The magical art of magnetic resonance imaging to study the reading brain

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This article, published in *Frontiers for Young Minds*, a journal which makes scientific articles accessible for younger audiences, discusses how magnetic resonance imaging (or MRI) can be used to study the secrets of the human brain, including how it looks, works, grows and learns. The young people in your life may find it interesting!

Introduction

Do you like to read? Have you read the Harry Potter books? Reading is an ability that is learned through instruction (e.g., a teacher or parent teaching you) and needs much practice at home or in school. Many different things help us become great readers. As we grow up, we have many experiences, and our bodies, our thinking, our feelings, and the environment around us are always changing. Early in life, we learn the easier skills, like understanding the meaning of certain sounds, recognising faces, or walking. In fact, learning starts even before we are born! As we grow, we learn more complex skills, like speaking words and sentences, reading, and how to interact with others. Learning new skills goes hand-in-hand with the development of the brain. But many different things can affect how we develop, including changes in our environments, our learning experiences, or even our DNA, which is the biological information that our parents pass on to us.

This is also true for reading. Reading is an ability that we practise for a long time before we become good at it. But this practice starts long before we pick up our first book or go to school. Before we are even born, we start listening to sounds and hearing basic parts of language. These experiences shape areas of the brain that later help us to develop reading skills. In 1983, *a professor named Jeanne Chall said* that learning to read happens in several stages (Figure 1). Today we know that many different factors can affect these reading stages and that learning to read can differ among individual children and across the globe. *Such differences exist because* many things can affect reading development, like where we grow up, which language we speak, the vocabulary of our language, our ability to play games with speech sounds (e.g., say "banana" without saying the sound /b/), and how good we are at understanding stories.

How the brain learns to read

Brain imaging techniques, such as magnetic resonance imaging (MRI) make it possible to study how the brain learns. MRI is like a big camera that can take images of different parts of the body – for instance, the brain. MRI works by measuring signals coming from water molecules in the body. Every single part of the body is a little bit different, and because of that, the MRI signal coming from each part differs a bit, too. Using computers scientists can create detailed

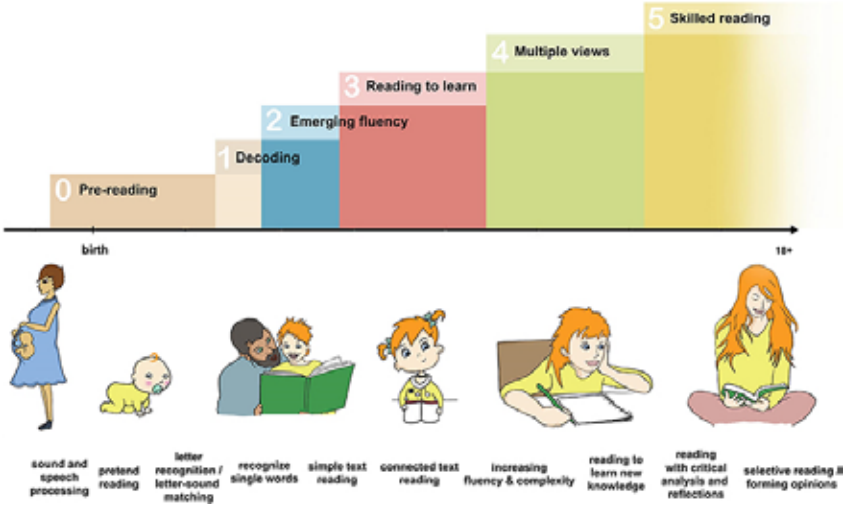

Figure 1. Step-by-step, we learn to read. There are several stages that we may take to become fluent readers. Learning to read starts from the time a baby starts growing and continues throughout schooling and until young adulthood

(Illustrations: N. M. Raschle; the top part of this graphic is adapted from *Chall*).

images from these signals (if you are interested in reading more about the physics of MRI, you can read '*The physics of MRI and how we use it to reveal the mysteries of the mind*' written for children by Kathryn Broadhouse). MRI allows us to study both how the brain works while we are doing or feeling something (the brain's function), as well as how the brain is built (its structure).

When the brain grows and learns, connections between different parts of the brain are created. Over time, these connections build networks. Networks are different parts of the brain that work together. Like a well-trained musical group, brain networks help us learn skills like reading. While we learn, the cells of the brain (called neurons) connect to each other by reaching out their tiny arms (called axons) or even by growing new arms. Over time, many axons connect to each other and build long highways, called white matter tracts. These highways allow information to travel from one part of the brain to another. Using MRI, scientists have learned that we can read because different parts of the brain become more active and communicate with each other as we learn. These brain areas have funny-sounding names: occipitotemporal area, or the 'letter box' of the brain (where we process letters and words); temporoparietal area (helps us to play with the sounds of our language, such as figuring out that 'banana' without the sound /b/ is 'anana'); and inferior frontal region (the 'captain' that directs us). When brain areas talk with each other often, the highways can become stronger.

An important highway for reading is a collection of axons that we call the arcuate fasciculus, because it is shaped like an arc. Within the network of brain areas that help us to read, paths like the arcuate fasciculus allow the transportation of information from one area to another. In children who struggle with reading, the brain's reading network is sometimes built a bit differently or the information takes other routes. In some brains, the highways transporting the information between the reading areas may be narrow, like having just one lane of traffic instead of two. Or the highways may be less smooth, like a road with a bumpy surface or many traffic lights. These differences make communication between the brain regions challenging and, in some children, reading becomes a difficult task (Figure 2).

