

The “Reading Brain” is Taught, Not Born: Evidence From the Evolving Neuroscience of Reading for Teachers and Society

by Rebecca Gotlieb, Laura Rhinehart, and Maryanne Wolf

“Words strain,
Crack and sometimes break, under the burden,
Under the tension, slip, slide, perish,
Decay with imprecision, will not stay in place,
Will not stay still.”

~T.S. Eliot
Burnt Norton, Four Quartets

For decades, while loving adults have read children rhymes like *Humpty Dumpty* and tales of fairies and heroes, researchers from multiple areas have sought to understand how the human brain ever learned to read, why it sometimes doesn't, and how this collective knowledge can help all children learn to read wisely and well. It is the cumulative knowledge gained from disciplines ranging from psycholinguistics and neuroscience to educational practice that comprises the evolving science of reading. From the outset, it is essential to emphasize that the science of reading is neither static, nor reducible to the common assumption that it is synonymous with phonics, however important phonics is in instruction.

In this paper we will describe contributions to the science of reading from cognitive neuroscience, an area in which researchers study the underpinnings of different cognitive functions, like reading or math. As we will explore here, the study of the brain-basis of reading begins with the fact that, unlike oral language, there is no ready-made genetic program for learning to read. Rather, for human-invented capacities like reading, the brain must create new circuits. It does so by recycling (Dehaene, 2009) and connecting some aspects of older parts that are genetically programmed, like vision, language, affect (emotional feeling), and cognition. The circuit for reading emerges slowly in the brain, as each potential component part develops separately in the first five years. It takes all of our collective efforts as educators and parents to continue to develop these parts and, very importantly, to teach children how to connect the

different parts fast enough to decode and understand written language. This is the first reading circuit that connects language processes like phonology and semantics with vision and conceptual knowledge. Over time, this basic circuit is elaborated and becomes the foundation of increased knowledge, empathy, critical analysis, and novel thought. Little could be more important for our society and, indeed, our species.

Here we offer an historical lens on how research from cognitive neuroscience and education provides insights for how to teach, connect, and strengthen the reading circuit. Two key contributions of cognitive neuroscience will be emphasized:

- the study of the reading brain's development and its relation to reading disabilities
- a view of how the neuroscience of reading contributes to instructional practice now and into the future

A Brief Overview of the History of Connecting the Parts of the Reading Circuit

More than thirty years ago, one of the authors of this paper wrote an essay with the purpose of illustrating how basic reading theory research and neuroscience research can inform each other and offer implications for educational practice (Wolf, 1991). Today, despite advances in efforts to translate insights from neuroscience to classroom practice, many educators have never been given sufficient background in understanding the reading process and how this knowledge can help improve the ways we teach all children to read, including those who struggle.

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Beginning in the mid-late 1800s, physicians such as Paul Broca, Joseph Jules Dejerine, Adolf Kussmaul, and Rudolf Berlin studied the brains of individuals who had suddenly lost their ability to speak or read and individuals who unexpectedly (i.e., despite adequate speech, vision, and education) could not learn to read. In the 1960s and 70s the neurologist Norman Geschwind used these early collective insights to create our first models of the reading brain (Geschwind, 1974). His work, and that of his students like Al Galaburda (1989), became the modern foundation for the study of dyslexia, just at a time when our technologies transformed our capacities to study what the brain does when it reads.

