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Changes in visual function following optical treatment of astigmatism-related amblyopia

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Abstract

Effects of optical correction on best-corrected grating acuity (vertical (V), horizontal (H), oblique (O)), vernier acuity (V, H, O), contrast sensitivity (1.5, 6.0, and 18.0 cy/deg spatial frequency, V and H), and stereoacuity were evaluated prospectively in 4- to 13-year-old astigmats and a non-astigmatic age-matched control group. Measurements made at baseline (eyeglasses dispensed for astigmats), 6 weeks, and 1 year showed greater improvement in astigmatic than non-astigmatic children for all measures. Treatment effects occurred by 6 weeks, and did not differ by cohort (<8 vs. ⩾8 years), but astigmatic children did not attain normal levels of visual function.

Keywords: Astigmatism; Amblyopia; Children; Visual performance; Treatment

1. Introduction

Degraded visual input during early development can result in neural visual deficits that are clinically termed *amblyopia.* These deficits are evidenced by reduced visual performance in the absence of any ocular cause. Previous research has shown that patterns of visual deficits in amblyopia can be dependent on the nature of the disruption of visual input present during development (Dobson, Miller, Harvey, & Mohan, 2003; Levi & Klein, 1982; McKee, Levi, & Movshon, 2003; Mitchell, Freeman, Millodot, & Haegerstrom, 1973). For example, in astigmatism-related amblyopia, presence and severity of visual deficits can be specific to stimulus orientation. This pattern of amblyopia, termed *meridional amblyopia* (Mitchell et al., 1973), develops as a result of the orientation-specific defocus characteristic of uncorrected astigmatism, although some studies have found deficits that are independent of stimulus orientation in individuals with some types of astigmatism (Dobson et al., 2003; Harvey, Dobson, Miller, & Clifford-Donaldson, 2007). Meridional amblyopia has been documented in several types of visual function, including grating acuity (Atkinson et al., 1996; Cobb & MacDonald, 1978; Dobson et al., 2003; Freeman, 1975a; Freeman, Mitchell, & Millodot, 1972; Gwiazda, Scheiman, & Held, 1984; Harvey, Dobson, Miller et al., 2007; Mitchell & Wilkinson, 1974; Mitchell et al., 1973; Mohindra, Jacobson, & Held, 1983), vernier acuity (Gwiazda, Bauer, Thorn, & Held, 1986; Mitchell et al., 1973), contrast sensitivity (Freeman, 1975b; Freeman & Thibos, 1975; Mitchell & Wilkinson, 1974), and stereoacuity (Mitchell et al., 1973). Previous studies of astigmatic individuals have also documented reduced best-corrected recognition acuity (Atkinson et al., 1996; Dobson, Tyszko, Miller, & Harvey, 1996; Dobson et al., 2003; Harvey 2002; Harvey, Dobson,

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Clifford-Donaldson, & Miller, 2007; Harvey, Dobson, Miller et al., 2007; Kershner & Brick, 1984), reduced stereoacuity for complex stimuli (Harvey, Dobson, Miller et al., 2007), and reduced best-corrected vision *across stimulus orientations* in grating acuity, vernier acuity, and contrast sensitivity (Harvey, Dobson, Miller et al., 2007).

Previous research has demonstrated that optical correction of astigmatism, i.e., restoration of normal visual input, can be an effective treatment of astigmatism-related amblyopia during early childhood (Cobb & MacDonald, 1978; Mitchell et al., 1973; Mohindra et al., 1983). However, some evidence suggests that this form of plasticity may be limited to a sensitive period. Retrospective studies of a small number of astigmatic adults have found that meridional amblyopia occurs rarely in those who received eyeglasses prior to age seven years, but frequently in those who received eyeglasses after age seven (Cobb & MacDonald, 1978; Mitchell et al., 1973). Two prospective studies (Harvey, Dobson, Miller, & Sherrill, 2004; Harvey, Dobson, Clifford-Donaldson et al., 2007) have examined the effect of optical correction on astigmatism-related amblyopia in children who are members of a Native American tribe with a high prevalence of astigmatism. The first study, which included subjects three to five years of age, found no significant improvement in best-corrected recognition acuity or grating acuity, and no reduction in meridional amblyopia, in astigmatic children after an average optical treatment duration of four months, relative to a non-astigmatic control group (Harvey et al., 2004). In contrast, the second study, which included subjects 4–13 years of age, showed significantly greater improvement in best-corrected *recognition* acuity in astigmatic children compared to the improvement over time shown by a normal (non-astigmatic) age-matched control group after an average treatment duration of six weeks (Harvey, Dobson, Clifford-Donaldson et al., 2007). Furthermore, the significant improvement in best-corrected recognition acuity was found both in children age seven years or younger, the age previously believed to mark the end of the sensitive period for successful treatment (Cobb & MacDonald, 1978; Mitchell et al., 1973), and in children older than age seven years (Harvey, Dobson, Clifford-Donaldson et al., 2007). However, the results also indicated that after one year of optical treatment, astigmatic children still had significantly poorer best-corrected visual acuity than did non-astigmatic children. It was not clear whether the persistence of reduced acuity after one year of treatment was due to reduced plasticity in this age range, or to poor treatment compliance in some subjects.