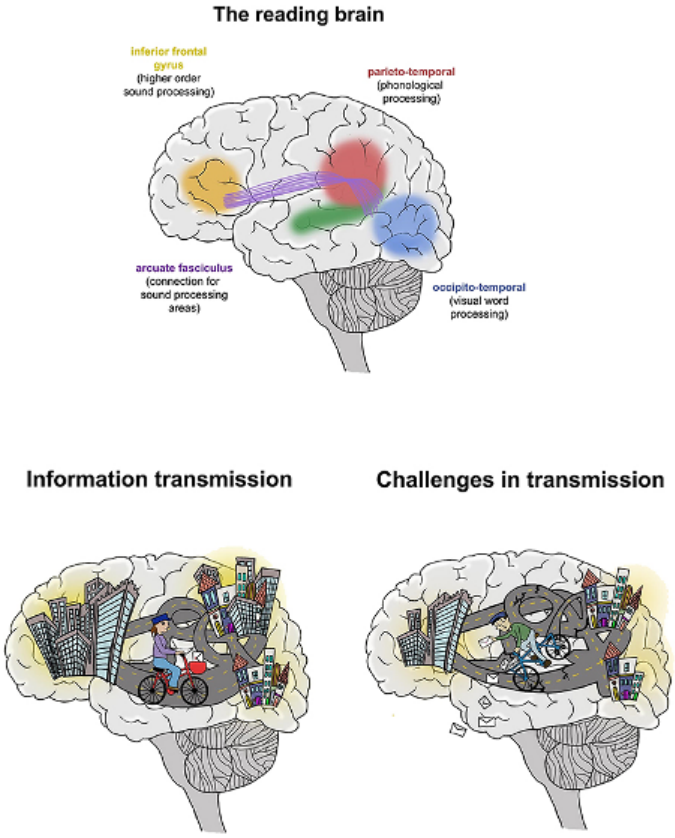

Figure 2. The reading brain. At the top, you can see the names and functions of brain regions that are used for reading. Together, these brain regions form the brain's reading network. During reading, these areas become more active and talk with each other. Sometimes information transmission in this network goes smoothly (bottom left), but sometimes it can be more challenging (bottom right)

(Illustrations: N. M. Raschle).

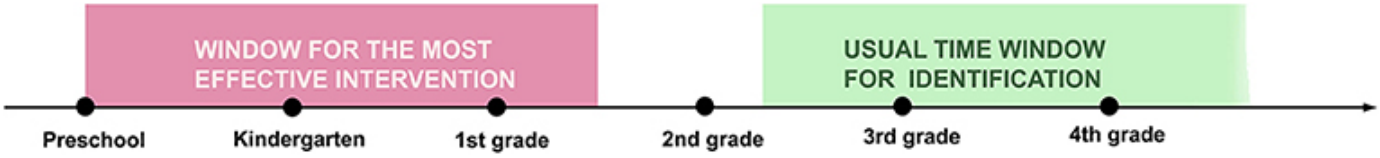

Figure 3. The dyslexia paradox. In most children, reading problems are not discovered until the second or third grade (green area). However, the best and most effective window for helping them is much earlier (pink area).

Developmental dyslexia and the dyslexia paradox

The development of the human brain is complex, and it is not surprising that some brains develop differently than others. Sometimes these differences can have consequences that are discovered only much later in life. In a regular school class, about one or two in a class of 20 children find learning to read extremely challenging. Many researchers would like to be able to predict, as early as possible, which children may struggle with reading. It is much easier to help a child when the problems start than to wait and try to help them years later. When we are young, our brains are much more flexible for things like language, and this makes it easier to learn new things and address problems. Also, if help comes very late, some struggling children may become sad, frustrated, or experience bullying and may even stop wanting to learn. Some parents may become impatient and think their child is not trying hard enough. These are important reasons why scientists want to help identify these children as early as possible.

Some children who have reading difficulties may be diagnosed with developmental dyslexia, which is a type of reading disability. Usually, this diagnosis is made after the children have been trying to learn to read for quite some time (like in second or third grade). The struggle to read has nothing to do with missed practice, laziness, or lack of trying. However, by this time, children need to catch up quite a bit to do well in school, which is a big challenge. As mentioned before, research has shown that the best time to help children with reading is in kindergarten or first grade, when the brain is a lot more mouldable. The difference between when we identify children who struggle with reading and when they could best be helped is called the dyslexia paradox, because it is something that contradicts itself (Figure 3).

Scientists have shown that we can detect early signs of reading difficulties through spoken, written, or computer tests. We were curious to know whether MRI could also be used to detect early differences in the brains of children who would ultimately have difficulty reading. We found that *young children* who later *struggle with learning to read* seem to have a *different reading network*. But, with support and the right teaching, this can be changed.

The magic of helping others

Unlike the wizards in Harry Potter, scientists cannot read people's minds or use any other forms of magic. But we have come up with various methods and technologies to study the learning brain, one of which is MRI. MRI has allowed scientists to study the parts of the brain that enable us to read and has shown us what might be happening in the brains of children who struggle with reading. With each study, scientists learn more about how we learn and why it is harder for some people to learn than it is for others. Eventually, this information may help us to support each child to reach his or her goals. And being able to do so is true magic.

Glossary

MRI: Stands for magnetic resonance imaging. MRI allows scientists to take images of all parts of the human body. It works with strong magnets and radio waves.

Neuron: Nerve cells within the brain or spinal cord.

Axon: A part of the nerve cell that can connect with other cells and in this way transport information from one cell to another cell.

White Matter Tract: A collection of many axons connecting different brain areas with each other.

Dyslexia: A learning disorder that involves difficulty reading due to problems identifying speech sounds and learning how they relate to letters and words.

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