Paper 2

THE SCIENCE OF READING

> "At one magical instant in your early childhood, the page of a book - that string of confused, alien cyphers - shivered into meaning. Words spoke to you, gave up their secrets; at that moment whole universes opened. You became, irrevocably, a reader." (Alberto Manguel)[1]

How children learn to read is a miraculous process, and after much research, it is no longer a mystery. While people have been guessing for centuries about what happens, modern science has finally unlocked the secrets of the reading process.

In this paper, we will be looking at the most recent results from neuroscience, and the results of research into the psychology of reading.

On the basis of the science, we will look at what this means about teaching children to read.

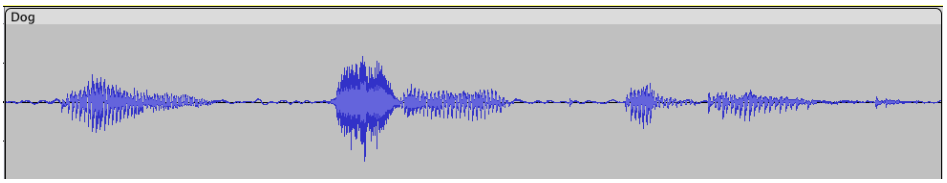
The Key … a Universal Code

What are we talking about when we discuss reading?

> "All known writing systems code the sound of spoken language… Being able to read means being able to decode writing and recover speech."[2]

To put it another way, it's the process of looking at written symbols on a page and translating them into known words.

What does this say? It's a picture of the histogram, or sound wave, of a short English sentence.

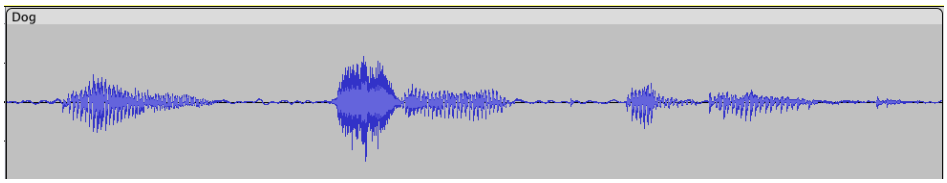


[1] Blevins, W. (2006), *Phonics from A to Z*, Scholastic

[2] Willingham, Daniel T. (2017), *The Reading Mind: A Cognitive Approach to Understanding How the Mind Reads*, *Jossey-Bass, An Imprint of Wiley*

The sentence is this:

I see a dog.



The first bunch of sound (on the histogram – the sound wave itself) is the word "I". The second cluster is the word "see" (the big burst of sound is the "s" phoneme). The third section is "a … dog". You will notice that the sounds run together. They also bear little clear relationship to the seven phonemes (sounds) in the sentence.

Most children learn to speak English by the age of two. It's miraculous. From simple words like "Ma" and "milk" and "book", they end up understanding sentences (like "I see a dog."), then generating their own sentences, and then, wonder of wonders, using them to get what they want.

Learning to speak is natural. It happens *automatically*. It's "hard wired" into the brain.

> "Foorman [Professor of Education at Florida State University] says 'humans are biologically specialised to produce language and have done so for nearly one million years. Such is not the case with reading and writing. If it were there would not be illiterate children in the world still.'"[3]

[3] Blevins, W. (2006)

However, learning to read is *not* something that happens of its own accord.

"Human beings were never born to read,"[4] writes Maryanne Wolf, Professor at the UCLA Center for Dyslexia, and one of the major experts in the field.

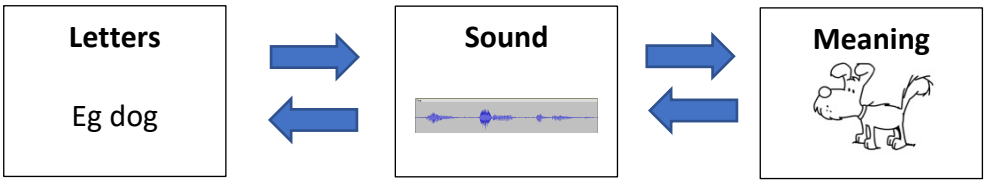
Why is Writing Different?

