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Neuroanatomical and behavioral asymmetry in an adult compensated dyslexic ☆

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Abstract

Individual differences in cortical anatomy are readily observable, but their functional significance for behaviors such as reading is not well understood. Here, we report a case of an apparent compensated dyslexic who had attained high achievement in visuospatial mathematics. Data from a detailed background interview, psychometric testing, divided visual field tasks measuring basic word recognition (word naming, nonword naming, and lexical decision), and more controlled word retrieval (verb, category, and rhyme generation), and measurements of his atypical brain structure are described. The findings suggested that enhanced "top-down" processing could provide the means to compensate for deficient "bottom-up" word decoding skills in this case. Relative to controls, this individual also evidenced unusually large asymmetries on several divided visual field lexical tasks, an extreme leftward asymmetry of the planum temporale, and a rare form of Sylvian fissure morphology (Steinmetz type 4, [Steinmetz, H., Ebeling, U., Huang, Y., & Kahn, T. (1990). Sulcus topography of the parietal opercular region: An anatomic and MR study. *Brain and Language, 38*, 515–533.]). We suggest that certain forms of brain organization may be associated with successful behavioral compensation for dyslexia, and that anatomical variations in the right hemisphere may be important contributors to individual differences in reading acquisition and achievement.

Keywords: Individual differences; Dyslexia; Planum temporale; Planum parietale; Cerebral asymmetries; Reading; Visual half-field; Sylvian fissure; Compensation

1. Introduction

Dyslexia is a developmental disorder that severely impacts the acquisition of reading skills, despite normal intelligence, and the absence of hard neurological signs. This specific reading disability is most often associated with deficient phonological processing (Gottardo, Stanovich, & Siegel, 1996; Shankweiler & Lieberman, 1989; Wagner & Torgesen, 1987). Many dyslexic individuals are unable to achieve normal levels of reading comprehension, and remain dyslexic as adults (Felton, Naylor, & Wood, 1990; Flowers, 1995). However, others are eventually able to read fluently for comprehension and succeed in occupations that require high levels of literacy (Fink, 1998). Understanding the neural underpinnings of reading in such compensated dyslexics may allow us to identify alternate forms of brain organization that enable successful behavioral compensation.

Behaviorally, most studies indicate that difficulties with phonological processes persist in adults who have achieved good reading despite childhood diagnoses of dyslexia, as evident in tasks such as nonword reading

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(Bruck, 1990; Flowers, 1995; Gallagher, Laxon, Armstrong, & Frith, 1996), phoneme awareness (Bruck, 1992; Flowers, 1995; Gallagher et al., 1996), and spelling (Bruck, 1990; Gallagher et al., 1996; Lefly & Pennington, 1991). Although these studies differ in how compensation is operationally defined, there is substantial evidence that phonological deficits persist into adulthood despite the good reading comprehension that some childhood dyslexics ultimately achieve.

Since it appears that dyslexic deficiencies in phonological awareness are never eliminated regardless of age or level of reading achievement (Bruck, 1992; Lefly & Pennington, 1991), it is important to consider alternate reading mechanisms that may enable compensation. Some research suggests that dyslexics do not make greater than normal use of orthographic information during phonological word processing (Bruck, 1992). However, interactive compensatory models of reading suggest that well developed higher level reading subskills (e.g., reliance on context and semantic knowledge) can compensate for weaker lower level subskills (e.g., sound-letter associations) and contribute to individual differences in reading achievement (Rumelhart, 1977; Stanovich, 1980). Supporting this view, college-age dyslexics, relative to controls, show greater effects of sentence context on word naming (Ben-Dror, Pollatsek, & Scarpati, 1991). Similarly, higher level processes (listening comprehension, general knowledge, and vocabulary) moderate the relationship between phonological performance (nonword reading and phonological awareness) and reading comprehension in adults with a childhood diagnoses of dyslexia (Ransby & Swanson, 2003). This suggests that phonological skills may be less important for adult, than for child, readers. Although neither of these studies attempted to identify compensated adult readers, the findings imply that top-down processes may contribute to improvements in reading comprehension that some dyslexics achieve.

Even less is known about the neural substrates of reading in compensated dyslexics. To our knowledge no study of explicitly defined compensated dyslexics has explored cerebral asymmetries using behavioral methods. The most relevant study may be that of Atchley, Story, and Buchanan (2001) who studied college students with a history of developmental language disorder (DLD) using a divided visual field semantic priming paradigm. Activation of the subordinate meaning of ambiguous words was obtained for LVF/RH trials for control participants, but not for the DLD students. This finding could imply a RH word meaning access deficit in higher functioning adults with developmental language dysfunction.

A few neuroimaging studies have compared brain activity profiles associated with compensation. For example, Ingvar et al. (2002) observed that, relative to controls, the compensated dyslexics had a smaller spatial extent of RH perisylvian activation, but increased levels of activation in right medial frontal and perisylvian areas during spoken word reading. During silent word reading, the dyslexics also showed increased activation in the right temporoparietal area. In a letter rhyme decision task compensated dyslexics had fewer regions activated than controls, with markedly less activation in the insula, left premotor, and Wernicke's area (Paulesu et al., 1996). An investigation by Shaywitz et al. (2003) utilized fMRI to compare normal readers, compensated dyslexics, and persistent dyslexics. Relative to controls, both dyslexic groups had underactivation of superior temporal and occipitotemporal regions, and overactivation of right inferior frontal areas during a nonword rhyme decision task. However, only the compensated dyslexics activated additional regions including right superior frontal and midtemporal areas, and left anterior ÿcingulate gyrus. Although the tasks, subject groups, and imaging techniques vary greatly in these studies, the results suggest that impaired readers who learn to compensate utilize a somewhat different network of brain regions during reading than do normal readers or those with persistent dyslexia.

One factor contributing to variation in brain activity profiles could be structural variation in the underlying neural substrate. Leonard, Voeller, Lombardino, Morris, and Hynd (1993) compared Sylvian fissure morphology in a heterogeneous group of dyslexic individuals (including some compensated adults) with that of their unimpaired relatives and controls. They found an exaggerated *leftward* planar asymmetry and a "parietal shift" in the right hemisphere of three compensated individuals. A parietal shift occurs when the planum temporale posterior to Heschl's gyrus is severely truncated or absent while the planum parietale is relatively enlarged making a steep ascent directly posterior to Heschl's sulcus (V formation, Witelson & Kigar, 1992; type 4, Steinmetz, Ebeling, Huang, & Kahn, 1990). (Fig. 1 depicts various Sylvian fissure configurations in schematic form). This unusual planum temporale truncation results in a relative enlargement of the parietal lobe at the expense of the temporal lobe, more commonly in the right than the left hemisphere (Witelson & Kigar, 1992). In the Leonard et al. (1993) study, two of the dyslexics, but none of the controls or the relatives of the dyslexics, had parietal shifts bilaterally. A third compensated individual had a unilateral right parietal shift characterized by a rare subtype fissure called type 4 (Steinmetz et al., 1990). Here, not only is the planum temporale missing, but the parietal operculum is also truncated because the planum parietale rises anterior to the postcentral sulcus. In both type 4 and type V the posterior parietal lobe is enlarged. All three of the compensated dyslexics with parietal shifts were highly successful in professions that depended more on visuospatial than linguistic skill.

A subsequent study of compensated college students replicated the finding of greater leftward planum temporale asymmetry in the dyslexic individuals, particularly in those who had achieved good reading comprehension despite severe phonological deficits (Leonard et al., 2001). In this study, however, dyslexics and controls did not differ in the degree of parietal shift. Given the heterogeneity of behavioral and anatomical presentation in different