Major advances in imaging technology have allowed researchers to non-invasively study individuals and their brains in real-time while they read or do other tasks. The two most widely used tools are functional magnetic resonance imaging (fMRI) and event-related potential (ERP) measures. The fMRI tools measure changes in blood flow in the brain. This allows scientists to localize *where* brain activity is occurring when we read. For example, we can now demonstrate that when the reader begins to see a word, a region of the brain's "visual word form area" is activated (Yeatman et al., 2013). However, fMRI can't illuminate with great specificity *when* that activation happens in the reading process. ERP measures are well suited to help us understand when brain activity is occurring; they are precise to within milliseconds. The ERP tools measure the electrical and magnetic fields that brain cells, called neurons, create when they are active during a task like reading. Thus, we can demonstrate that the visual word form area is being activated within the first 200 milliseconds (McCandliss et al., 2003), and the phonological processes are

activated around 200 milliseconds, while semantic processes for understanding a word's meaning are activated later at about 400 milliseconds (Coch, 2017). Together these tools and others provide a vivid picture of what the reading circuit includes, how the circuit builds new connections in the brain, and how dependent the circuit is on cultural factors (e.g., the type of writing system) and educational instruction.

Cognitive Neuroscience's Key Contributions to the Science of Reading

Neuroscientist Stanislas Dehaene (2009) has argued that understanding the multifaceted nature of the reading circuit will greatly enhance how teachers teach reading. Over the last 20 years, findings about the reading circuit provided new ways of conceptualizing instruction, as seen in some of the many rigorous, evidence-based intervention studies, often federally funded by the National Institute of Child Health and Human Development, the Institute of Education Sciences, and the Office of Special Education Programs. Although a large body of this research focused on the importance of phonological processes like phoneme awareness in assessment and explicit phonics-based instruction, one group of studies demonstrated the need for instruction in multiple aspects of language, cognition, and affect. For example, several randomized control trials provide important evidence showing that early intervention that supports multiple components of the reading circuit combined with phonics emphases is significantly more effective than phonics instruction alone (Lovett et al, 2017; Morris et al, 2012; Pallante & Kim, 2013). Thus, while ample evidence demonstrates that phonics instruction is critical to early reading development in most children, fluent reading requires development and instruction simultaneously in multiple aspects of language and cognition, including prosody, pragmatics, orthography, semantics, syntax, morphology, and background knowledge (Wolf, 2008; Wolf et al., 2009; see also Orkin et al., 2022).

What does all this mean for educators and policymakers? First and foremost, these insights show the complexity of the teacher's task in teaching reading. The herculean job of educators is no less than to help the brain develop a skill it could not otherwise, which requires creating an entirely new circuit in the brain. From this perspective, learning to read is best enhanced by providing young readers with explicit, systematic, phonics-forward, language-based, multicomponent instruction that supports and connects to the develop-

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ment of the many other cognitive skills that make up fluent reading. Development over time is crucial. Reading-relevant neural changes occur across the whole first two decades of life and buttress the need for multiple years of literacy instruction, starting well before kindergarten and continuing past secondary education. Thus, all teachers in all grades must have a thorough understanding of what reading requires over time and how they can help it develop across multiple subjects.

Teachers cannot do this work in a vacuum. The impact of the environment on the brain, coupled with the prolonged development of reading, suggests that educators should not be the only contributors to literacy's development. Reading development occurs in the home and community, as well as at school. The differential effects of COVID on children and schools in privileged versus unprivileged communities is testimony to the importance of society in the development of the reading brain.

Within this context, some neuropsychologists developed a theory known as the Child-World Model to explain the effects of environment (broadly defined) on neurodevelopment and skill development (Waber, 2010). Such a view reveals how disability, as well as COVID-based regressions in learning, may lie within an environment rather than an individual—i.e., the instructional environments may not be set up to enable an individual to demonstrate his or her strengths or needs. While this insight is important for better supporting individuals with learning disabilities, it is also germane to providing more culturally relevant instruction or providing educational environments that can help youth learn academic content. Similarly, general education can benefit from principles of Universal Design for Learning (UDL). UDL has its roots in neuropsychologists' recognition that there is vast individual variability among young people and that there are opportunities (especially through technology) to better serve students on the margins of this spectrum of variability (Meyer et al., 2014; Rose & Meyer, 2002).