Because reading and writing as an idea – the notion of **making *marks* that code for *sounds*** - was only invented just under 4,000 years ago (the Semitic alphabet of c1700 BCE)[5]. It was copied by the Phoenicians (c1000 BCE), then the Greeks (c800 BCE), and finally the Etruscans (Romans) in around 700 BCE.

It is a code that was deliberately invented and – like *any* code (morse, sign language, computer code, etc) - has to be deliberately learned.

A B C D E F G H
I K L M N O P Q
R S T V X Y Z

It is a remarkable system. Our modern "Roman" alphabet[6] is a 26-letter code that enables us to translate a *spoken* word like "dog" into three letters (12% of the total code).



Of course, "dog" is the word in English. The French however say "chien" (for dog). The Italians say "cane". The Germans say "hund".

[4] Wolf, Maryanne, (2018) *Reader come Home*, and *Proust and the Squid* (2007), Harper Collins
[5] Crystal, D. (1995), *The Cambridge Encyclopedia of the English Language*, CUP
[6] The original Roman alphabet (shown here) had only 23 letters. In later centuries the letters J, U and W were added, to map extra sounds, and so the standard Western alphabet has 26 letters.

There is no international word/sound for dog. It varies from one language to another, but there *is* an international code for the letters.

That's what children have to learn. Once they have done that, they can unlock **all words**.

As an adult, and as a good reader, it is easy to forget how important these basics are. By the time we are grown up, reading is automatic. We can read at up to 500 words a minute[7] and don't even see the individual words.

Here's an experiment to show what's going on. Four words, two made up, two real ones:

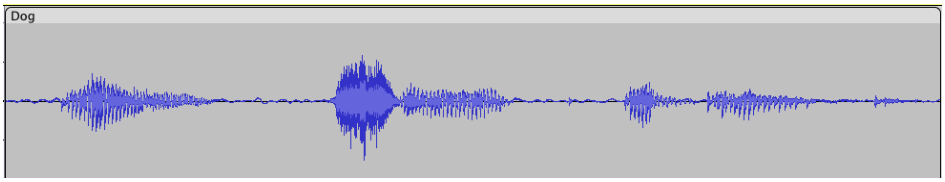
1 departition	*(11 letters)*
2 magnetoencephalography	*(22 letters)*
3 nuck	*(4 letters)*
4 trichotillomania	*(16 letters)*

Numbers 1 and 3 are *not* real – but it was easy to say them, wasn't it (to "decode" the letters)? The numbers 2 and 4 *are* real words, which despite their length, you could also say. Number 2 is a medical procedure (images of the brain). Number 4 means "an inexplicable need to pull out your own hair".

In saying them, you are using the pathways that children need to learn – letters … to sound … to meaning.

Seeing Words or Seeing Sounds?

When children learn to speak, they hear continuous speech.



I see a dog.

As our example makes clear, the sounds "run" together. The sounds of two words ("a dog") are continuous. There are no hard edges, no discrete packages in speech.

Children have to be taught that "dog" is a **word** – sounds representing a thing, symbolized or encoded as a set of letters.

[7] Dehaene, Stanislas (2010), *Reading in the Brain, the New Science of How we Read*, Penguin

In an enriched environment, with lots of pictures and lots of books, the idea of words becomes very familiar to children over time – ideally in the first several years of life.

Does this mean that we teach children to read by getting them to memorize the words themselves?

After all, children know thousands of words. One estimate is that they have a vocabulary of 10,000 words by the time they are five years old.[8]

The modern science answers this question emphatically: **NO** (to teaching the words, as opposed to teaching the letters).

