Medical Xpress

How the brain learns to read—development of the "word form area"

April 26 2018, by Emilie Reas

The ability to recognize, process and interpret written language is a uniquely human skill that is acquired with remarkable ease at a young age. But as anyone who has attempted to learn a new language will attest, the brain isn't "hardwired" to understand written language. In fact, it remains somewhat of a mystery how the brain develops this specialized ability. Although researchers have identified brain regions that process written words, how this selectivity for language develops isn't entirely clear. A recent *PLOS Biology* study by researchers from the University

Paris-Saclay adds significantly to our understanding of the changes supporting reading acquisition in the child brain.

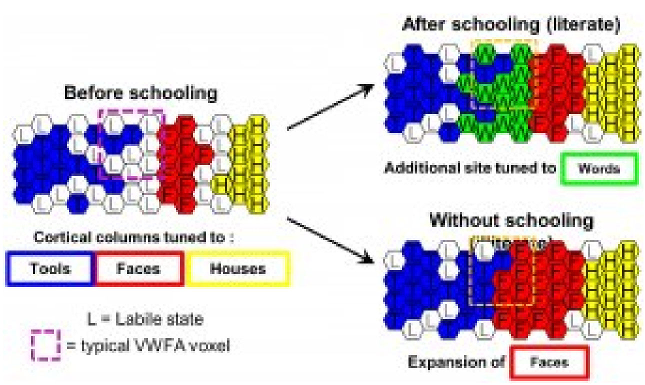
Earlier studies have shown that the ventral visual cortex supports recognition of an array of visual stimuli, including objects, faces, and places. Within this area, a subregion in the left hemisphere known as the "visual word form area" (VWFA) shows a particular selectivity for written words. However, this ventral occipitotemporal region is characteristically plastic. It's been proposed that stimuli compete for representation in this malleable area, such that "winner takes all" depending on the strongest input. Supporting this idea, studies have reported that higher reading ability is related to reduced responsivity to faces and stronger right lateralization of face representation, suggesting that word representation may invade neural real estate devoted to face processing. But this idea has yet to be confirmed, and the evolution of specialized brain areas for reading in children is still not well understood.

The emergence of brain's word form area

In their study, Dehaene-Lambertz and colleagues monitored the reading abilities and brain changes of ten six-year old children to track the emergence of word specialization during a critical development period. Over the course of their first school-year, children were assessed every two months with reading evaluations and functional MRI while viewing words and non-word images (houses, objects, faces, bodies). As expected, reading ability improved over the year of first grade, as demonstrated by increased reading speed, word span, and phoneme knowledge, among other measures.

Even at this young age, when reading ability was newly acquired, words evoked widespread left-lateralized brain activation, most strongly in ventral occipitotemporal cortex. This activity increased over the year of school, with the greatest boost occurring after just the first few months.

Importantly, there were no similar activation increases in response to other stimuli, confirming that these adaptations were specific to reading ability, not a general effect of development or education. Immediately after school began, the brain volume specialized for reading also significantly increased. Furthermore, reading speed was associated with greater activity, particularly in the VWFA. Using multivoxel pattern analysis to examine patterns of brain activity, the researchers found that activation patterns to words became more reliable with learning. In contrast, the patterns for other categories remained stable, with the exception of numbers, which may reflect specialization for symbols (words and numbers) generally, or correlation with the simultaneous development of mathematics skills.



What predisposes one brain region over another to take on this specialized role for reading words? Before school, there was no strong preference for any other category in regions that would later become word-responsive. However, brain areas that were destined to remain "non-word" regions showed more stable responses to non-word stimuli even before learning to read. Thus, perhaps the brain takes advantage of unoccupied real-estate to perform the newly acquired skill of reading.

The VWFA showed the expected word-specific multi-voxel activation pattern, but also showed activity patterns unique to other visual categories. This suggests that reading does not, in fact, invade and replace regions devoted to other functions, but that representations for words and other stimuli can overlap.

These findings add a critical piece to the puzzle of how reading skills are acquired in the developing child brain. Though it was already known that reading recruits a specialized brain region for words, this study reveals that this occurs without changing the organization of areas already specialized for other functions. The authors propose an elegant model for the developmental brain changes underlying reading skill acquisition (Figure). In the illiterate child, there are adjacent columns or patches of cortex either tuned to a specific category (e.g., faces, tools, etc.), or not yet assigned a function. With literacy, the free subregions become tuned to words, while the previously specialized subregions remain stable.

The plastic developing cortex

The rapid emergence of the word area after just a brief learning period highlights the remarkable plasticity of the developing cortex. In individuals who become literate as adults, the same VWFA is present. However, in contrast to children, the relation between reading speed and activation in this area is weaker in adults, and a single adult case-study by the authors showed a much slower, gradual development of the VWFA over a prolonged learning period of several months. As the researchers note, "the fast changes induced by reading acquisition that we observed here betray the intense plasticity of children's immature ventral occipitotemporal cortex."

Despite the malleability of the VWFA and surrounding cortex, its location was consistent across children, stable and reproducible. This suggests that its location is, to some extent, pre-constrained. Yet the factors that predestine this region for word selectivity remain a mystery, and as the authors explain, "the precise identification of those constraints, whether cytoarchitectural or connectional, is an important goal for further research." Whatever the reason, this region appears primed to rapidly adopt novel representations of symbolic words, and this priming may peak at a specific period in childhood. This finding underscores the importance of a strong education in youth. The authors surmise that "the success of education might also rely on the right timing to benefit from the highest neural plasticity. Our results might also explain why numerous academic curricula, even in ancient civilizations, propose to teach reading around seven years."

More information: Lucia W. Braga et al. Tracking Adult Literacy Acquisition With Functional MRI: A Single-Case Study, *Mind, Brain, and Education* (2017). DOI: 10.1111/mbe.12143

S. Dehaene et al. How Learning to Read Changes the Cortical Networks for Vision and Language, *Science* (2010). DOI: 10.1126/science.1194140

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https://medicalxpress.com/news/2018-04-brain-readdevelopment-word-area.html

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