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Understanding Dyslexia: The Intersection of Scientific Research and Education

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Thank you, Chairman Alexander and Ranking Member Murray, for holding this hearing and for the invitation to speak to you today about the intersection of scientific research and education in dyslexia. Thank you Senator Cassidy and Senator Mikulski for co-chairing today's hearing.

Brain Imaging Technology: Advances in Understanding the Brain Bases for Reading and Dyslexia

The research I will be describing today has largely emerged from the field of neuroscience. The ability for scientists to use brain imaging technology to non-invasively study the brain's structure and function has resulted in tremendous advances to the understanding of the human brain, how it processes sensation, how it learns, how it remembers, and how it builds knowledge. Neuroscientists have been able to produce maps of brain regions underlying cognition and, importantly, skills that are uniquely human, such as reading.

Reading, a cultural invention that allows us to represent speech in symbolic form, involves a coordination of the brain's language areas with the visual and auditory systems. At my center at Georgetown University, we have studied brain activity with functional MRI (fMRI) while participants process words [1]. We use this approach to characterize the developmental trajectory of reading acquisition [2] and to study reading in different writing systems [3] and in different languages [4]. In the cognitive neuroscientific community, there has been an explosion in the use of brain imaging for the purpose of visualizing the reading brain. Unlike other areas of cognition, reading is a uniquely human skill and cannot be ecologically simulated using animal models. The non-invasive nature of fMRI allows scientists to study children (around or even prior to the time that they begin to read) and to study them repeatedly so that brain changes over time can be captured.

What researchers have learned is that the process of learning to read changes the brain's structure and function. People who never had the opportunity to learn to read manifest a different pattern of brain activity and have differences in brain anatomy compared to those who do learn to read [5], [6]. It seems that learning to read involves co-opting of brain regions involved in language and visual object recognition, and these become "recycled" into a "reading network." In other words, as teachers are bringing about critical literacy skills in children through formal education, the children's brains change above and beyond the changes that occur based on maturation.

Research also indicates that the brain needs to make some adjustments when becoming a reader, not only re-allocating brain functions from processing common objects to processing letters and words, but also adapting new rules. So while it is OK for objects, such as a chair, to be recognizable as the same object when it is viewed from the right or from the left, this is not OK for mirror letters such as p and q, and b and d. While these may look like the same object with mirror-reversal to a beginning reader (who will confuse them), successful reading acquisition requires that they become recognized as representing distinctly different letters [7].

Brain imaging technology has also heightened our understanding of dyslexia. Since our first implementation of functional MRI to study dyslexia in 1996 [8], the field has grown rapidly and made significant contributions to the science of dyslexia. While researchers had already been using MRI to scrutinize brain structural differences in dyslexia, functional MRI has allowed researchers to visualize brain activity in groups of people with and without dyslexia.

For example, functional MRI has been used to look at word processing and reading in children [9] and adults [10] with dyslexia . It has also been used to examine other functions that are not involved in reading, but may be affected in dyslexia (either as a part of having dyslexia, or as a consequence from having dyslexia) [11].

Using brain imaging, researchers have also examined the impact of intensive reading intervention. We have learned that adults with dyslexia not only make gains in reading, but also show brain plasticity, as demonstrated by increases in brain activity [10]. Brain anatomy is also malleable; in another study we found that reading intervention resulted in growth of brain tissue in children [12]. Together, these studies illustrate how reading gains in people with dyslexia are brought about by complex physiological and anatomical brain changes. Researchers are also evaluating to what degree brain imaging data can foreshadow the amount of reading gains that are made in children down the road [13], similar to prior work in which researchers identified behavioral measures such as rapid naming and phonemic awareness to be predictive of later reading outcome [14].

Some of the same brain areas that are compromised for reading are also underactive when children with dyslexia solve arithmetic tasks [15], highlighting the far-reaching consequences of dyslexia and their complex connection to other forms of learning disabilities.

Interestingly, through brain imaging research we sometimes encounter brain-based observations for which there were no obvious indications from behavioral studies. For example, we found that the brains of females with dyslexia do not conform to the neurobiological model of dyslexia that was largely derived from studies of males [16]. This might have important implications for diagnosing and treating females with dyslexia.

Together, brain imaging research has become an important tool for understanding reading and is a leading contributor in addressing the multitude of theories that have been proposed to explain dyslexia.