> "Phonics … work[s] better than whole-word teaching … [because] recent research on the brain's reading networks proves [the whole-word approach] was wrong."[9]
>
> "Eye movement studies have revealed that skilled readers attend to almost every word in a sentence and process the letters that compose each word (McConkie and Zola, 1987). Therefore reading is a "letter-mediated" rather than "whole-word-mediated" process (Just and Carpenter, 1987)."[10]
>
> "What percentage of the three major inquiries in the US, the UK and Australia since 1998 recommended *not* teaching the alphabetic code early, systematically and explicitly? What percentage concluded that whole language or whole word approaches would be most effective in raising literacy? *[The answer to both questions:]* Zero."[11]

The code is *not* about acquiring words. It is about **decoding the letters** – the *sounds* of the words.

> "[Children] must learn the alphabetic principle; the idea that letters correspond to sounds."[12]

Does this mean a set of complex options, tailored to the individual? No. On that topic Mark Seidenberg shares this illuminating comment:

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[8] Merritt, D. (2016) *Typical speech and language development for school age children* http://ctsec.org
[9] Dehaene (2010)
[10] Blevins, W. (2005) *Phonics from A to Z*, Scholastic
[11] Stone, Lyn (2018), *Reading for Life*, Routledge
[12] Willingham (2017)

> "How do children learn to read? … The answer is the same for all children. Cultural, economic and educational circumstances obviously affect children's progress, but *what they need to learn does not change*."[13]

One of the most persistent legacies of the "reading wars", which raged for decades, is that phonics is bad for children. Not just unfashionable, but actively harmful.

Here is an instructive rebuttal from one of the pre-eminent experts in the field, Professor Anne Castles[14].

Myths about Phonics Instruction

Myth	Evidence	References
Phonics teaches children to read nonwords	The aim of phonics instruction is to equip children with the skills to sound out words independently. Nonwords are primarily used not for teaching but for assessment, to index children's phonics skills independently of their word knowledge. An analogy would be measuring heart rate to assess cardiovascular fitness: we don't train the heart to beat more slowly, but we assess this function to measure how effective a fitness training program has been.	Castles et al (2009)
Phonics interferes with reading comprehension	At a basic level phonics supports comprehension by allowing the child to link an unfamiliar printed word with a familiar word in oral vocabulary. Phonics also supports the development of fluent word reading ability, which in turn frees up the child's mental resources to focus on the meaning of a text. Erie et al's (2001) meta analysis found that children taught by a systematic phonics method made gains in text comprehension as well as in word reading and spelling.	Perfetti & Hart (2002) Ehri et al (2001)
English is too "irregular" for phonics to be of value	It is true that the English writing system is complex, and many words violate typical letter word	Share (1995)

[13] Seidenberg, Mark (2017), *Language at the Speed of Sight, How we read, why so many can't and what can be done about it*, Basic Books

[14] Anne Castles is a leading cognitive scientist, the author of over 100 articles and books and a board member of *Scientific Studies of Reading*

	mappings. However, learning phonics will still take a child a long way: more than 80% of monosyllabic words are completely regular and, for those that are not, a "partial decoding" will often bring a child close to the correct pronunciation, which can then be refined using oral vocabulary knowledge.	
Phonics is boring for children and turns them off reading	Phonics instruction is often portrayed as robotic and mechanical, but this is at odds with the array of engaging and enjoyable structured phonics programs currently available. And, through its positive effects on reading attainment, phonics instruction is associated with greater motivation to read, more extensive reading for pleasure, and higher academic self-esteem.	Kirsch et al (2002) Anderson et al (1988) McArthur & Castles (2017)

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How Does the Brain Read?

> "When children learn to read, they are building neurological connections between parts of the brain that store letters (visual information) and sounds (phonological information)."[16]

Modern science can now tell us what happens when we read.