A prime example of this variability pertains to children with reading challenges like

dyslexia. An important area of insight from cognitive neuroscience concerns how the development of a reading circuit is impacted by the interaction between an individual's biology and environment. Dyslexia provides a case study in this interaction because children from families with a history of dyslexia have a genetic propensity to have a range of reading challenges (e.g., Snowling et al., 2003). Dyslexia is usually described as a specific learning disability associated with difficulties with phonology, decoding texts, retrieval, reading fluency, word recognition, and spelling. The reality is as complex as reading itself. Cognitive neuroscientists have come to understand that while the brains of individuals with and without dyslexia are far more alike than different, there are indeed differences in the brains of people who have dyslexia (e.g., Pollack et al., 2015). Further, there are differences even among individuals with dyslexia. We now know that there is considerable heterogeneity in dyslexia with different constellations of strengths and weaknesses (Ozernov-Palchik et al., 2017). The implications of these findings are many, ranging from early screening and early intervention (including more targeted interventions for individuals with different profiles), to better general educational instruction.

There is a well-known “dyslexia paradox”: early intervention works best for children with dyslexia, yet most diagnoses do not occur before second or even third grade (Ozernov-Palchik & Gaab, 2016). Early screening is a critical antidote to this paradox. For example, a pediatrician developed a quick, 10-item screener that assesses 4-year-olds' early literacy skills (Iyer et al., 2019). Because the screener only takes a minute or two to administer, a pediatrician could administer it to a child during a regularly scheduled check-up. Results from this brief screener could prompt families to strengthen home literacy practices and/or seek out preschool programs that have a focus on early literacy.

Most states now have legislation related to early, universal screening in kindergarten of students at risk of dyslexia (National Center for

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Improving Literacy, 2022), yet ambiguous policies and inconsistent practices have led to concerns that these screenings are not generally implemented in a way that substantially helps students at risk of dyslexia (Gearin et al., 2021). Some of our work at the Center for Dyslexia, Diverse Learners, and Social Justice at UCLA involves a model demonstration project, funded by the Office of Special Education Programs, to develop a model for early screening and intervention for students at risk of dyslexia. Towards that end, we are collaborating with several local elementary schools to help them use data from effective screeners for dyslexia risk to determine the strengths and needs of all children and to implement appropriate interventions for students identified as at risk of dyslexia by the screener.

A unique aspect of this model is that we are targeting literacy interventions to match students' specific area(s) of need (e.g., phonological awareness deficits, fluency-related areas indexed by naming speed). Our model is guided by Ozernov-Palchik's et al. 2017 study on subtypes of students with reading challenges, which showed that specific profiles of strengths and weaknesses in reading can be identified early in kindergarten and first grade. Further, the interventions that are part of our model demonstration project are informed by decades of research from the National Institute of Child Health and Human Development, among others, on the characteristics of reading interventions that lead to the best results (e.g., Lyon, 1998).

An often neglected area in cognitive neuroscience research and the science of reading in general is attention to the social and emotional ramifications of learning challenges to children and adolescents. Despite many efforts to inform parents, educators, and society at large about the strengths and needs of individuals with dyslexia, many children and youth are subjected to unfair prejudices about their intelligence and work ethic. Consequently, many individuals internalize these negative messages, with costs to their sense of self (Daley & Rap-polt-Schlichtmann, 2018) and ultimately their ability to develop their full potential. Whether Leonardo da Vinci or California Governor Gavin Newsom was/is dyslexic is less important than the emotional detriment of considering themselves less able than others when they were children.

Future Directions

Just as our understanding of the reading brain has contributed over time to the science and

practice of reading and its instruction, we believe it has much more to give before systematic, comprehensive literacy instruction is available in every classroom. Although there is considerable progress in understanding that phonics is a critical component in reading instruction, a deeper understanding of the reading circuit involves more emphasis on connecting encoding and decoding skills with multiple aspects of word and world knowledge. We need more evidence-based programs that address and connect all the components of the circuit. These programs must use explicit, systematic, and engaging instruction, along with metacognitive supports (Lovett et al., 2017; Petscher et al., 2020; Wolf et al., 2009).

