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# Reading disability and enhanced dynamic spatial reasoning: A review of the literature ☆

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ABSTRACT

Previous research on reading disabilities (RD) has primarily focused on the cause and expression of the disability. The vast majority of this research has focused on the disorder itself, although it has been proposed that RD embodies other qualities not necessarily related to language or reading deficits. In fact, strengths in nonverbal processing and visual-spatial talents have been proposed to exist in persons with RD. However, the limited empirical data on this matter have yielded inconsistent results. The purpose of this review was to examine this literature, focusing on research concerning dynamic and complex spatial processing or reasoning in people with dyslexia. Our review suggests that there is little evidence in support of a spatial advantage in people with dyslexia, and, in fact, the data show that RD samples most often perform worse or equal to non-RD samples. An exception to this general conclusion may be performance on holistic visualization of complex figures, where RD samples have consistently demonstrated faster response times even though accuracy rates often do not exceed that of controls. The possibility of a unique spatial processing neurology that develops through right-left hemisphere interactions in persons with RD is discussed based on preliminary fMRI data.



## 1. Background

While estimates vary, the rate of developmental reading disability (RD), or dyslexia, in the school age population is thought to be around 7–10%, with 1.5 boys to every girl (Shaywitz & Shaywitz, 2005; Smith, Gilger, & Pennington, 2002).[1] The NICHD adopted definition of RD is "…a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge" (Lyon, Shaywitz, & Shaywitz, 2003, pg. 2).

Genetic, neurologic and behavioral research on RD has presented a fairly consistent picture of the condition's deficits and origins (Demonet, Taylor, & Chaix, 2004; Ramos & Fisher, 2009; Schumacher, Hoffman, Schmal, Schulte-Korne, & Nothern, 2007; Shaywitz & Shaywitz, 2005; Smith et al., 2002). Even though there is still much to learn, several aspects of the disorder are important to note: First, RD is neurodevelopmental, in that functional and structural studies of the brain indicate that anomalies associated with RD are present early on, with apparent origins in prenatal embryologic and fetal growth periods (Demonet et al., 2004; Eckert, 2004; Richlan, Kronbichler, & Wimmer, 2011). People with RD, or even a familial risk for RD, typically present with some form of dysfunction in the left hemisphere ventral–dorsal–anterior "reading pathway" along with anatomical differences in these regions (Eckert, 2004; Ramos & Fisher, 2009; Richlan et al., 2011). Second, genetic research has identified more than several key risk genes that may run in families. Some of these genes are known to play a part in key neurodevelopmental events like neuronal migration and axonal guidance, paralleling the anatomical differences seen in RD brains (Ramos & Fisher, 2009; Schumacher, Hoffman, Schmal, Schulte-Korne, & Nothern, 2007). Third, deficits in word decoding or phonological awareness are a hallmark symptom of RD. This core cognitive deficit may manifest

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[1] Broader definitions of poor reading that do not require a significant discrepancy with nonreading abilities may yield prevalences as high as 20% or more, and in other linguistic populations where written language is more phonetically consistent than English, such as Italian, the frequency of RD can be significantly lower (Paulesu et al., 2001).

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itself early on in oral language, and then later as the child learns to read (Demonet et al., 2004; Shaywitz & Shaywitz, 2005). Finally, intense (preferably early) remediation can improve reading skills in RD individuals. Proven remediation programs for children are often multisensory-whole language approaches, and several studies have shown that these programs can "normalize" the RD brain, improving the function of the left hemisphere "reading pathways" (Keller & Just, 2009; Simos et al., 2002).

The vast majority of RD research has, understandably, focused on the cause and expression of the disability, particularly the left hemisphere language-oriented problem. However, some have proposed that RD is a condition with other qualities not obviously related to the language centers (Gilger & Kaplan, 2001; Nicolson & Fawcett, 1994; Schneps, Rose, & Fischer, 2007). In support of this, research has demonstrated that the RD brain is diffusely atypical probably due to early developmental perturbations, with anatomical and functional differences not limited to the left hemisphere language regions highlighted above (Eckert, 2004; Galaburda, LoTurco Ramus, Fitch, & Rosen, 2006; Gilger & Kaplan, 2001; Hynd & Semrud-Clikeman, 1989; Linkersdorfer, Lonnemann, Lindberg, Hasselhorn, & Fiebach, 2012; Maisog, Einbinder, Flowers, Turkeltaub, & Eden, 2008; Richlan, Kronbichler, & Wimmer, 2009; Richlan et al., 2011). In fact, this research suggests that structural and/or functional differences in right hemisphere, cerebellar regions, and frontal, parietal and temporal areas not formally considered part of the traditional "reading pathway" are present in RD samples. Additional data that also indicate that people with RD may show other behavioral deficits as well that are not as clearly linked to classic language problems such as phonological processing. These include weaknesses in areas like orthographic processing, cognitive-temporal sequencing, and parvo-magnocellular visual path processing (Howard, Howard, Japikse, & Eden, 2006; Nicolson & Fawcett, 1994; Schneps, Brockmole, Sonnert, & Pomplun, 2012; Skotten, 2005; Stein, 2001).

