RESEARCH REPORT

BRAIN MORPHOLOGY AND NEUROPSYCHOLOGICAL PROFILES IN A FAMILY DISPLAYING DYSLEXIA AND SUPERIOR NONVERBAL INTELLIGENCE

Jason G. Craggs[1], Juliana Sanchez[1], Michelle Y. Kibby[2], Jeffrey W. Gilger[3] and George W. Hynd[4]

([1]Center for Clinical and Developmental Neuropsychology, University of Georgia, Athens, GA, USA; [2]Washington State University, Pullman, WA, USA; [3]California State University, Los Angeles, CA, USA; [4]Purdue University, West Lafayette, IN, USA)

ABSTRACT

Behavioral research suggests that individuals with dyslexia may have exceptional skills in nonverbal cognitive processes, while genetic studies have noted that giftedness, high IQ and/or special talents tend to run in families. Taken together, these results suggest that persons within families (particularly offspring) may share similar cortical systems supporting those functions. Postmortem and in vivo imaging studies have linked dyslexia to abnormalities in the structures associated with the parietal operculum (PO) (e.g., planum temporale, supramarginal gyrus, and angular gyrus). In this paper we present data on a single family showing a link between dyslexia, superior nonverbal IQ and atypical PO presentation. We consider the psychometric and neurological patterns of this family as a tentative etiological test of the putative dyslexia-talent association.

Key words: developmental dyslexia, reading disability, magnetic resonance imaging, brain morphology, gyral typology, family study, nonverbal IQ, giftedness, genetics

INTRODUCTION

Reports suggest that individuals with poor linguistic skills can often be found in occupations that rely heavily on nonverbal cognitive processing and visual-spatial skill domains (Aaron and Guillemarde, 1993; West, 1991; Colangelo et al., 1993; Hassler, 1990; Winner and Casey, 1993) [e.g., artists, mechanics, drafting, engineering, etc. (von Karolyi et al., 2003; Winner et al., 1991, 2001)]. Moreover, some research indicates that individuals with linguistic deficits often have special talents, such as high IQ, or giftedness, particularly in the nonverbal domains (West, 1991; Winner et al., 2001). Some believe that such giftedness is more frequently found in people with dyslexia than in normal readers (Aaron and Guillemarde, 1993; West, 1991; Colangelo et al., 1993; Hassler, 1990; Winner and Casey, 1993).

The idea of linking nonverbal excellence to dyslexia can be seen in the work of Geschwind and colleagues (Geschwind and Behan, 1982; Geschwind and Galaburda, 1987). They suggested that the developmental processes and neurology underlying dyslexia are such that the dyslexic brain is more adept at certain (nonverbal) skills than are the brains of non-dyslexics. This appears particularly true when discussing "relative" or "within-person" neurocognitive strengths and weaknesses, where individuals with dyslexia often perform at higher levels on right-hemisphere (visual-spatial) tasks relative to performance on left-hemisphere (linguistic) tasks (Winner et al., 1991; Rugel, 1974; Smith et al., 1977; Gordon and Harness, 1977; Naidoo, 1971).

Neurodevelopmental models of giftedness in individuals with dyslexia, as well as giftedness and dyslexia alone, often predict cortical morphology differences resulting from events occurring soon after conception and largely completed in-utero (Geschwind and Behan, 1982; Geschwind and Galaburda, 1987; Witelson et al., 1999; Hiemenz and Hynd, 2000; Casanova et al., in press). Moreover, what is known about the timing and characteristics of these neurodevelopmental hallmarks strongly suggests genetic mediation.

Remarkably, biological forces which influence cortical development are present shortly after fertilization. Around the third week of gestation, fetal cells begin forming the neural tube. As seen in Figure 1, about one week later the neural tube differentiates into three distinct components: the proencephalon, the mesencephalon, and the rhombencephalon. The proencephalon further subdivides into the telencephalon and diencephalon, with the telencephalon evolving into the cerebral hemispheres. During the second through fourth months of gestation, rapid cell proliferation and expansion provides the final shape and form of the cerebral hemispheres. By the fourth month of gestation, enough neocortical cell proliferation forces the cortex to fold over the insula. Simultaneously, regulatory events guide the shape and development of the sylvian fissure (SF) – around which are structures vital for language (Bernard et al., 1988). Consequently, around the