Unfortunately, there are old and new reading wars that persist in pitting phonics and what we conceptualize as multicomponent instruction that includes phonics, against other forms of instruction, like Balanced Literacy and/or culturally responsive teaching. The reading brain is neutral and indeed shows how important word and world knowledge are to its circuit building. Similarly, affect, identity, and culture impact the experience of becoming literate (Gotlieb et al., under review). We believe that a major future contribution in cognitive and affective neuroscience is to show how evidence-based, multicomponent reading instruction that integrates social-emotional engagement and support will help the majority of students.

While neuroscientists have learned a great deal about both affect and reading, there is minimal neuroscientific research connecting the two. We expect that in the coming years, our work and that of others (e.g., Immordino-Yang & Knecht, 2020) will show that students' strong feelings and emotional thinking about texts can propel their reading fluency development. We expect neuroscientific evidence to complement what many educators have already observed—that deep reading

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requires both a repository of cognitive and language skills and also strong affective engagement. We hope such evidence can dissolve the unnatural conceptualization of science-based approaches as being in opposition to cultural and affective factors and instead show the power of integrating them in assessment, instruction, and intervention.

We are particularly hoping to study this direction with Black, LatinX, and Native youth, who are those most adversely affected by inadequate literacy instruction in the U.S. Greater understanding of the role of affect in reading development in these populations will push our education system to contend with the ways that these students' affective and academic experiences are being insufficiently addressed in our educational and judicial systems today.

In conclusion, the science of reading, like all of science and like language itself, "will not stay still" (T.S. Eliot, 1936). With insights from cognitive neuroscience, educators, clinicians, and policymakers, this cumulative work will continue to evolve with ever more implications for classroom instruction and for all those who experience challenges in becoming fully literate. ■

References

- Coch, D. (2017). *Reading From a Mind, Brain and Education Perspective*. Mind, brain, and education companion textbook. Schwartz, M. & Pare-Blagoev, J. (Eds.) Routledge Press.
- Daley, S. G., & Rappolt-Schlichtmann, G. (2018). Stigma consciousness among adolescents with learning disabilities: Considering individual experiences of being stereotyped. *Learning Disability Quarterly*, 41(4), 200-212.
- Dehaene, S. (2009). *Reading in the brain: The new science of how we read*. Penguin Group.
- Eliot, T. S. (1936). "Burnt Norton" from *Four Quartets* in *Collected Poems, 1909-1962*.
- Galaburda, A. (1989). *From reading to neurons*. MIT Press.
- Gearin, B., Petscher, Y., Stanley, C., Nelson, N. J., & Fien, H. (2021). Document analysis of state dyslexia legislation suggests likely heterogeneous effects on student and school outcomes. *Learning Disability Quarterly*, 0731948721991549.
- Geschwind, N. (1974). *Selected papers on language and the brain*. (R.S. Cohen & M. W. Wartofsky, eds.) D. Reidel Publishing Company.
- Gotlieb, R. J. M., Immordino-Yang, M. H., Gonzalez, E., Rhinehart, L., Peuschel, E., Mahjouri, S., & Nadaya, G., (Under Review). *Becoming literate: Educational implications of coordinated neuropsychological development of reading skills and social-emotional functioning among diverse youth*.
- Immordino-Yang, M. H., & Knecht, D. R. (2020). Building meaning builds teens' brains. *Educational Leadership*, 77(8), 36-43.
- Iyer, S., Do, D., Akshoomoff, N., Malcarne, V. L., Hatrup, K., Berger, S. P., ... & Needlman, R. (2019). Development of a brief screening tool for early literacy skills in preschool children. *Academic Pediatrics*, 19(4), 464-470.
- Lovett, M. W., Frijters, J. C., Wolf, M., Steinbach, K. A., Sevcik, R. A., & Morris, R. D. (2017). Early intervention for children

at risk for reading disabilities: The impact of grade at intervention and individual differences on intervention outcomes. *Journal of Educational Psychology*, 109(7), 889.