In the present study, we examine prospectively changes in grating acuity for vertical (V), horizontal (H), and oblique (O) stimuli, vernier acuity for V, H, and O stimuli, contrast sensitivity for V and H stimuli, and stereoacuity for complex stimuli that occur following optical treatment of astigmatism-related amblyopia. Because previous retrospective and prospective studies suggest that *meridional* amblyopia may not be responsive to optical correction beyond age seven years (Cobb & MacDonald, 1978; Mitchell et al., 1973), or perhaps even earlier (Harvey et al., 2004), the present report groups subjects into a younger cohort (YC, <8 years of age) and an older cohort (OC, ⩾8 years of age). Outcome of best-corrected recognition acuity for these subjects has been reported previously (Harvey, Dobson, Clifford-Donaldson et al., 2007).

2. Methods

2.1. Subjects

Subjects were children in grades K-2 (recruited during the 2003/04 school year) and children in grades 4–6 (recruited during the 2001/02 school year) who attended one of five elementary schools located on the Tohono O'odham Reservation in southern Arizona, and children at a sixth elementary school on the reservation who participated in a preliminary study during the 2000/01 and 2001/02 school years. Recruitment years for different grades were selected in order to minimize the possibility of recruiting children who participated in a previous eyeglass treatment study of Tohono O'odham preschool children (1997–2001, Dobson et al., 2003; Harvey et al., 2004; Miller, Dobson, Harvey, & Sherrill, 2000; Miller, Dobson, Harvey, & Sherrill, 2001). This population was chosen for the study because there is a high prevalence of astigmatism (Dobson, Miller, & Harvey, 1999; Dobson, Miller, Harvey, & Sherrill, 1999; Harvey, Dobson, & Miller, 2006) and astigmatism-related amblyopia (Dobson et al., 1996, 2003; Harvey et al., 2004) among the Tohono O'odham.

The Institutional Review Board of the University of Arizona approved this study. Prior to each child's participation, written informed consent was obtained from a parent or guardian, and written assent was obtained from children in grades 4, 5, and 6.

2.2. Procedures

Each child was scheduled to participate in an initial eye examination, a baseline best-corrected vision testing session, a six-week follow-up best-corrected vision testing session, a one-year follow-up eye examination, and a one-year follow-up best-corrected vision testing session. Refractive error correction for the baseline and six-week follow-up vision testing sessions was determined at the initial eye examination, and refractive error correction for the one-year follow-up vision testing session was determined at the one-year follow-up eye examination.

At the eye examinations, each child underwent a complete eye examination including cycloplegic refraction, conducted by a pediatric ophthalmologist (JMM) at least 40 min after instillation of one drop of proparacaine (0.5%) and two drops of cyclopentolate (1%) separated by an interval of 5 min. Eyeglasses were prescribed for (a) children who had ⩾2.00 diopters (D) of astigmatism in either eye, and (b) children who had uncorrected recognition acuity worse than 20/20 and significant refractive error (myopia ⩾0.75 D in either meridian, hyperopia ⩾2.50 D in either meridian, astigmatism ⩾1.00 D in either eye, anisometropia ⩾1.50 D spherical equivalent). Eyeglass prescriptions were determined by cycloplegic autorefraction (Nikon Retinomax K+, Nikon Inc., Tokyo, now manufactured by Righton Manufacturing Co., Tokyo), confirmed by retinoscopy and by subjective refinement (when possible). Correction of hyperopic refractive error was reduced by one-third or by 1.00 D, whichever was greater (Guyton, Miller, & West, 2003).

The baseline vision testing session was conducted on a separate day approximately two to three weeks after the initial eye exam. The first follow-up vision testing session was conducted approximately six weeks after the baseline session, and the one-year follow-up vision testing session was conducted approximately two to three weeks after the one-year follow-up eye examination (approximately one year after the baseline vision testing session). Eyeglasses were prescribed only for children who met the above criteria, and these children were given their eyeglasses at the beginning of the baseline vision testing session. However, all children wore eyeglasses