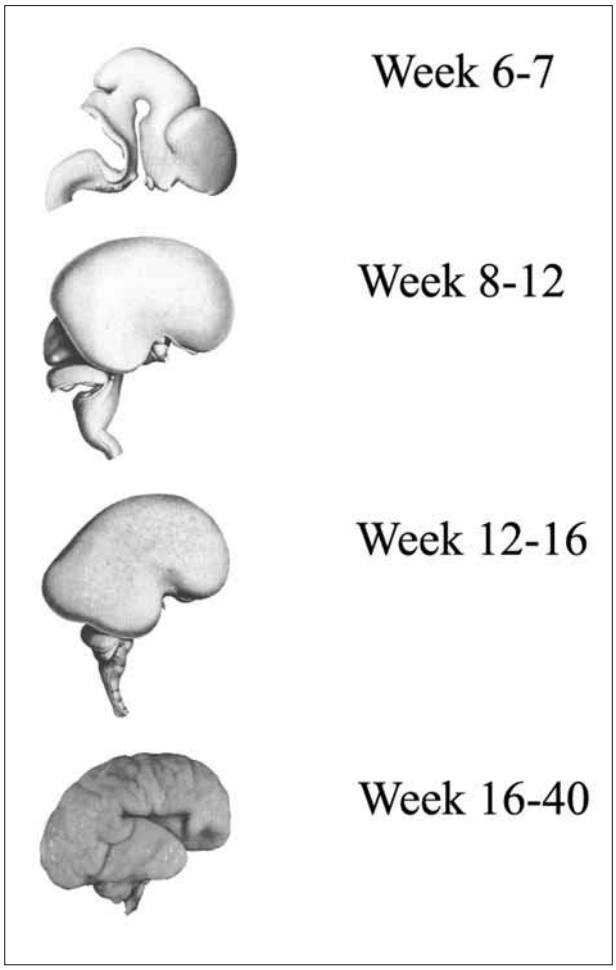

Fig. 1 – *Cortical development [Reprinted from Nolte (2002) with permission].*

fourth month of gestation, the basic shape of the brain is fairly well-defined, yet the surface of a cortex remains fairly smooth.

Although little is known about the events that guide structural asymmetry, their influence is obvious as early as the third trimester. Planar asymmetry, for example, is generally apparent around week 29-31 (Wada et al., 1975; Chi et al., 1977). Further, this time period may be sensitive for prenatal insults which can influence the normal patterns of asymmetry (Eckert et al., 2002). Hormones may have a negative effect on neurodevelopment, increasing the probability of an individual manifesting dyslexia (Sherman et al., 1987). For the remainder of the gestational period, neuronal migration, glial differentiation, synapse formation, and some myelination continues (Nolte, 2002).

In this paper we present data on a single family whose neuropsychological profile suggests a link between dyslexia and superior nonverbal IQ. We will consider the psychometric and neurological patterns in these family members as an investigation of the etiology of the putative dyslexia-talent association and as a preliminary step towards identifying what may be a familial (genetic) factor leading to unique brain morphology that, in turn, manifests itself as both dyslexia and nonverbal talents. Before presenting these results, we review some pertinent background information.

Pathogenesis and Epidemiology of Dyslexia

Dyslexia is diagnosed behaviorally and is typically characterized by poor reading in the absence of other handicapping or adverse environmental conditions (American Psychiatric Association, 2000). Prevalence rates of developmental dyslexia or reading disability have been estimated as high as 20% and as low as 3%, with a commonly cited mean prevalence of 5-7% in the school-aged population (American Psychiatric Association, 2000; Lyon, 1995). A substantial body of evidence suggests that dyslexia has a neurobiological basis (Kline, 1986; Kibby and Hynd, 2001; Shaywitz et al., 2002; Miller et al., 2003) and to some extent is genetic in origin (Fisher and DeFries, 2002; Smith et al., 2002).

Neurology and Genetics

Dyslexia is commonly found to run in families. Children of parents with dyslexia show a dramatic increase in the incidence of dyslexia when compared to children who do not have a parent with dyslexia (Miller et al., 2003). Twin studies demonstrate that approximately 40-50% of the risk for dyslexia is due to genetics rather than the common family environment (Fisher and DeFries, 2002). Ongoing linkage and gene mapping studies have suggested that chromosomes 1, 2, 3, 6, 7, 15, and 18 may carry genes that potentially increase the risk for dyslexia (Grigorenko et al., 1997; Smith et al., 2002; Fisher and DeFries, 2002). These genes do not appear to be sex-linked and have variable or incomplete expression across family members (Elbert and Seale, 1988; Smith et al., 2002).

The genes that predispose an individual to dyslexia may do so via aberrant cortical development (Gilger et al., 2001a; Gilger and Kaplan, 2001b). These developmental abnormalities may be genetically mediated by genes operating early on in-utero (Sherman et al., 1987; Eckert et al., 2002). Postmortem and in-vivo imaging studies have linked dyslexia to structural abnormalities in the left hemisphere cortical language areas including the planum temporale, supramarginal gyrus, and angular gyrus (Hynd and Semrud-Clikeman, 1989; Galaburda, 1993; Miller et al., 2003; Filipek, 1995; Morgan and Hynd, 1998; Habib and Robichon, 2003).

Neurogenesis and Epidemiology of Superior Nonverbal IQ

Because research in general tends to focus on disease processes, constructs such as giftedness are