Available online at www.sciencedirect.com
SCIENCE DIRECT
Brain and Cognition 61 (2006) 195–210
Brain and Cognition
www.elsevier.com/locate/b&c

Mathematics learning disability in girls with Turner syndrome or fragile X syndrome

Melissa M. Murphy [a,b], Michèle M.M. Mazzocco [a,b,c,*], Gwendolyn Gerner [b], Anne E. Henry [b]

[a] Johns Hopkins School of Medicine, Department of Psychiatry and Behavioral Sciences, Baltimore, MD, USA
[b] Kennedy Krieger Institute, 3825 Greenspring Avenue, Painter Bldg, Top Floor, Baltimore, MD 21211, USA
[c] Department of Population and Family Health Sciences, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

Accepted 31 December 2005
Available online 24 February 2006

Abstract

Two studies were carried out to examine the persistence (Study 1) and characteristics (Study 2) of mathematics learning disability (MLD) in girls with Turner syndrome or fragile X during the primary school years (ages 5–9 years). In Study 1, the rate of MLD for each syndrome group exceeded the rate observed in a grade-matched comparison group, although the likelihood of MLD persisting through the primary school years was comparable for all three groups. In Study 2, formal and informal math skills were compared across the syndrome groups, a normative group, and children from the normative group who had MLD. Few differences were observed between the Turner syndrome and normative groups. Despite having rote counting and number representation skills comparable to those in the normative group, girls with fragile X had difficulty with counting rules (e.g., cardinality, number constancy). However, this difficulty did not distinguish them from the MLD group. Overall, counting skills appear to distinguish the Turner syndrome and fragile X groups, suggesting that the specificity of math deficits emerges earlier for fragile X than Turner syndrome.

Keywords: Fragile X syndrome; Turner syndrome; Mathematics learning disability

1. Introduction

Turner syndrome and fragile X syndrome are two X-chromosome associated disorders, both of which are linked to poor math performance (Bennetto, Pennington, Porter, Taylor, & Hagerman, 2001; Bruandet, Molko, Cohen, & Dehaene, 2004; Grigsby, Kemper, Hagerman, & Myers, 1990; Kemper, Hagerman, Ahmad, & Mariner, 1986; Mazzocco & McCloskey, 2005; Rovet, 1993; Rovet, Szekely, & Hockenberry, 1994; Temple, Carney, & Mullarkey, 1996; Temple & Marriott, 1998). Indeed, children with either syndrome are more likely than children from age, grade, and IQ matched comparison groups to meet criteria for math learning disability (MLD) even as early as kindergarten (Mazzocco, 2001). However, it is unclear whether MLD in young children with Turner syndrome or fragile X represents a persistent phenotypic characteristic or a short term delay. In addition, the nature of the math difficulties in either syndrome may vary substantially due to differences in their respective cognitive phenotype (Bennetto et al., 2001; Mazzocco, 1998, 2001; Mazzocco & McCloskey, 2005; Molko et al., 2003; Rivera, Menon, White, Glaser, & Reiss, 2002; Rovet, 1993, 2004; Rovet & Buchanan, 1999; Rovet et al., 1994). Although there is very little research comparing math performance in children with Turner syndrome versus fragile X, there is theoretical support for the notion that the nature of math difficulties may differ because of these contrasting phenotypes. As such, exploring MLD and its manifestation in syndromes with known genetic causes may inform our understanding of variations in underlying sources of math difficulties. Towards that end, the present study was designed to examine both the persistence of early math difficulties during the primary school years and the nature of those difficulties among children with Turner syndrome or fragile X.

* Corresponding author.
E-mail address: mazzocco@kennedykrieger.org (M.M.M. Mazzocco).

0278-2626/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.bandc.2005.12.014

1.1. Turner syndrome

Turner syndrome results from the partial or complete loss of one of the two X chromosomes typically present in females. Its prevalence is approximately 1 in 1900 live female births (Davenport, Hooper, & Zeger, in press). One consequence of X monosomy is that the ovaries of females with Turner syndrome fail to develop, resulting in a lack of estrogen production (Ross & Zinn, 1999). Estrogen may influence performance, particularly on verbal and nonverbal memory tasks (Ross, Roeltgen, Feuillan, Kushner, & Cutler, 2000), and may contribute to the cognitive phenotype associated with Turner syndrome (McCauley, Kay, Ito, & Treder, 1987; Ross & Zinn, 1999; Ross et al., 2000). Females with Turner syndrome do not typically meet criteria for mental retardation; however, they may have learning disabilities, particularly in the area of mathematics (Rovet, 1993).

