Brain Imaging and Reading Instruction: Time for Caution

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In recent years neuroscience research has added to our understanding of brain functioning. One popular approach has been to capture brain activity in visual images that are displayed on a computer, a process known as neuroimaging. Neuroimaging reveals which parts of the brain are active when the individual is responding to sound, touch, visual displays, and other stimuli, and the results are useful in gaining a better understanding of brain functioning. Some researchers are using this technique to study brain activity during specific reading tasks, and that's the focus here.

Stanislaus Dehaene (2012, 2016), an often quoted cognitive neuroscientist, studies neural activity by using functional magnetic resonance imaging (fMRI), a technique that measures changes in blood flow to the brain during different activities. He discovered that looking at a single word activates the neurons in a particular area of the brain. He concedes that other areas of the brain are involved in reading but says that the specific area he has studied is the key because in order to read, the individual must make a connection between written and spoken language, and that area of the brain is where the two connect. He further asserts that the brain processes individual letters when reading words and that children thus need to learn to match letters to speech sounds in order to learn to read. Shaywitz, et al. (1996), using neuroimaging to study dyslexics, has drawn similar conclusions.

Steven Strauss (2005), a linguist and neurologist, expresses several concerns about neuroimaging as it applies to reading. First, he notes that imaging can show where neural activity occurs in the brain when the subject is looking at a single word or responding to the letter-sound units in the word, but that's all it shows. Interpretations of the finding—for example, that the brain is processing a word sound by sound—aren't necessarily correct. Second, he cautions that the technology is constrained, able to generate only "snapshots" of neural activity at specific points in time. The technique can capture the moment when the eyes focus on a word but cannot show what happens in the brain over time when whole pages are being read. Third, he stresses that although phonological processing activates one area of the brain, semantic processing activates a different area, and there's no reason to conclude that either area is the center of reading just because of neuroimaging results. Strauss also raises other issues with neuroimaging that further support hesitancy about using the research to explain the reading process or guide instruction. Farnsworth (2022) and Guy-Evans (2023) also express caution about the fMRI technique in general, noting that shifts in blood flow in the brain don't occur instantly, so the time lag between increased blood flow to a particular area of the brain and the action being performed can make it difficult to interpret the obtained images.

Another critical issue with neuroimaging as it applies to reading is that it focuses only on the visual stimuli coming *into* the brain but does not consider the expectations coming *from* the brain that influence perception. This is an aspect of brain activity noted by Hawkins and Blakeslee (2004), Strauss, Goodman, and Paulson (2009), and Lieff (2015), among others. For example when an oral reader sees THE LITTLE PUPPY and says THE TINY LITTLE PUPPY, the inserted word *tiny* has to be considered a linguistic and/or semantic expectation of the reader, not the reader's response to the word on the page. This perspective on brain functioning sees reading as one of many behaviors that are guided by the predictive capacities of the brain—a brain that is highly adaptable to new experiences because it continually uses past experiences to anticipate features of new ones. A full model of brain activity during reading must account for the neural activity related to the predictive aspects of the process as well as the activity related to incoming visual stimuli.

Contributing to the predictive aspect of brain functioning is what Konovalov and Krajbich (2018) describe as a Bayesian process of pattern learning. From their own fMRI brain research, they conclude that the brain readily detects patterns and regularly updates its pattern knowledge with reference to prior knowledge. Their research can be considered as useful as Dehaene's and yet leads to the view that perceiving and responding to language patterns may be the key to reading. Instead of beginning readers needing to learn to sound out words, they may instead need experiences that help them detect and make use of the patterns that are evident in words and sentences, including morphological patterns (know, knowing, knowledge), or grammatical patterns found sentences (e.g., subject-verb-object) as well as phonological patterns (make, take, cake). However, neuroimaging is still too rudimentary to provide definitive information about readers' responses to these complexities.

In narrowing the scope of research to what can be measured by fMRI or comparable technologies, neuroimaging has oversimplified the nature of brain functioning as it relates to reading. The work of other researchers indicates the greater complexity of the brain, whether it is reading or performing any number of other tasks (e.g., Grossberg, 2019, 2021; Hawkins, 2021), and much more work is needed to explain the predictive functions of the brain and how they influence perceptions and behavior (e.g., Trafton, 2019). For now, neuroimaging research is simply too narrow in scope to provide useful guidance for teachers of reading.

The oversimplification has also led to claims that don't match the reality of observable reading behavior. For example, Dehaene (2013) maintains that the brain processes words letter by letter and that readers must connect the letters to sounds in order to read. He claims that the process is to "decipher words, recognize them auditorily, and access their meaning." However, he ignores the fact that the meaning of some words actually determines their pronunciation. Homographs such as *tear* and *wind* are good examples. Neither can be pronounced without first attending to the meaning, and that requires considering the context within which the words are used: *A* ***tear*** *fell from her eye when she looked at the* ***tear*** *in the fabric* or *Let's* ***wind*** *up this game before the* ***wind*** *gets too strong*. Another issue that Dehaene does not consider is that readers of all ages regularly come across words that they have never heard before. Sounding them out does not result in auditory recognition and thus access to the word's meaning. The reader must do more. Also, if readers have not heard a word before, they may pronounce it incorrectly when they first see it in print and yet will still be able to understand its meaning. An example is the adult who had run across the word *myriad* in print as a teen and decided it was pronounced *MY-rade*. He understood the meaning of the word quite well but discovered only later in life that he was saying it incorrectly. Such phenomena, which don't fit Dehaene's model of reading, call for rethinking the model.

