How to Read: A *Written* Guide

By **Ben Tauber**

"Dylan, like many other dyslexic children, went to great lengths to disguise his challenges. He employed his excellent oral vocabulary, sophisticated humor and emotional intelligence to keep us all distracted from the thing that privately shamed and haunted him: Dylan thought he was stupid." Kyle Redford, a teacher and a mother of a dyslexic son, retells her son's experience with dyslexia. "Too many educators still whisper the word, too few students get identified early, and many don't get identified at all... Dylan had to wait until fourth grade to learn to read." Lack of awareness around dyslexia is confounded by the many questions science still has about dyslexia.

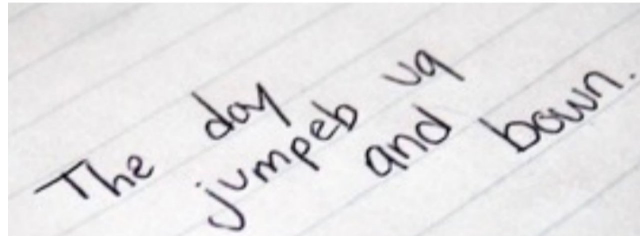
It is common for people to associate dyslexia with flipping letters such as "b" and "d" and poor spelling. Although not all people with dyslexia have the same experiences, some common behavioral characteristics are poor spelling, poor reading speed, and poor reading accuracy. Given the dynamics of a classroom these factors can compound and cause other issues. Students who struggle with reading and are required to do so in front of a group will become experts in evading this uncomfortable situation. Deirdre Griffin, a registered educational psychologist, writes "Some respond by 'acting out' or becoming upset about going to school or completing homework, others choose to give up – deciding it's better to not bother than to try and fail, while others opt to become the class clown." Aside from reading and writing, Griffin describes many other tasks that may be especially difficult for those with dyslexia. These include: poor planning, organization, and difficulty remembering dates including the current one. All of these factors can have deleterious effects on a student's self-esteem. To understand how differences in reading abilities arise, it is important to understand how humans' ability to read evolved in the first place.

The human brain has evolved to recognize faces because there is an evolutionary benefit to recognizing friend and foe quickly. Similarly, color vision was selected for as this gave us advantages such as determining the quality of food. These energetically expensive systems evolved due to the immense evolutionary pressure to be efficient at these behaviors. Many of our ancestors, stretching deep into the vertebrates, share these abilities. This demonstrates how far back in time these traits developed. The time scale for the evolution of these traits is on the order of hundreds of thousands of years. Our ability to read, on the other hand has only been around for approximately 5,400 years, as this is when the first written language formed. There are *color-vision* and *face recognition* regions to the brain because evolution has selected for it. However, there has not been time nor significant evolutionary pressure to create a *reading center* of the brain. Yet, as evidenced by your understanding of this text so far, many people have little difficulty reading. How can we accomplish such a feat if we did not evolve to have a reading center in our brains?

Stanislas Dehaene, a French neuroscientist working at *Institut national de la santé et de la recherche médicale* and a professor at the College of Paris, proposed the theory of neural recycling. "We can learn to read because we have a region which we inherit from evolution," Dehaene says; "[this region's] function is sufficiently close to reading and we can recycle [it] for this function." An area in the left posterior temporal lobe is highly tuned to respond to detailed images such as faces, objects, lines, and shapes. Dehaene proposes "We recycle areas that have to do with object recognition, shape recognition because our brain did not evolve for reading." This area of the brain has been termed the visual word form area. Multiple studies give strong evidence that this area is the site of grapheme interpretation and was recycled from other responsibilities. A

study compared the activity of the visual word form area in Israeli and American participants. When the known language was shown to the participants, functional MRI showed increased activity. However, when Hebrew was shown to the American participants and vice versa no increase in activity was noted. This indicates that the visual word form area is especially tuned to respond to letters we are familiar with. Evidence that the visual word form area evolved for purposes other than reading comes from an interesting observation. When first learning to write, children will often write their letters in a mirrored fashion, as depicted in Figure 1. It is unlikely that children have seen mirrored letters or that anyone is teaching children to write mirrored letters. Dehaene proposes it is likely that mirrored writing is a remnant from the visual word form area's previous responsibility as a face and object recognition center. When you see a picture and the mirror image of that picture, your eyes receive completely different sets of data. However, your brain is able to determine that the content is the same. This phenomenon is known as symmetry generalization and is very useful for objects and faces. However, letters require more specificity so this generalization must be unlearned, demonstrating neural recycling. Given the evidence for neural recycling and brain imaging, the visual word form area has been shown to be key in grapheme analysis. Grapheme analysis is one large component to the comprehension of the written word however; a word must be represented phonologically in the brain as well. This phonological representation occurs in Wernicke's area.

