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The Science of Dyslexia

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Thank you, Chairman Smith, for holding this hearing and for the invitation to speak to you today about the brain-based scientific understanding of dyslexia.

Brain Imaging Technology has Advanced Our Understanding of the Brain Bases for Reading and Dyslexia

Since the 1991 US-led invention [1] of functional magnetic resonance imaging (fMRI), there has been an explosion in the use of this technique for the purpose of observing the locations and characteristics of activity in the human brain underlying sensation and cognition. While researchers had already been using standard MRI to scrutinize brain structural differences in dyslexia, fMRI has allowed researchers to visualize the reading brain in action. Unlike other areas of cognition, reading is a uniquely human skill and cannot be ecologically simulated using animal models. Further, the non-invasive nature of this technique allows for tracking children over time. Since our first implementation of fMRI to study dyslexia at the National Institutes of Health in 1996 [2], the field has grown rapidly and made significant contributions to the science of dyslexia.

Reading, a cultural invention that allows us to represent speech as 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 while participants process words [3]. We use this approach to characterize the developmental trajectory of reading acquisition [4], study non-alphabetic reading [5], and uncover differences in people with dyslexia [6]. To address the multitude of theories that have been proposed to explain dyslexia, we have also studied the brain as it engages in other tasks thought to be affected by reading disability [7]. We have examined the impact of intensive reading intervention and learned that adults with dyslexia not only make gains in reading, but also show brain plasticity, as demonstrated by increases in brain activity [6]. Brain anatomy is also malleable: in another study we found that reading intervention resulted in growth of brain tissue [8]; together, these studies illustrate how reading gains in people with dyslexia are brought about by complex physiological and anatomical brain changes.

We sometimes encounter brain-based observations for which there were no obvious indications from behavioral studies. For example, my research group has 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 [9]. This might have important implications for diagnosing and treating females with dyslexia.

Some of the same brain areas that are compromised for reading are also underactive when children with dyslexia solve arithmetic tasks [10], highlighting the far-reaching consequences of dyslexia and their complex connection to other forms of learning disabilities.

What remains challenging for much of this research is to be able to assess what is directly causing the reading problems and distinguish these factors from those that are a consequence or a byproduct of whatever is causing the dyslexia [11].

There have been notable discoveries across the country that demonstrate the interdisciplinary nature of this work. Linking with investigations into the genetic mechanisms of dyslexia, brain imaging studies have been conducted in carriers of dyslexia-associated genes [12]. Here is where animal models can and have been strategically employed: knock-out mice are used to find out how these dyslexia-associated genes operate ([13,14] Harvard University and University of Connecticut), filling the void where human research is limited. The molecular mechanisms have also been probed by examining MRI scans of children with dyslexia for the brain chemicals that support communication amongst brain cells ([15,16] Haskins Laboratory, CT, and University of Southern California, CA). Together these studies, which are supported by the NIH, have improved our understanding and raised awareness of the complexity of dyslexia.

What are the Possibilities and What are the Limitations?

Imaging technology facilitates characterization of the intricate developmental changes that occur in our children's brains and the formal learning they experience in our educational system. We now know that learning to read–as my first-grade daughter is doing at this very moment–eventually leads to substantial changes in brain anatomy and function. Will brain imaging allow us to identify dyslexia earlier than first grade, or forecast who might benefit from intervention and of what kind? Neuroscientists are working on these possibilities, and imaging data are proving indicative of future reading outcomes in dyslexia ([17] Stanford University, CA). Factors constraining these efforts are mostly technical in nature. Future technological advances may allow us to surmount these hurdles. The development of better technologies, as envisioned in the President's BRAIN initiative, should continue to improve methods of monitoring the human brain, allow for observations that are based on one individual person rather than a group of people, with application to younger children, and with the ability integrate information across different levels of inquiry.

Practical Implications: How is the Knowledge Applied?

Academic researchers are bound by academic practices to publish in specialty journals. These are often inaccessible, physically and conceptually, to those who directly operate as educators in the field. Researchers are at risk of pursuing theories that are not relevant to real classroom settings. Conversely, teachers may not be implementing approaches that have been proven to be successful by rigorous research studies. As such, a significant barrier is the physical and cultural distance between academic research and educational practices.

Some agencies have addressed this problem via targeted funding mechanisms. The NSF Science of Learning Centers are a notable example of creating an environment to integrate knowledge across multiple disciplines, establishing common grounds for conceptualization and connecting research with educational challenges. These conduits need to be increased if we are to have more than a dialogue spanning the gamut from neuroscience to classroom activities.

Others are stepping up to fill the gap. For example, to address concerns that basic research about reading is not available to teachers, the International Dyslexia Association (IDA) has provided guidelines on the desired capabilities for teachers of students with dyslexia ("Knowledge and Practice Standards for Teachers of Reading" [18]). These have also been used by the IDA to accredit those university teacher training programs in reading that promote high standards for comprehensive and rigorous training of teachers [19]. This is in addition to the longstanding efforts by the IDA to bring researchers, practitioners, and parents together (for example, through their international and local conferences) and to provide resources by which parents can learn about dyslexia, gauge the current state of research and practice, and make decisions about their child with information that is relevant and accessible to them.

Less welcome contributors to this arena are commercial entities that purport to marry research-based knowledge to address educational needs, such as poor reading skills, but use questionable approaches and put the goal of creating profit before the goal of translating research into educational gains for children. These need to be countered by efforts in which researchers and educators work together. <u>These problems can be addressed by training opportunities that expand the knowledge base in each field with respect to the other, and by funding opportunities that promote collaboration</u>.

Overall, the science of dyslexia has made significant advances in the last 25 years. With these, challenges have arisen which can be met by federal support for science and education intertwined, by academic and educational institutions embracing 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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