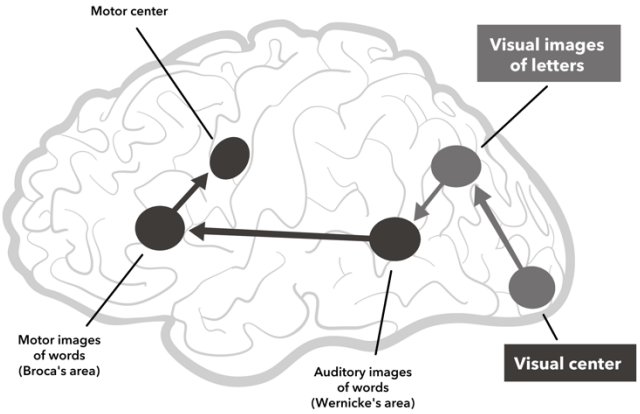
In the nineteenth century, important discoveries were made in neurological science. A French doctor called Paul Broca found in the 1860s that injuries to parts of the brain had catastrophic effects on speech and understanding. The crucial speech center he found is still called "Broca's area".

In Germany, a decade later, Carl Wernicke found another key center – which is still called "Wernicke's area".

Here is a simplified "map" of the major language processing centers:

[15] Castles, A. et al (2018) "Ending the Reading Wars: Reading Acquisition from Novice to Expert", in *Psychological Science in the Public Interest*, 19

[16] Buckingham, J. et al (2019) "Systematic and explicit phonics instruction: A scientific, evidence-based approach to teaching the alphabetic principle", in *The Alphabetic Principle and Beyond*, PETA



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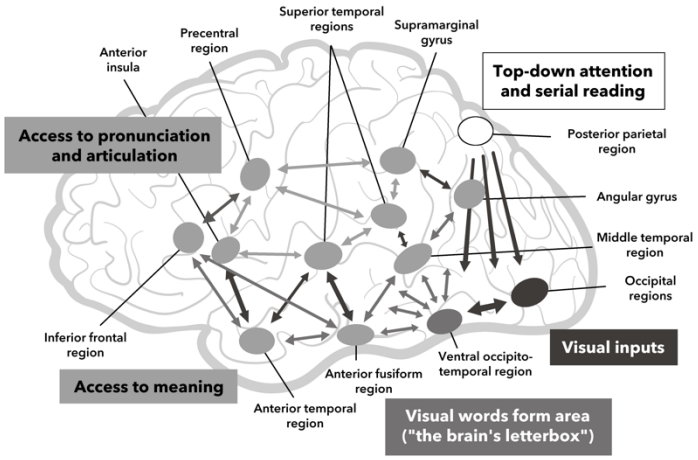
What these scientists established beyond any doubt is that the brain processes language in specific areas. It was thought that Broca's and Wernicke's areas were the key points. However, modern imaging techniques (MRis and PET scans) have refashioned our understanding completely.



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These are the words of Professor Dehaene, one of the world's leading neurologists as he describes *how* the brain reads:

> "The left occipitotemporal "letterbox" [language centre] identifies the visual form of [the letters]. It then distributes this visual information to numerous regions, spread over the left hemisphere [of the brain], that encode word meaning, sound pattern, and articulation."[19]

[17] Dehaene (2010)
[18] Dehaene (2010)
[19] Dehaene (2010)

In common English:

> The eyes read the letters (eg dog). This is fed to the visual input section of the brain (rear left hemisphere). The word is decoded, connected to its sound and meaning, and referenced to one's full vocabulary bank (different but adjacent sections of the "letterbox' region on the left side). In the process, the brain connects all these elements together and understands what is being read (comprehension).

All this happens in milliseconds for those who are competent readers.

For beginning readers, however, the neural connections have to be set up by very careful instruction – letters – sounds – meanings (and while we're at it) spellings.

The science has now confirmed beyond any doubt that all people use the visual centers of the brain – particularly its "natural" (or preferential) inclination to search for meaningful shapes (like faces) and lines. Shapes – lines – letters – words – meaning.

It is a classic of linguistic history that only one letter has endured unchanged for nearly 4,000 years – from the time of the earliest alphabet[20]. Which one is it, and why is it significant?

The answer is

O

It has survived utterly unchanged … because it is the perfect exemplar of a symbol used to represent sounds. The "o" is easy to memorise – not unlike a face (which is *not* accidental). It is instantly recognizable, whether tiny or big. It is easy to draw – one stroke only. And it expresses one of the most important of all vowel sounds – the open "o". In fact, it is a *like* an open mouth.