Figure 1 It is common for all children to write letters backwards. This may be evidence of neural recycling and not necessarily dyslexia. Image Courtesy of understood.org.



In 1993 Monica Strauss Hough, a researcher at East Carolina University, detailed the experience of Patient R.C.

"R.C. was a sixty six-year-old female who suffered to left hemisphere strokes verified by CT scan and neurological examination. After the first stroke, the CT revealed a lesion involving the posterior portion of the first temporal gyrus."

R.C. had her stroke in Wernicke's area resulting in death of the brain tissue and loss of function of that brain region. Her deficits included many phonological abnormalities including: inability to complete animal naming, inability to read, and poor auditory comprehension. This and earlier case studies lead researchers to hypothesis that Wernicke's area is heavily involved with phonological processing. In August of 2017, Kamel El Salek et al. used functional magnetic resonance imaging to look at participants' brains when completing reading tasks. Their aim was to more accurately and consistently identify Wernicke's area for brain mapping prior to brain surgery. El Salek writes "As a reading comprehension task, [incomplete sentences for which participants had to fill in a blank] can activate areas in the posterior temporal cortex that pertain to language processing." This technique allows for the highly precise identification of a brain structure needed for surgery. The authors reported that this specific type of reading test more precisely and consistently activated Wernicke's area as compared to word generation from a single letter prompt or word generation from a category prompt. Salek proposes the success of this test, as compared to the other tests, is due to participants simultaneously reading and semantically representing phonemes. Semantic representation of phonemes or phonological representation is the ability to cognitive relate the sound combinations that comprise a word. This experiment provides further evidence for the phonological importance of Wernicke's area.

Given the need for proper phonological representation in reading it was previously thought that this was the area in which dyslexic people struggled. French cognitive scientist Frank Ramus describes his work with this theory: " [we] initiated a series of ex-

periments tapping the phonological deficit in dyslexia and, against our expectations, none of them was consistent with the hypothesis of degraded representations. It also appeared that to us that the published literature was not as supportive as it seemed." Ramus and others proposed a new theory for dyslexia. Instead of an issue with the representation of phonemes, they proposed dyslexia is caused by an inefficiency with accessing these phonological representations. Although seemingly a subtle difference between the representation of phonemes its self and the access of the representation of phonemes it implies a completely different anatomical structure. Boets et al. (2013) published important findings in support of this theory. Boets showed pseudo-words to neuro-typical and dyslexic participants during MRI testing. Phonologic similarities of letters in pseudo-words and the degree of activation for specific brain areas was analyzed. To the surprise of the researchers, no difference in phonological representation was observed between dyslexic and neuro-typical participants. This became a large detractor of the prevailing theory that dyslexia is due to poor phonological representation. While studies have shown that phonological representation is not a source of dyslexia, poor access theory has received more support. Further support for the poor access theory, known as the connectivity theory of dyslexia, came with Boets' next experiment. As part of this study Boets et al. conducted functional connectivity analysis. This group looked at the relative residual signal intensity across 13 anatomical structures active during reading tests. They found that dyslexic participants had weaker connectivity in the area of Wernicke's area. Further evidence for the connectivity theory of dyslexia came with structural analysis of the collection of nerve fibers stretching from the visual word form area and Wernicke's area onto the frontal cortex in dyslexic populations. This tract of fibers is called the arcuate fasciculus. Jason Yeatman and his colleagues demonstrated that the arcuate fasiculus has structural differences in dyslexic people that contribute to inefficiency. This inefficiency is thought to be the base for the connectivity issue that causes poor access to phonological representation in dyslexic brains. Fortunately, the brain is highly plastic which allows it to be taught and grow. This means that although people with dyslexia will always have certain difficulties with reading and writing, it is possible for them to practice and improve these skills with proper education.

In our educational system there are two primary methodologies: the Whole Word approach and a phonics based approach. As the name would imply the Whole Word approach to reading education relies on gaining meaning from the entire word. This is in contrast to the phonics approach which breaks up a word into parts to ascertain its meaning.