- Lyon, R. G. (1998). The NICHD research program in reading development, reading disorders and reading instruction: A summary of research findings. *Keys to Successful Learning: A National Summit on Research in Learning Disabilities*.
- McCandliss, B. D., Cohen, L., & Dehaene, S. (2003). The visual word form area: Expertise for reading in the fusiform gyrus. *Trends in Cognitive Sciences*, 7(7), 293-299.
- Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal design for learning: Theory and practice*. CAST Professional Publishing.
- Morris, R. D., Lovett, M. W., Wolf, M., Sevcik, R. A., Steinbach, K. A., Frijters, J. C., & Shapiro, M. B. (2012). Multiple-component remediation for developmental reading disabilities: IQ, socioeconomic status, and race as factors in remedial outcome. *Journal of Learning Disabilities*, 45(2), 99-127.
- National Center on Improving Literacy. (2022, February). *State of dyslexia: Explore dyslexia legislation and related initiatives in the United States of America*. <https://improvingliteracy.org/state-of-dyslexia>.
- Orkin, M., Vanacore, K., Rhinehart, L., Gotlieb, R., & Wolf, M. (2022). The more you know: How teaching multiple aspects of word knowledge builds fluency skills. *The Reading League Journal*, 3(2), 4-13.
- Ozernov-Palchik, O., & Gaab, N. (2016). Tackling the 'dyslexia paradox': Reading brain and behavior for early markers of developmental dyslexia. *Wiley Interdisciplinary Reviews: Cognitive Science*, 7(2), 156-176.
- Ozernov-Palchik, O., Norton, E. S., Sideridis, G., Beach, S. D., Wolf, M., Gabrieli, J. D., & Gaab, N. (2017). Longitudinal stability of pre-reading skill profiles of kindergarten children: Implications for early screening and theories of reading. *Developmental Science*, 20(5), e12471.
- Pallante, D. H., & Kim, Y. S. (2013). The effect of a multicomponent literacy instruction model on literacy growth for kindergartners and first-grade students in Chile. *International Journal of Psychology*, 48(5), 747-761.
- Petscher, Y., Cabell, S. Q., Catts, H. W., Compton, D. L., Foorman, B. R., Hart, S. A., Lonigan, C. J., Phillips, B. M., Schatschneider, C., Steacy, L. M., Terry, N. P., & Wagner, R. K. (2020). How the science of reading informs 21st-century education. *Reading Research Quarterly*, 55(S1), S267-S282.
- Pollack, C., Luk, G., & Christodoulou, J. A. (2015). A meta-analysis of functional reading systems in typically developing and struggling readers across different alphabetic languages. *Frontiers in Psychology*, 6, 191.
- Rose, D. H., & Meyer, A. (2002). *Teaching every student in the digital age: Universal design for learning*. Association for Supervision and Curriculum Development.
- Snowling, M. J., Gallagher, A., & Frith, U. (2003). Family risk of dyslexia is continuous: Individual differences in the precursors of reading skill. *Child Development*, 74(2), 358-373.
- Waber, D. P. (2010). *Rethinking learning disabilities: Understanding children who struggle in school*. Guilford Press.
- Wolf, M. (1991). Naming speed and reading: The contribution of the cognitive neurosciences. *Reading Research Quarterly*, 123-141.
- Wolf, M., (2008). *Proust and the squid: The story and science of the reading brain*. Harper Collins.

Wolf, M., Barzillai, M., Miller, L., Gottwald, S., Spencer, K., Norton, E. (2009). The RAVE-O Intervention: Connecting neuroscience to classroom practice. *Mind, Brain, and Education*. Special Issue. 3(2), 84-93.

Yeatman, J. D., Rauschecker, A. M., & Wandell, B. A. (2013). Anatomy of the visual word form area: Adjacent cortical circuits and long-range white matter connections. *Brain and Language*, 125(2), 146-155.



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