Unlike a hieroglyphic[21]

which typically has many lines, the letters of our alphabet require on average just three strokes[22] (eg A, B, F, H, etc) and *never* more than four. It is a brilliant system.

[20] Crystal, D. (1995)
[21] The pictographic Egyptian writing that predates the alphabet by a few hundred years. This example shows an "L".
[22] Dehaene, S. (2009)

The Challenges

Working with children, as every teacher knows, means understanding their limitations. These have enormously important implications for structuring classrooms.

Let's look at the big three challenges[23] and their implications for teachers:

(1) Working memory

Scientists have long suspected that people can only keep a small number of items in their short-term memory. Imagine a shopping list. How many items can you recall without forgetting something? If you had someone read out a phone number, and couldn't write it down – how long would you remember it?

A rough rule of thumb is seven (items).[24] More than that, and things fall out of the short-term memory.

For teachers, this means that teaching *new* material – for example new words – should not consist of more than a small number all at once.

Working memory then has to be activated, and after repetition, transferred into long- term memory. The more repetitions, the more "overteaching", the more redundancy – the better. It is up to the teacher to make this fun, but note – this is *not* "drill and kill" – it is catering to the child's need *not* be overloaded … for *that* way leads to stress and burnout.

(2) Processing speed

Children's brains are like computers. Some are very fast, they can process lots of things at once; yet others struggle - they can only digest a few things at once.

If a child shows these signs[25] - repeats parts of the sentence, has trouble explaining a concept easily, takes a long time to complete a task, forgets instructions, becomes overwhelmed by information, gets worried about time – you are looking a child whose mental competencies are being challenged too much. Slow down. Offer more support. Don't let them get anxious.

(3) RAN – random access naming

[23] Stone, L. (2019) *Reading for Life: High Quality Literacy Instruction*, Routledge
[24] Miller, G. A. (1956). "The magical number seven, plus or minus two: Some limits on our capacity for processing information". *Psychological Review*. 63
[25] Stone, L. (2019)

This is the ability to automatically access the name of something. Imagine you are on a quiz show: you are shown a picture of a flower and you have to remember the name for it. Is it a chrysanthemum, a fuchsia, or a rhododendron?

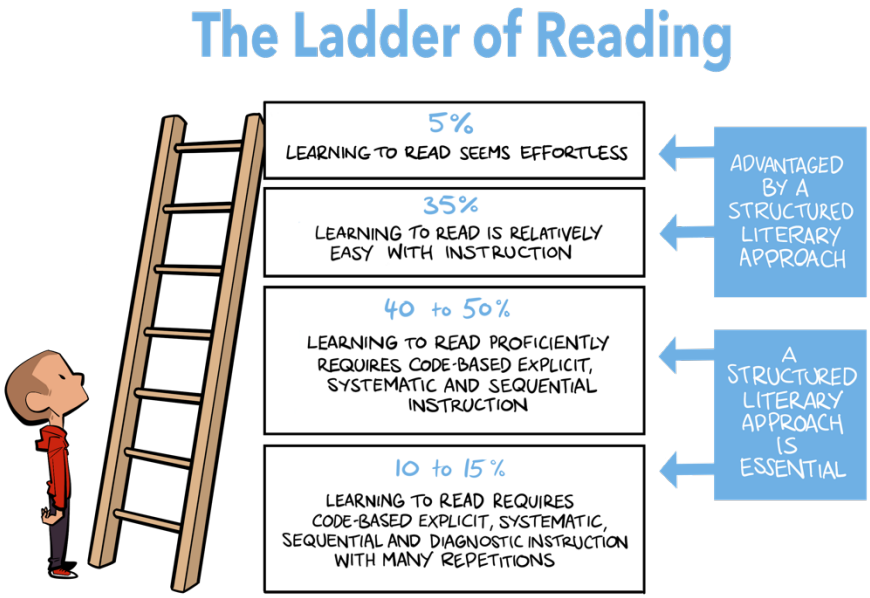
This is the problem of RAN. A child will have been shown many letters and words, and over time, they will memorize them. When they see them again, can they instantly recognize them in order to read them?