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While researchers are careful to assess what is directly causing the reading problems and to distinguish these brain differences from those that are a consequence or a byproduct of whatever is causing the dyslexia [17], it has become clear that children who eventually have dyslexia are likely to exhibit early signs of brain differences [18], much like specific behavioral measures in young children are lower for those who eventually go on to have dyslexia. This is not surprising given the brain–behavioral relationships and the fact that dyslexia is heritable. Scientific evidence supports genetic involvement, and a connection between dyslexia-associated genes and differences in brain activity [12,13]. Despite the fact that dyslexia often runs in families and there is research to explain genetic involvement, this knowledge is greatly underutilized when it comes to early identification. When a parent has dyslexia, the chances that their child has dyslexia are significantly higher, approximately 40%. Having this information provides a critical piece of information for educators and health care providers to consider when confronted with a child who is experiencing difficulties in learning to read, or even better, prior to that point. As such, a family history of reading disability should be noted on questionnaires for entering kindergarteners along with health conditions (allergies, asthma) and home language environment. A family history of dyslexia can be very predictive of children at risk for reading difficulties [20] and, together with early behavioral measures of skills known to predict later reading outcome (such as phonemic awareness and letter naming [21]), can be used to signal that a child is at risk for difficulties in learning to read.

How else can we harness this knowledge to help children with dyslexia? Brain imaging research has helped people understand that the brains of children and adults with dyslexia are different. Their struggles with reading are not because they are stupid or because they are not trying hard enough. This helps children, parents, and teachers understand that there is an explanation for their reading difficulties. There should be no stigma.

Brain imaging has helped scientists characterize dyslexia, and investigations are ongoing to refine theoretical brain-based models. However, these studies are conducted in a research setting and involve groups of participants. They are generally not conducted in a single person, and brain imaging is not used to make a determination of whether a specific child has dyslexia. Parents and teachers, however, often think that it does. Parents wish for a brain scan in their child because they see their child's difficulties with learning to read and often feel that the school is not recognizing the problem. They wish that they could get a picture of the child's brain to put in front of the teacher to "prove" they have dyslexia as a way to get more help for their child. However, brain imaging data cannot be used in this way.

Parents have difficulties in gauging whether there is a problem with their child's reading abilities and, if so, what to do about it. I have personally been in this situation recently when my daughter in 1st grade seemed to have trouble sounding out words and reading fluently. This became especially worrying when she exhibited anxiety and avoidance around reading, showing clear frustration and describing it as stupid activity. I quickly realized the difference between my understanding of how reading is evaluated (using standardized tests that tap into a range of reading skills, such as decoding, fluency, and comprehension, and skills that support reading, such as phonemic awareness, rapid naming and working memory) and how it is measured in the school (text-reading accuracy using a story with a picture providing content clues). And I learned that as long she reads at grade level, even if her performance continues to drop throughout the school year, and even though her level of reading is not aligned with her potential, she will be described as a normal reader. As such, the perspective on a child's performance when it comes to reading is very different in terms of the setting (home or school) and depending on the observer, because different observers use different contexts and have different goals. Recognizing the importance of early intervention, I arranged for my daughter to receive explicit instruction that bolstered both her phonemic (sound) and orthographic (visual word form) awareness over the summer. As a result of this, she moved from scoring at the 16th percentile as a 1st grader to the 75th percentile as a 2nd grader on a standardized measure of reading accuracy, and she is thriving.

Not all parents have the resources or knowledge to intervene early. Learning to read is complicated, and for parents of a struggling reader, it is very challenging to determine if there is a problem and what to do about. Fortunately, there are resources that are helpful to parents, teachers, and students. For example, the website Understood.org, a free, comprehensive online resource to support families of children with learning and attention issues (for which I serve as an expert contributor), can be a lifeline. Here, parents can access the information on early warning signs and learn what to do and how to take action. The information is provided in clear terms, while remaining tied to current scientific knowledge.

Overall, the science of dyslexia has made significant advances. However, academic researchers, even those working in classrooms, are bound by academic practices to publish in specialty journals, which in turn can be inaccessible, physically and conceptually, to those who directly operate as educators in the field. Consequently, teachers may not be implementing approaches that have been proven to be successful by rigorous research studies. Conversely, researchers may be pursuing theories that are not relevant to real classroom settings. As such, there remains a physical and cultural distance between academic research and educational practices.

Some agencies have addressed this problem. The National Science Foundation's Science of Learning Centers are a notable example of creating an environment to integrate knowledge across multiple disciplines, establishing common ground for conceptualization and connecting research with educational challenges. However, the dialogue between science and the classroom is still far too limited. Academic and educational institutions will need to embrace a cultural change that facilitates jointly tackling the collective complexity of dyslexia, and engaging a common language and a common understanding of how to harness the knowledge of teaching and learning to the benefit of children with dyslexia.

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