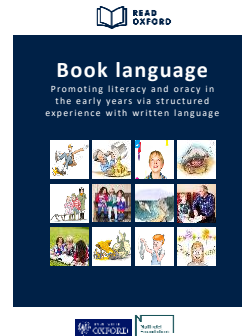
DOI: 10.1177/09637214221103264

www.psychologicalscience.org/CDPS



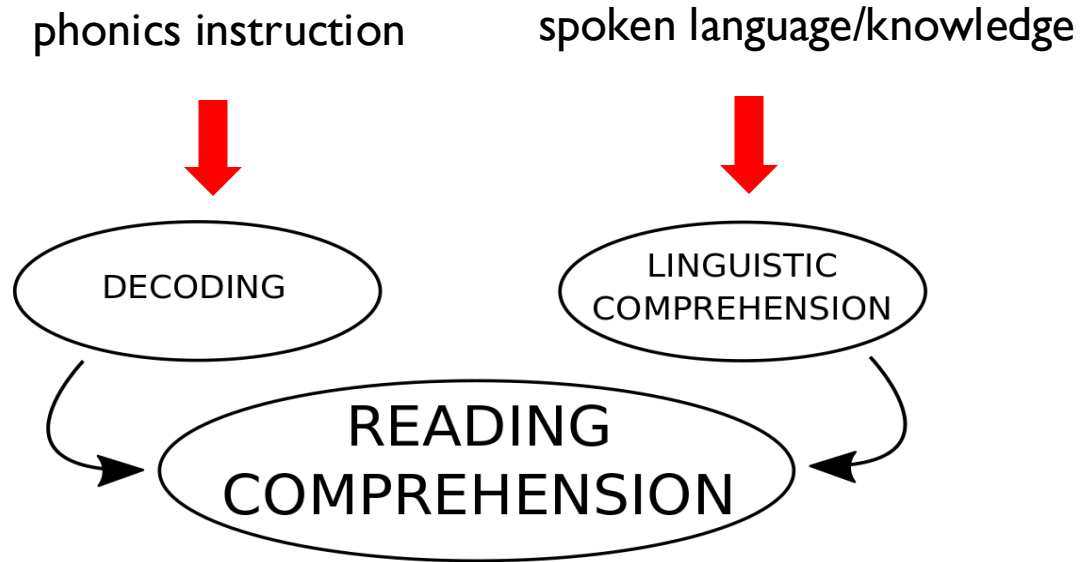
Abstract

The onset of literacy marks a significant change in children's development. Written language is more complex than everyday conversation, and even books targeted at preschoolers contain more varied words and more complex syntax than child-directed speech does. We review the nature and content of children's book language, focusing on recent large-scale corpus analyses that systematically compared written and spoken language. We argue that exposure to book language provides opportunities for learning words and syntactic constructions that are only rarely encountered in speech and that, in turn, this rich experience drives further developments in language and literacy. Moreover, we speculate that the range, variety, depth, and sophistication of book language provide key input that promotes children's social and emotional development. Becoming literate changes things, and researchers need to better understand how and why reading experience shapes people's minds and becomes associated with a range of skills and abilities across the life span.