Once again, teachers need to be able to detect the symptoms of what may be developing troubles. Here is what one practising remedial teacher says: "[The solution has to be] ordered, controlled, distraction-free practise, founded on the broad base of letter-sound relationships"[26].

The Ladder of Reading

All of this leads us to the issue of individual differences.

Not all children are the same in their needs. This *particularly* relates to the acquisition of reading.



[27]

[26] Stone, L. (2019)
[27] Dr Jan Hasbrouck, "The Science of Reading: An Overview", *The Reading League*, 2019, https://www.youtube.com/watch?v=YTvHSgoTeZE

It has been noted, by none other than the National Reading Panel[28], that there are strata of difficulty (or competencies) when it comes to learning to read.

> "The National Reading Panel reported that about 5% of children find learning to read to be a readily achieved process. About 60% find early reading difficult, and a third to a half of that number have great difficulty…. Research shows that the quality of the teacher is the single greatest in school influence on student achievement."[29]

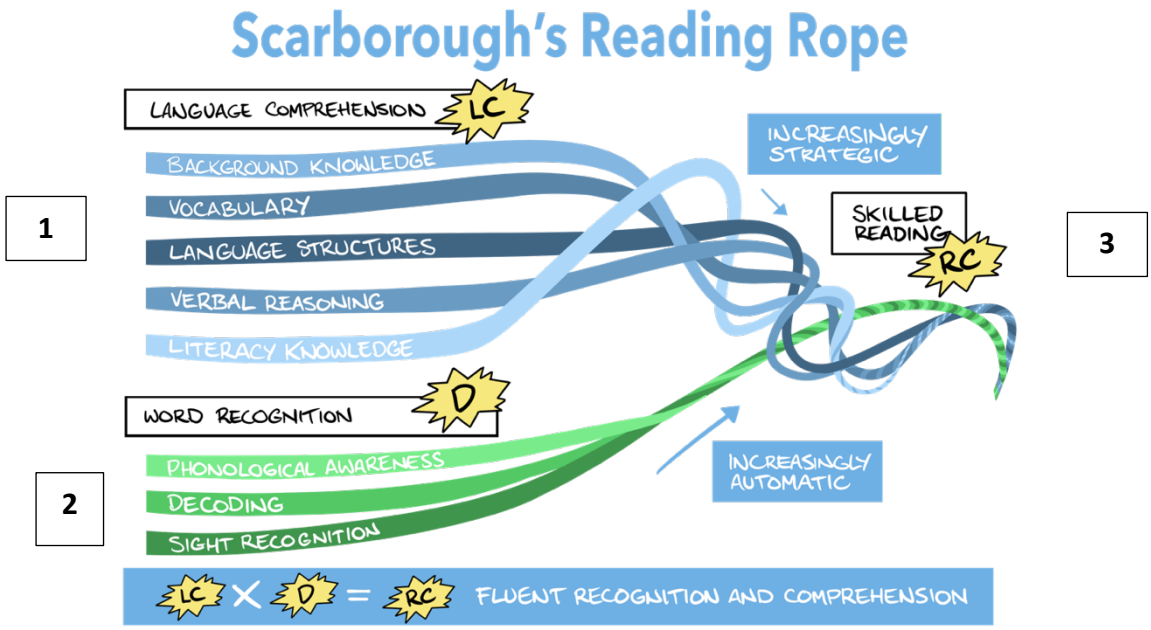
The diagram above shows a rough breakdown.

This powerful acknowledgement of differential abilities can be combined with earlier comments about the challenges. For a lot of children, reading is ***not*** a skill that comes easily. It requires years of careful teaching and a strict adherence to an evidence-based program.

What Does the Science Say About Effective Reading Instruction?

The key to this has been well- established by the research.

Dr. Hollis Scarborough, the famous American psychologist and literacy expert, came up with a schema in the 1990s which deconstructs and identifies what is involved in learning to read.



