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Reading Abilities: Importance of Visual-Spatial Attention

Children with dyslexia may read poorly for several reasons. Recent research suggests that in addition to skills with language sounds, visual-spatial attention may be an important predictor of reading abilities.

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You are reading these words very quickly. A typical adult has a reading vocabulary of 50,000–100,000 words, yet can identify a printed word seen for merely 1/200th of a second. Reading is essential for learning, from literature to physics, from paper to screens on e-readers and smart phones. Yet, about 10% of children have developmental dyslexia, an unexplained difficulty in learning to read [1]. Such poor reading is often associated with undesirable outcomes, such as lower educational attainment [2]. Dyslexia is likely caused by multiple factors, and the importance of those factors may vary between children [3] and across languages with different relations between spoken and written forms of language [4]. Research from Franceschini *et al.* [5] reported in this issue of *Current Biology* now reveals that a weakness in visual-spatial attention in pre-reading kindergartners is an important risk factor for becoming a poor reader.

In all languages, under typical developmental conditions, children learn spoken language effortlessly and without formal instruction. In contrast, reading must be learned through explicit educational instruction over several years. Learning to read words can be conceptualized as learning to map the sound units of spoken language (phonemes) onto the written units of print (graphemes) so that meaning, initially related to spoken language, can be extended to print.

Because many children with dyslexia appeared to hear and talk successfully at home before struggling to read at school, early conceptualizations of

dyslexia focused on putative visual deficits made manifest with print. Although there is evidence for visual deficits in dyslexia [6,7], the most common cause of dyslexia was reconceptualized in the 1980s as a weakness in the processing of language sounds, and especially in phonemic awareness — the ability to explicitly recognize and manipulate the sounds of language [8]. This weakness makes it difficult for beginning readers to map the sounds of language onto print and to accurately identify (decode) individual words. Additionally, weakness in rapid serial naming (even of color patches) has been associated with poor reading [9,10]. This weakness renders reading slow and laborious and impedes the comprehension, and pleasure, of reading text.

Research has focused on children and adults who are well-characterized as dyslexic and have long struggled with reading. Such research has two important limitations. First, learning to read has reciprocal interactions with the basic skills that underlie reading itself. Thus, practice with reading enhances phonemic awareness and other reading-related processes [11]. Evidence that these skills are necessary precursors for learning to read, rather than simply a consequence of reading, is that pre-reading children in kindergarten who score poorly on tests of phonemic awareness and rapid naming are more likely to become poor readers over the next few years [12]. Second, remedial interventions that help children with dyslexia appear to be most potent at the youngest ages, before dyslexia is typically diagnosed. Therefore, early identification of risk factors for dyslexia helps identify

children who may benefit the most from early intervention.

Franceschini *et al.* [5] addressed the cause of poor reading by behaviorally testing 96 pre-reading Italian-speaking kindergartners (five-year-olds) not only with typical tests of phonemic awareness and rapid naming, but also on two tests of visual-spatial performance. Although visual-spatial processes appear to be distant from the verbal processes associated with reading, studies in adults with dyslexia have revealed deficits in visual-spatial performance, often with nonverbal material [7]. These studies motivate the idea that a weakness of visual-spatial attention, independent of language, could cause dyslexia [13].

In the new study [5], one visual-spatial task required visual search across five lines of 31 symbols (not letters) and marking each occurrence of a target symbol. In the second task, children performed a spatial cuing task. In a control condition, children very briefly viewed, on the left or right of a central fixation point, an ellipse at one of four orientations, and then selected from among four alternatives which ellipse they had just viewed. The spatial cuing conditions built upon seminal research about visual attention from Michael Posner [14], who showed that attention is automatically or exogenously drawn to a spatial location by brief highlighting of that location. In the spatial cue condition, the left or right side of the display was very briefly highlighted (that is, cued) just before the appearance of the ellipse. Such a cue naturally attracts the participant's visual attention to that side of the display. Then, the ellipse appeared on the just-previously highlighted side (valid cue condition) or on the opposite side (invalid cue condition). Performance is typically better on the validly cued side because attention has already been drawn to that side (and worse on the opposite side because attention has been pulled away from that side).

Franceschini *et al.* [5] followed these pre-readers longitudinally across the

1st and 2nd grades as they received explicit reading education, and discovered that 68 children became typical readers and 14 children became poor readers (or dyslexic — the precise boundary between poor reading and dyslexia is somewhat arbitrary at present). The critical question was what measures in pre-reading kindergartners best predicted their future reading ability. The kindergartners who went on to become poor readers made significantly more errors on the visual search task. The same children performed normally on the no-cue ellipse-matching task, but failed to exhibit the typical benefit of the valid spatial cues in the cued conditions. Indeed, about 60% of children who went on to be dyslexic performed poorly on the visual-spatial tasks. Several analyses across all the children revealed that scores on the visual-spatial tasks predicted future reading performance better than typically used language and naming measures, and provided significant predictive information even after the language and naming scores were accounted for. Thus, visual-spatial scores were substantial and independent predictors of future reading ability.

These findings have several important implications for understanding the growth of reading ability and hazards for that growth. First, they support the importance, and potentially casual role, of visual-spatial attention in learning to read. It is noteworthy that as many as 40% of children diagnosed with attention deficit hyperactivity disorder (ADHD) also have reading difficulties [15], and this may reflect the demands of attention on learning to read. Second, these findings enhance the ability of educators to better identify children at risk for dyslexia before reading failure. In combination with other behavioral and brain measures that predict future reading problems [16–19], there may be substantial gains in the ability to predict which pre-reading children are at risk for dyslexia, and perhaps which remedial intervention is best for a particular child.

A fundamental question posed by these findings is what role visual-spatial attention plays in learning to read. A working hypothesis is that visual-spatial mechanisms support the growth of visual coding of print (orthography) [13]. There is evidence that early reading is associated with bilateral

brain activation that typically becomes left-lateralized as reading skill grows [20], and perhaps visual-spatial attention is critical in early stages of learning to perceive print efficiently. Learning to read requires mapping phonology onto orthography, but prior research and educational intervention has focused on the phonological demands of learning to read. Other recent hypotheses highlight a possible deficit in the cross-modal mapping of auditory and visual stimuli [19]. These new findings may provide a framework for appreciating the visual and orthographic demands of learning to read.

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Speciation Genetics: Reinforcement by Shades and Hues

Mating with a member of another species can seriously reduce an organism's fitness, so mechanisms ought to evolve to prevent it where hybridizing species meet. This old idea of 'reinforcement' has found new support in an elegant pair of studies of the ecological genetics of flower colour in an annual herb.

John R. Pannell

Well adapted organisms should not waste time and resources mating with

genetically incompatible partners. So it is not surprising that signals have evolved that appear to help individuals assess their prospective partners'