A further complication of the current RD picture actually began decades ago with the pioneering work of Geschwind and colleagues (Galaburda, 1992; Geschwind & Behan, 1982; Geschwind & Galaburda, 1987). They described a phenomenon observed in some of their RD patients: many seemed to have a propensity for better than average nonverbal (spatial) skills and related abilities. Geschwind and Galaburda (1987) and Geschwind and Behan (1982) proposed a theory to explain this apparent correlation, and a variety of other phenomena. A simplification of their theory was that a left hemisphere neurological pathology and secondary right hemisphere neurological exceptionality led to both the language-related weaknesses and the nonverbal strengths. This hemispheric "imbalance" was thought to be due to early prenatal developmental events governed primarily by genes, hormones, and other factors. They reasoned, for example, that the neural anomalies of prenatal origin found in RD brains represent disruptions in cortical development that could lead to unique reorganizations of neural pathways. The long-term developmental effects of these anomalies could, therefore, contribute to the enhancement of certain skills, particularly in nonpathological right hemisphere. Although many spatial or nonverbal skills involve both hemispheres to varying degrees, regions of the right hemisphere may be particularly important in these aspects of cognition (Maurer & Lewis, 2013; Schendan & Stern, 2007).

### 1.1. The RD-spatial ability association

That people with RD may be predisposed to higher than normal spatial or nonverbal abilities has received significant attention in the popular press (Cowen, 2004; Eide & Eide, 2006; Paul, 2012; West, 1997) and this belief maintains a strong representation on the web, in certain paraprofessional groups, public presentations, and in certain treatment approaches. Some go so far as to say that individuals with RD are/will be better suited than their normally reading peers (nRD) to deal with the less language-oriented world of tomorrow, where computers, visualization, and rapid processing of incoming nonverbal material may be needed (West, 1997). Others have even referred to RD as a "gift" or "advantage" because of these purported advanced skills (Davis, 2010). Unfortunately, when this RD advantage is discussed it is often based on little empirical data. Often this assertion has been based on select samples, anecdotal reports or a biased representation of available information. Indeed, experimental studies on nonverbal spatial abilities in RD samples have yielded inconsistent results (e.g., von Károlyi & Winner, 2005; Winner, French, Seliger, Ross, & Weber, 2001). For instance, while one RD–nRD group comparison study found an RD global visualization task advantage (von Károlyi, Winner, Gray, & Sherman, 2003), these same researchers in a larger study found no RD–nRD difference on an assortment of other spatial visualization tests (Winner et al., 2001). In fact, on some tests, subjects with RD performed *more poorly* than the controls.

On the other hand, there are reports of interview and survey data suggesting that there are very successful people with RD who are business leaders, artists and scientists (Eide & Eide, 2006; Hassler, 1990; Steffert, 1998; West, 1997; Winner, Casey, DaSilva, & Hayes, 1991). At first glance this may not seem surprising, as there are people with a variety of disorders represented in these careers and we would expect at least some representation of people with RD in these jobs as well. But interestingly, people with RD *may be* over represented in gifted populations in K-12 schools and in certain careers that may require more holistic, nonverbal, visual learning, or creative thinking (e.g., architects, physicists, etc.; Bloom, 1985; Foley Nicpon, Allmon, Sieck, & Stinson, 2011; Gardner, 1983; Martino & Winner, 1995; Newman & Sternberg, 2004; Ruban & Reis, 2005; Schneps et al., 2007; Winner et al., 1991). For example, Winner et al. (1991) found an overrepresentation of reading problems in nonrighthanded artists, and Gilger and Hynd (2008) hypothesized that the percent of gifted-dyslexics in schools may exceed the number expected by chance if we assume that RD and giftedness are independent conditions.[2] Therefore, it is possible, although very tentative, that people with RD have a cognitive advantage that enables them to succeed in such careers or leads them to select such careers and practice concomitant skill requirements (Bacon, Handley, & Mcdonald, 2007; Taylor & Walter, 2003; Winner et al., 1991, 2001).

### 1.2. Purpose and focus of this review

Results from empirical work on the question of superior spatial abilities in individuals with RD are highly variable. The studies can be quite different with regard to sample demographics, nonverbal tests administered, general methodologies, analytical techniques, and more. Given the persistence of the idea that there is an RD–nonverbal talent association, along with the inconsistencies across studies, the field would benefit from a broad and critical look at the available research. Hence, the purpose of this review.

Our goal is to review the literature on experiments designed to assess spatial abilities in RD samples. It is important to highlight

[2] For the purpose of illustration, Gilger and Hynd (2008) performed a simple test of the RD-giftedness association. They hypothesized that the two conditions were independent, and then applied Law of Independent Probabilities and the Multiplicative Rule of Probabilities to see if the observed rates of RD-giftedeness (twice exceptionality) were higher than expected to occur by chance (McClave & Sincich, 2003). The authors showed that the predicted value is significantly lower than the observed suggesting some support that students with RD are overrepresented in gifted school programs. However, this statistical method requires many uncontrolled assumptions and, as the authors recognized, the question needs to be better addressed.