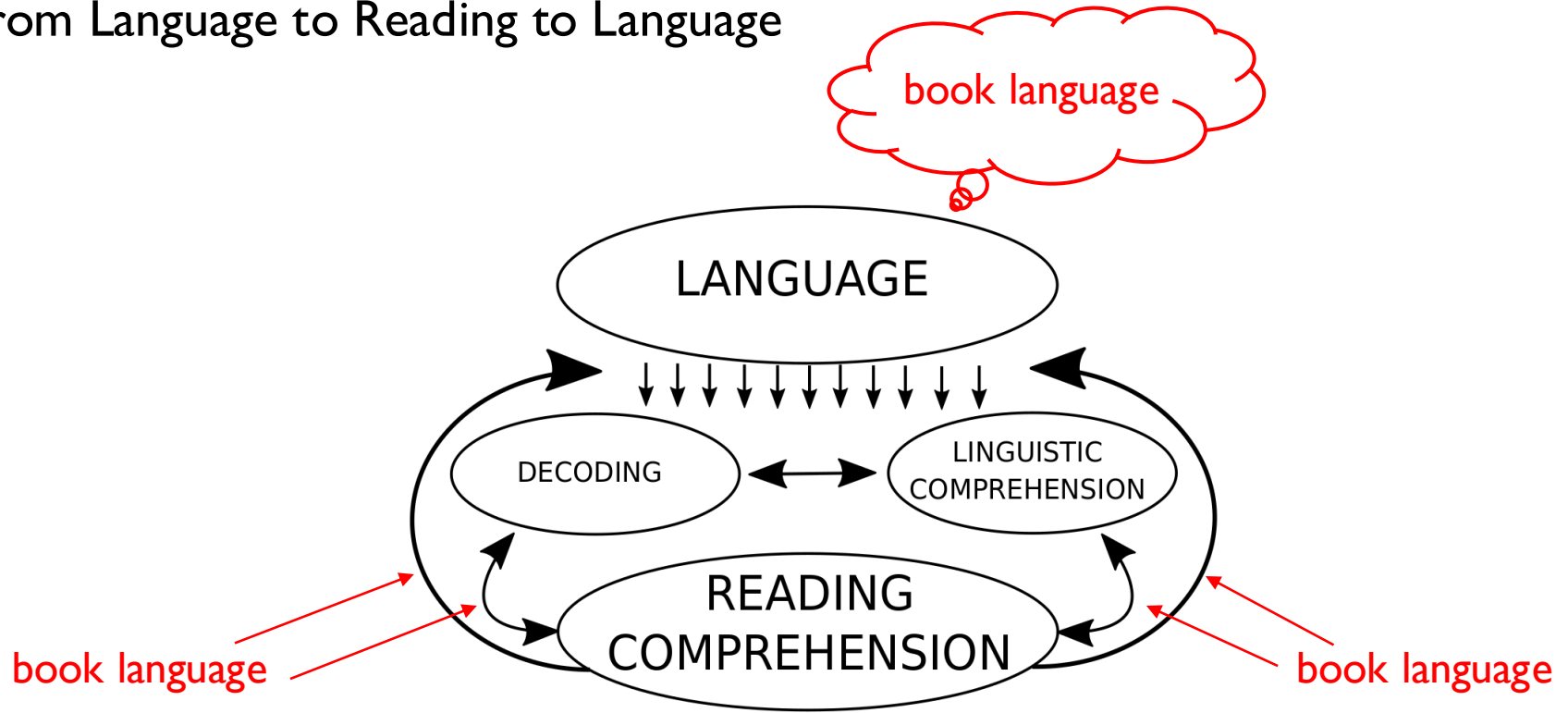


readoxford.web.ox.ac.uk

From Language to Reading to Language



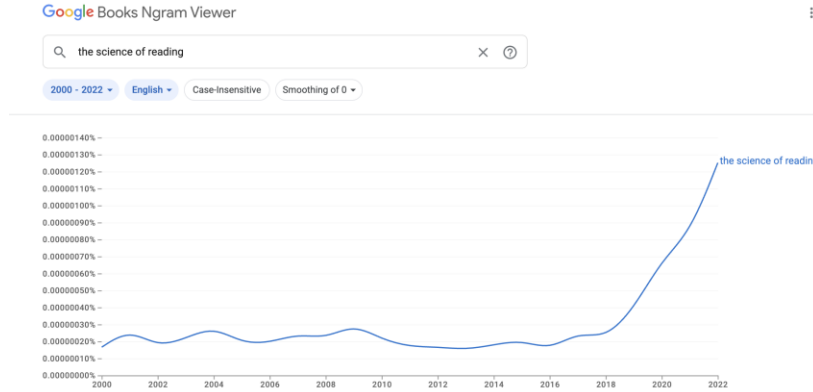
From Language to Reading to Language



Closing thoughts:
science,
and ‘the Science of Reading’

“The science of reading”

books



academic
books and
journal articles

Google Scholar

	In Title	Anywhere in article
2005-2015	53	2,370
2006-2026	257	9,390

Defining science...