1.2. Fragile X syndrome

Fragile X syndrome is the leading known cause of inherited mental retardation. It occurs in approximately 1 in 4000 to 1 in 9000 live births (e.g., Crawford, Acuna, & Sherman, 2001) as the result of a single gene mutation on the long arm of the X-chromosome (Verkerk et al., 1991; Yu et al., 1991). This mutation leads to impaired production of a protein (FMRP) that is important for neural development. Although there is much phenotypic variability in children with the syndrome, most males with fragile X meet criteria for moderate to mild mental retardation (i.e., IQ scores between 36 and 70; Bailey, Hatton, & Skinner, 1998). In contrast, ~50% of females with fragile X will have mental retardation (Rousseau et al., 1994), whereas the remaining females may have less severe cognitive impairments including learning disabilities, or may have no noticeable effects of the syndrome (Cronister, Hagerman, Wittenberger, & Amiri, 1991; Hagerman, Hills, Scharfenaker, & Lewis, 1999). To investigate the subtle aspects of the cognitive phenotype in fragile X, in the present study we limited participation to those individuals with fragile X without mental retardation, which included only females.

1.3. Prevalence and persistence of MLD

Difficulties with mathematics in Turner syndrome or fragile X are seen throughout the life span, including the early primary school age years (Grigsby et al., 1990, 1996; Kovar, 1995; Mazzocco, 1998, 2001; Mazzocco, Pennington, & Hagerman, 1993; Miezejeski & Hinton, 1992; Rovet, 1993), the later school years (Buchanan, Pavlovic, & Rovet, 1998; Mazzocco, 1998; Rivera et al., 2002; Rovet, 1993; Rovet et al., 1994; Temple et al., 1996), and adulthood (Bennetto et al., 2001; Bruandet et al., 2004; Grigsby et al., 1990; Mazzocco et al., 1993). Rovet (1993) found that 55% of girls with Turner syndrome between the ages of 6 and 16 years met criteria for MLD, either alone or in combination with reading disability (RD). (In Rovet's study, MLD was defined as performance below the 25th percentile on the Arithmetic subtest of the Wide Range Achievement Test-Revised.) This percentage exceeded the rate observed in the comparison group of sixth graders, of whom only 26% met criteria for a learning disability in mathematics, reading, or both. Using an even more conservative criterion than Rovet (i.e., quotient scores below the 10th percentile on the Test of Early Math Ability-second edition; TEMA-2), Mazzocco (2001) reported that 43% of girls with Turner syndrome met criteria for MLD. This percentage was significantly higher than the 10% observed among a gender, grade, age, and IQ matched comparison group of girls without Turner syndrome.

There are fewer studies of MLD in girls with fragile X syndrome; however, among girls with fragile X, Mazzocco (2001) reported that five of the nine girls with fragile X (56%) included in her initial study met criteria for MLD, defined as performance below the 10th percentile on the TEMA-2. This prevalence rate was not significantly different from the prevalence rate of 20% observed among an age, grade, and full scale IQ matched comparison group of girls without fragile X. However, when the MLD criterion was broadened to include performance below the 12th percentile on the TEMA-2, the group difference became significant: 87% of the girls with fragile X scored below the 12th percentile compared to 20% in the comparison group.

Although together these studies indicate greater prevalence of MLD in Turner syndrome or fragile X relative to comparison groups, the studies were cross-sectional, and were not designed to address whether MLD in girls with Turner syndrome or fragile X persists over time, or whether it reflects a transitory delay. Over the school age years, children can vary as to whether they meet criteria for MLD (Francis et al., 2005; Shalev, Manor, Auerbach, & Gross-Tsur, 1998; Silver, Pennett, Black, Fair, & Balise, 1999). For example, among a relatively normative sample of children recruited from a large suburban school district, Mazzocco and Myers (2003) found that approximately 44% of primary school age children meet investigator-defined criteria for MLD during at least one of their primary school age years. However, approximately 66% continued to meet this criterion for one or more of the remaining primary school years, whereas the remainder did not meet the criterion more than once (Mazzocco & Myers, 2003). Individual variability over time has led some researchers to suggest that the criteria for MLD must be met at more than one point in time, if the classification of MLD is to be valid (Geary, 2004; Geary, Hamson, & Hoard, 2000).

Given the elevated prevalence of math difficulty in both Turner syndrome and fragile X, it is important to assess whether the early MLD observed in girls with Turner syndrome or fragile X persists over time at a rate that matches or exceeds the frequency reported for the general population (Mazzocco & Myers, 2003). Determining the persistence of MLD in Turner syndrome and fragile X will contribute to understanding the degree to which children