[28] National Reading Panel (2000)
[29] Hempenstall, K. (2016), *Read About It: Scientific Evidence for Effective Teaching of Reading*, Centre for Independent Studies

[30]

The key elements of this model are that it involves an 'interweaving' (like a rope or thread) between three distinct but related components all involved in acquiring reading skill – two at the input stage, and one at the output end:

(1) Language Comprehension (LC)

Children must bring to the task of reading background knowledge, a knowledge of words (vocabulary), an understanding of language (syntax etc), the ability to connect ideas (inference) and some knowledge of the common literacy forms (like genre). They must understand the standard conventions of written English.

(2) Word Recognition (D = decoding)

Children must have phonological awareness, be able to recognize units of sound (phonemes, syllables) and to learn to 'decode' these elements from print.

These interweaving elements, over time, lead to:

(3) Fluent Reading and Comprehension (RC – reading comprehension)

The processes become increasingly automatic and sophisticated, leading to "fluency" in reading, with greater and greater comprehension.

If any part of language comprehension (LC) is missing or minimal (eg a non English speaking child), there is a problem. If a child can't decode (D) effectively, there is a problem.

Only when **Language Comprehension** and **Decoding** are properly formed in the child's skill set can the full linguistic "weaving" (the rope) take place so he can read fluently and with good comprehension (RC).

The Need for 'Structured Literacy' Instruction

The science has come down very much on the side of a 'structured' approach. Episodic interventions, or a random approach, or 'balanced literacy' (a mixed approach), have been shown to be both inefficient and confusing.

This means instruction for beginner readers needs to be:

[30] Scarborough, H. S. (2001). "Connecting early language and literacy to later reading (dis)abilities: Evidence, theory, and practice" In S Neuman & D Dickinson (Eds), *Handbook for research in early Literacy* Guilford Press

(1) Systematic

Working from a pre-existing plan that captures all necessary elements (phonological awareness, phonics and so on); sequenced (from easy to hard, foundational to more complex) and one which avoids confusion (eg avoiding b and d being taught together).

(2) Explicit

Not expecting children to figure it out or guess, but giving ***direct*** instruction[31]. This should start with a demonstration, move on to guided practice (whole class or small group), then to independent (individual) practice. This has been summed up by one expert as "I do" (the teacher models the teaching point),"'We do" (the group practise it) and then "You do" (the child does it on his own)[32].

(3) Effective

The focus must be on what actually works in the classroom. It must include constant checking and evaluation – informed by the key questions **Who?** (who am I teaching), **What?** (what does he need to do to improve) and **Is it working?** (evaluation and feedback).

It is important not to place too great a load on children's working memory, particularly in the early stages. Working from simple phonemic clusters (eg cat) to more complex phonic elements (eg bread) is vital.

Repetition and redundancy (sometimes called "overteaching") are essential to ensure that the child can commit each element to his long- term memory and retrieve it automatically.

In the beginning, use of "decodable" readers is backed by the science.

A common argument often put by opponents of the research – that phonics and decodable texts are not real literature – ignores the fact that the research sees such things as where children start – not where they finish.

Fully formed authentic texts will come later; they need to learn the code and master reading first.

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[31] Piasta, S., Hudson, A. (2022) Key Knowledge to Support Phonological Awareness and Phonics Instruction, *The Reading Teacher*

[32] Dr Jan Hasbrouck, "The Science of Reading: An Overview", *The Reading League*, 2019, https://www.youtube.com/watch?v=YTvHSgoTeZE

To Sum Up

Learning to read is a miraculous process. What we ask children to do is really quite complex.

Although based on their prior knowledge of spoken English, it requires very careful teaching of sound-letter relationships – phonics – the code that allows them to unlock all words.

All the research is unequivocal: that is the way to have them master reading.

The scientists now have a clear idea of what is going on in the brain and of how the various elements of linguistic input work together.

Because we are asking a lot of most children, many of whom might struggle (see the Ladder of Reading), the process needs to be taken very slowly and to be as explicit and systematic as possible.

The good news is that with this sort of application, and the untiring use of evidence-based techniques, children **CAN** successfully learn to read.