The phonics based system, sometimes referred to as the sub-lexical approach, emphases decoding of words. Decoding involves breaking a word up into individual sounds. The word "food" would be broken down to the "f" sound, double "oo" sound, and "d" sound. The smallest part of a word that makes a single sound is referred to as a grapheme and the sound is a phoneme. Students can either be taught the connections between phonemes and graphemes explicitly or embedded in text. Explicit education often involves flash cards or other memory aid devices to help students' learning. Embedded instruction has students read as a group and as exam-

"Dislexia,"licensed by CC0.

ples of complex phoneme-grapheme pairings present themselves in the text the teacher discusses them. A method that uses a combination of these two variations is the Orton-Gilligham method. Dr. Samuel Orton and others invented Orton-Gilligham or OG in the 1920s. In addition to a large phonics component OG relies heavily on multi-sensory education. In addition to seeing and hearing the phoneme, students would write out phonemes in sand, shaving cream, or on carpet remnants. Students may take shots with a foam ball on an indoor basketball hoop while reciting grapheme-phoneme combinations. This type of education is best practice for those with learning differences (LD) such as dyslexia or attention difficulties.

The Whole Word approach relies on the assumption that children acquire reading skills at the word level, rather than from individual letters. David Ingram, a researcher at Arizona State University, wrote, "First, children acquire words, not individual consonants and vowels, and show little awareness of segments...children are word-oriented, not segment-oriented." These assumptions stem from a philosophical theory that a whole is more than the sum of its parts. In the classroom this approach includes sight memorization techniques, reading aloud in a group, and prioritizing finding texts that interest the student. Especially in English language education, where a large percentage of words cannot be decoded using phonics given the lack of phonetic spelling, sight word memorization becomes necessary.

Although there is overlap between the two methodologies, the emphasis is different. Phonics relies on decoding of words where as the Whole Word approach relies on gaining meaning from a word as a whole. The Whole Word approach often supplements phonics which has become the predominate method of education in The United States of America. There is support in the literature for the benefits of phonics over the Whole Word reading method. Melissa Schmidgall, a researcher at The Ohio State University, and her team conducted a comparative analysis of several Whole Word reading protocols and a phonics based protocol. They found that there was no difference in efficiency or efficacy between Whole Word reading methods. They students cumulative word-reading performance was better when phonics instruction was used. It is important to note that this study was completed on neuro-typical students.

Just as brain structure affects learning, learning changes the structure of the brain. Michel Thiebaut de Schotten, a researcher at King's College, conducted a study that looked at the microstructure of illiterate people, literate people, and people who had learned to read as adults (ex-illiterate). The results of the study demonstrated structural difference between illiterate and literate people. The micro structural differences this team noted may be due to the diameter of the neuron's axon, the density of the axons in the arcuate fascicles, or the quality of the myelination or insulating covering. The compelling component of the study was that the results from ex-illiterate and literate participants were indistinguishable. This Demonstrates that learning changes the way the brain is structured at the cellular level. In 2014 Alicia Che, a researcher at the University of Connecticut, conducted a genetics study that looked these micro-structural components. The gene DCDC2 has been linked to dyslexia and is believed to causes differences in receptor density and cortical development. Specifically Che found that neurons in a mouse model with this dyslexia genetic variation had reduced temporal precision in action potentials firing. As the timing of action potentials is key to neuronal communication, such a finding may further support the connectivity theory of dyslexia. Several other genes have been linked to dyslexia as well. The relation between these genes, epigenetics, and environmental factors in the cause of dyslexia is still under investigation.

Reading is a highly complicated behavior that requires the seamless integration of many cognitive functions. Using advanced brain imaging, scientists have started to unravel the mystery of how humans who did not evolve to read gained such a remarkable function. Through this research a neural explanation for dyslexia has started to come to light. Having this neural base bolsters the idea that dyslexic people are not merely stupid or lazy, but in fact have cognitive differences. Changes in ped-

agogy have produced great results not only for students with learning difference such as dyslexia but for students in general. Redford explains this progress. "Dylan came of age during an educational renaissance. Over the last two decades, educators have learned that there are effective interventions for learning problems like dyslexia that used to merely carry scary names. We have also learned that dyslexia can be identified early, and there are effective evidence-based reading methods to ensure that children with dyslexia CAN learn to read." Despite the difficulties dyslexia causes, many people with dyslexia learn to successfully navigate their difference and achieve in their own ways.

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