Of course, neuroscientists may eventually provide valuable insights into the reading process and the ways in which people can most effectively learn to read. Ultimately, we need research that reflects not only the complexity of the brain but also key aspects of the reading process. For example, we need to understand brain functioning in skilled readers and struggling readers, beginning readers and mature readers, including when they are:

- reading successive paragraphs as well as individual words
- reading silently as well as orally
- reading different types of texts (e.g., predictable, decodable)
- reading texts on familiar as well as unfamiliar topics
- reading texts that are easy for a reader vs. those that are difficult for that reader

Until we have more information about neural activity related to these reading behaviors, we should not try to use neuroimaging research findings for making decisions about classroom practices.

As the research continues and matures, it would be advisable to bring a select number of highly effective teachers into the conversation, especially those who have successfully taught children to read, year after year. Researchers need to become aware of what those teachers do and need to tap their considerable expertise and insights into what children do when they read. Expert teachers' experiences will be invaluable in helping explain the findings of researchers, noting the strengths and shortcomings of research, and suggesting research questions that have yet to be addressed.

References

Dehaene, S. (2012). "Reading and the Brain." Presentation at the Peter Wall Institute, Vancouver, Canada: https://www.youtube.com/watch?v=25GI3-kiLdo.

Dehaene, S. (2013). "How the Brain Learns to Read." Presentation at the World Innovation Summit for Education: https://www.youtube.com/watch?v=25GI3-kiLdo

Dehaene, S. (2016). "The Brain Prize Presents: Stanislaus Dehaene." Presentation of The Brain Prize: https://www.brainfacts.org/thinking-sensing-and-behaving/language/2016/the-brain-prize-presents-stanislas-dehaene-110116.

Farnsworth, B. (2022). "EEG vs. MRI vs. fMRI—What Are the Differences?" Research Fundamentals (4 October): https://imotions.com/blog/learning/research-fundamentals/eeg-vs-mri-vs-fmri-differences.

Grossberg, S. (2019). "The Resonant Brain: How Attentive Conscious Seeing Regulates Action Sequences that Interact with Attentive Cognitive Learning, Recognition, and Prediction." *Attention, Perception, & Psychophysics 81*:2237-2264: https://doi.org/10.3758/s13414-019-01789-2.

Grossberg, S. (2021). "A Canonical Laminar Neocortical Circuit Whose Bottom-Up, Horizontal, and Top-Down Pathways Control Attention, Learning, and Prediction." *Frontiers in Systems Neuroscience* 15:650263: https://www.frontiersin.org/articles/10.3389/fnsys.2021.650263/full.

Guy-Evans, O. (2023). "Neuroimaging Techniques and What a Brain Image Can Tell Us." *Simply Psychology* (updated 9 February 2023): https://simplypsychology.org/neuroimaging.html.

Hawkins, J. (2021). *A Thousand Brains: A New Theory of Intelligence*. New York: Basic Books.

Hawkins, J. & Blakeslee, S. (2004). *On Intelligence*. New York: Times Books.

Konovalov, A. & Krajbich, J. (2018). "Neurocomputational Dynamics of Sequence Learning." *Neuron 98*, 1-12: https://linkinghub.elsevier.com/retrieve/pii/S0896627318303854.

Lieff, J. (2015). "How Does Expectation Affect Perception?" April 12 entry at the blog of Jon Lieff, M.D.: https://jonlieffmd.com/blog/how-does-expectation-affect-perception.

Shaywitz, S., Shaywitz, B.A., Pugh, K.R., Skudlarski, P., Fulbright, R.K., Constable, R.T., Bronene, R.A., Fletcher, J.M., Liberman, A.M., Shankweiler, D.P., Katz, L., Lacadie, C., Marchione, K.E., & Gore, J.D. (1996). "The Neurobiology of Developmental Dyslexia as Viewed Through the Lens of Functional Magnetic Resonance Imaging Technology"." In G.R. Lyon & J.M. Rumsey (Eds.). *Neuroimaging: A Window to the Neurologic Foundations of Learning and Behavior in Children*. Baltimore: Paul H. Brookes.

Strauss, S.L., Goodman, K.S., & Paulson, E.J. (2009). "Brain Research and Reading: How Emerging Concepts in Neuroscience Support a Meaning Construction View of the Reading Process." *Educational Research and Review 4*(2), pp 21-22: https://bit.ly/3ci3yKQ.

Trafton, A. (2019). "How Expectation Influences Perception." *MIT News* (July 15): https://news.mit.edu/2019/how-expectation-influences-perception-0715.