Oxford	Systematic study of the structure and behaviour of the physical and natural world through observation, experimentation, and the testing of theories against the evidence obtained
Cambridge	(knowledge from) the careful study of the structure and behaviour of the physical world, especially by watching, measuring, and doing experiments, and the development of theories to describe the results of these activities
Merriam-Webster	Knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method
Collins	the study of the nature and behaviour of natural things and the knowledge that we obtain about them.
Brittanica	Knowledge about or study of the natural world based on facts learned through experiments and observation
Wikipedia	A systematic discipline that builds and organises knowledge in the form of testable hypotheses and predictions about the universe

Adding in reading...

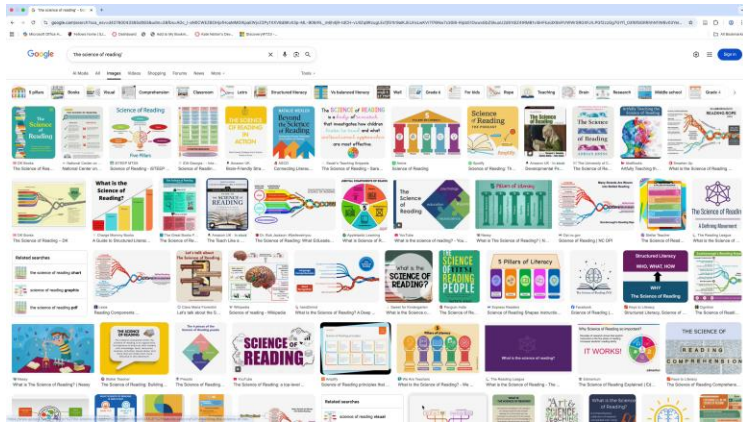
Oxford	Systematic study of reading through observation, experimentation , and the testing of theories against the evidence obtained
Cambridge	(knowledge from) the careful study of reading especially by watching, measuring, and doing experiments , and the development of theories to describe the results of these activities
Merriam-Webster	Knowledge or a system of knowledge about reading covering general truths or the operation of general laws especially as obtained and tested through scientific method
Collins	The study of the nature of reading and the knowledge that we obtain about it .
Brittanica	Knowledge about or study of reading based on facts learned through experiments and observation
Wikipedia	A systematic discipline that builds and organises knowledge in the form of testable hypotheses and predictions about reading

Definitions of “The Science of Reading”

“... the body of work referred to as ‘the science of reading’ is not an ideology, a philosophy, a political agenda, a one-size-fits-all approach, or a specific component of instruction. It is the emerging consensus from many related disciplines, based on literally thousands of studies, supported by hundreds of millions of research dollars, conducted across the world in many languages. These studies have revealed a great deal about how we learn to read, what goes wrong when students don’t learn, and what kind of instruction is most likely to work the best for the most students” (Moats, 2020).

“The Science of Reading”	reading science
Body of knowledge	Building knowledge about reading
That comes from specific disciplines	Via measurement, observation, experiments
About specific aspects of reading (typical, atypical, learning)	To test and build theories
Relevant to education	

Google search returns 10000s of hits!



- some good work and good resources, but many commercial products, and some making very bold claims
- vague statements alluding to:

“The Science of Reading movement....”

“This aligns with the Science of Reading field”

“SoR classrooms”

Danger of ‘the SoR’ being seen as a static entity that is the settled science in ways that might not be evidence-based and ultimately, won’t lead to gains in the classroom

Danger of missed opportunities; unfortunate, given the gains that have been made in nurturing evidence-informed practice



Caution



Caution

Science and Medicine

biomedical science → basic research on biology and disease

evidence-based medicine → applying that research to clinical practice

Science and Education

{ reading science → basic research on how reading works
the science of reading → applying that research to how reading is taught

nuanced terms – so careful work is needed to communicate and translate between science, education and policy



- Huge value of basic science, but caution needed:
 - Just because something is shown in a lab experiment doesn't mean it is directly relevant for teaching, e.g.,
 - WM training and reading comprehension
 - General inference strategies and reading comprehension instruction
 - Eye movements and reading comprehension
- But basic science can identify potential 'pedagogical targets' that are malleable – and together with expertise and experience from the classroom, evidence-informed instruction can build, through applied science, and be evaluated
- Virtuous circle to build knowledge between science and practice
 - The *what, why* and *how*
 - Methods of evaluation and standards of evidence

Mutio obrigada!

Fico à disposição para perguntas e discussões

