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All Roads Lead to Rome? Distinct Neural Circuits in Different Developmental Disorders are Related to Reading Difficulties in Children

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Description

Reading is defined as the ability to extract semantically meaningful, verbal information from written language. This is one of the most important cognitive academic abilities and has been found to be related to scores on the American College Test [1]. However, reading is not as intuitive as we may think. The neuroimaging era provides insights into the neural circuits involved in reading, and it appears that this cognitive ability relies not only on neural circuits related to language processing [2,3] but also those related to visual processing [3] and higher-level cognitive abilities, such as executive functions [4,5]. A fascinating orchestra of synchronized activation between the superior temporal gyrus and inferior frontal gyrus (i.e., language processing, see [2] the fusiform gyrus, cuneus and precuneus (i.e., visual processing, see ref. [3]), and the anterior cingulate cortex in particular and the cingulo-opercular and fronto-parietal cognitive control networks in general [4-6] all are needed for fluent reading. Given this involvement of multiple neural circuits and cognitive abilities, it is not surprising that reading difficulties may result from a variety of impairments or an altered activation in any of the aforementioned neural circuits. Alternatively, reading difficulties can result from a lack of synchronization between the activation of these neural circuits (i.e., altered functional connectivity). Children with dyslexia [3] attention deficit hyperactivity disorder (ADHD) [7], psychiatric disorders [8] epilepsy [9] autism [10], or mental retardation [11] all suffer from reading difficulties. However, these types of reading challenges are only the tip of the iceberg, as this is what a teacher notices in the classroom. Neuroimaging data provide us with insight into the underlying causes and pathway "flosses" (the bottom of the iceberg) that are the basis for these reading challenges. Children with dyslexia show an under activation of the fusiform gyrus compared to typical readers during reading [3], but also have decreased functional connectivity between visual- and executive functions-related regions (fusiform gyrus and anterior cingulate cortex) during reading [12] and the cingulo-opercular cognitive-control network (related to executive functions), even during rest [13]. Conversely, children with both ADHD and dyslexia, who showed much more severe reading difficulties than those with dyslexia alone, demonstrated greater activation in neural circuits related to executive functions (i.e., dorsolateral prefrontal cortex) compared to children with dyslexia during word reading (unpublished data). In the field of psychiatry, children with mood disorders demonstrated more severe reading and phonological-processing difficulties compared to those with behavioral disorders, as well as decreased white-matter diffusivity (fractional anisotropy) in white-matter tracks related to language processing (left arcuate fasciculus, which crosses the frontal and tempo-parietal language and reading regions) [14,15]. Neurologically, a case study of an epilepsy patient revealed reading difficulties that were manifested by right lateralized activation in the language-related right superior temporal lobe compared to a child with epilepsy with intact reading abilities and left lateralized activation in this region [16]. High-functioning children with autism and hyperlexia (i.e., an extraordinary ability to read words) showed greater activation of neural circuits related to visual processing (i.e., the fusiform gyrus) [17]. As of yet, there is no evidence of neural circuits supporting impaired reading in children with autism who have reading difficulties or for children with mental retardation. The main challenge of identifying the specific brain regions in many other neurological disorders that affect reading is in the inter-subjects variability. In Epilepsy, for example, reading difficulties can result from seizures in different brain regions related to language, visual processing or different cognitive abilities related to reading. Therefore, a functional / structural connectivity approach, which relates to associations between brain regions, related to these abilities would be more appropriate when characterizing the neural changes related to reading in these populations.

Determining the exact altered neural circuits related to reading difficulties is important and should be a part of the medical model of providing the most appropriate treatment for each disorder. If a child suffers from reading difficulty due to language-processing difficulties, then the appropriate intervention should focus mainly on this domain. However, for a child who suffers mainly from difficulties in executive functions, the treatment should focus on different domains. Neuroimaging data has the advantage not only to identify the neural circuits involved in underlying causes of reading impairment, but also can be used to evaluate the effectiveness of intervention programs, precisely and accurately. Another advantage of using nonscientific tools in the educational field of reading remediation is the preventative potential of its use. Recently, home literacy environment has been identified as having an impact on the developing brain: a greater home literacy environment was positively associated with activation in neural circuits related to semantic processing (i.e., the temporal-occipital-parietal junction) in 3-5 year-old children listening to stories in the MRI [18]. More research is needed to pinpoint at the neural circuits related to the inability to read due to environmental factors, such that we will be able to prevent the occurrence of illiteracy. Reading difficulties due to the hereditability of genes associated with dyslexia may also be predicted before the reading problems actually occur (i.e., in preschool). Neuroimaging data has shown that children with reading difficulties whose parents suffer from reading difficulties demonstrate much more diffused activation in neural circuits related to language

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(superior temporal gyrus), visual processing (fusiform gyrus), and executive functions (anterior cingulate cortex) compared to children with reading difficulties whose parents do not have reading difficulties [19]. Such genetic data could serve as a screen for the future existence of reading difficulties, which would provide reason for early treatment for children at-risk to develop reading difficulties due to environmental or genetic factors.

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