Stereoacuity in Unilateral Visual Impairment Detected at Preschool Screening: Outcomes from a Randomized Controlled Trial

Sarah R. Richardson,1 Charlotte M. Wright,2 Susan Hrisos,3 Deborah Buck,3 and Michael P. Clarke1,3

PURPOSE. Reduced stereoacuity is commonly found in association with reduced visual acuity or strabismus and may significantly affect neuro-developmental performance. Treatment for reduced visual acuity due to refractive error or amblyopia is believed to result in improved stereoacuity. This study was undertaken to investigate the effect on stereoacuity of treatment for unilateral visual impairment detected at preschool vision screenings, in the setting of a randomized controlled trial.

METHODS. Children identified through preschool vision screening were recruited and randomized to one of three groups (no treatment, glasses only, or full treatment with glasses and occlusion) for a period of 12 months, after which full treatment was given when indicated. Logarithm of the minimum angle of resolution (LogMAR) visual acuity and random-dot stereotest (Randot; Stereo Optical, Chicago, IL) stereoacuity were assessed at recruitment and at 12- and 18-month follow-ups by an orthoptist masked to group allocation.

RESULTS. One hundred seventy-seven children were recruited and randomized, 59 to each group. Comparison of stereoacuities showed an immediate median improvement of 30 seconds of arc in each group from refractive correction. Age significantly affected stereoacuity performance at recruitment (mean age, 4 years) but not at follow-up (mean age, 5 years). Deferring treatment did not affect final stereoacuity.

CONCLUSIONS. In this group, stereoacuity improved to a normal level as a result of refractive correction. Children in whom treatment was deferred for 12 months did not demonstrate significantly poorer stereoacuity than those in treatment. (Invest Ophthalmol Vis Sci. 2005;46:150–154) DOI:10.1167/ iovs.04-0672

Stereopsis is the binocular perception of depth. It results from the fusion of two slightly dissimilar retinal images and has been described as a benchmark for peak clinical performance of binocular vision.2,3 Stereoacuity depends on binocular cooperation between the eyes and good visual acuity in each eye. Reduced or absent stereoacuity is therefore commonly associated with strabismus or reduced visual acuity.4,5

Reduced stereoacuity has been reported to affect neurodevelopmental performance in children6 and may have significant long-term functional consequences. It currently disqualifies a person from a variety of professions in which entry depends on specified visual requirements—for example, piloting or navigating an aircraft7,8 or joining the police force.8,9 It is also thought to limit sporting ability and academic performance.10,11 When due to amblyopia, reduced stereoacuity may be associated with increased risk of injury to the nonamblyopic eye.12 These findings have been used as additional justification for preschool vision screening programs13 on the basis that treatment to improve visual acuity deficits caused by refractive error and amblyopia will result in a concurrent improvement in stereoacuity.

A multicenter randomized controlled trial of treatment for unilateral visual impairment, detected at preschool vision screening, recently found a significant improvement in visual acuity in children who had received treatment, compared with a control group of untreated peers.14 This article reports the effect of treatment on stereoacuity in the same group of children.

METHODS

The study was conducted in accordance with the tenets of the Declaration of Helsinki and with the approval by the UK North West Multi-Centre Research Ethics Committee. Children aged 3 years to 4 years 9 months with a unilateral visual impairment of 6/9 to 6/36 and without manifest strabismus were identified at preschool vision screening clinics. Once informed consent was obtained, subjects were recruited and randomized to one of three groups: (1) no treatment—glasses and occlusion deferred for 52 weeks; (2) glasses only—glasses prescribed, but occlusion deferred for 52 weeks; (3) full treatment—glasses prescribed followed by occlusion if visual acuity was not 6/6 after 6 weeks of glasses wear.

The degree of visual deficit was classified as mild if acuity was 6/9 or 6/12 at recruitment and moderate if 6/18 to 6/36 at recruitment. At 52 weeks, full treatment was given to children in the no-treatment and glasses-only groups, when still indicated. Visual acuity and stereoacuity were measured at recruitment and 52 weeks without refractive correction and at 54 and 78 weeks with refractive correction in all groups. Outcomes were assessed for the whole study group and also by mild and moderate visual acuity subgroups. Assessments were undertaken by an orthoptist masked to treatment allocation, and analysis was by intention to treat.

Visual acuity was assessed using the Crowded LogMAR Test (previously Glasgow Acuity Cards15), and stereoacuity was assessed with the standard (not preschool) random-dot stereotest (Randot; Stereo Optical, Chicago, IL).16 This stereotest consists of three items: pure random-dot shapes (500 and 250 seconds of arc), animals (400, 200, and 100 seconds of arc), and circles (400–40 seconds of arc). The

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TABLE 1. Baseline Group Characteristics at Recruitment: Visual Acuity, Stereoacuity and Age, by Group Allocation

<table>
<thead>
<tr>
<th>Recruitment</th>
<th>No Treatment</th>
<th>Glasses Only</th>
<th>Full Treatment</th>
<th>Linear Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (SD), mo</td>
<td>48.4 (5.1)</td>
<td>47.1 (5.2)</td>
<td>47.6 (4.5)</td>
<td>0.362</td>
</tr>
<tr>
<td>Number randomized (total = 177)</td>
<td>59</td>
<td>59</td>
<td>59</td>
<td>—</td>
</tr>
<tr>
<td>Median stereoacuity (range), seconds of arc</td>
<td>140 (40 to &gt;400)</td>
<td>140 (40 to &gt;400)</td>
<td>140 (40 to &gt;400)</td>
<td>—</td>
</tr>
<tr>
<td>Geometric mean (±1 SD)</td>
<td>148 (66–331)</td>
<td>156 (62–389)</td>
<td>158 (65–389)</td>
<td>0.594</td>
</tr>
<tr>
<td>Number with stereo value (total = 168)</td>
<td>57</td>
<td>57</td>
<td>54</td>
<td>—</td>
</tr>
</tbody>
</table>

* By ANOVA.

circle values were used for analysis, as these provide finer grading and a wider range of scores. This part of the test consisted of 10 boxes, each containing three circles. When viewed through polarizing glasses, one of the circles appeared to protrude from the page. Commencing with the box with the largest disparity, subjects were asked to indicate which circle was "sticking or jumping out" of the page. Stereo threshold was recorded as the smallest disparity correctly identified.

Children were classed as “negative” responders if they were unable to identify correctly the largest disparity (400 seconds of arc) and were allocated a notional score of 600 seconds of arc to enable inclusion in the analysis. However, to reflect the actual observation, this outcome was recorded as the smallest disparity correctly identified.

RESULTS

One hundred seventy-seven children were recruited and randomized into the three groups. Each group was comparable for size, mean age, and presenting visual and stereo acuity (Table 1). The spread of stereoacuities in each group at recruitment is shown in Figure 1. Baseline and outcome visual acuities have been reported in detail elsewhere.18

Comparison of median stereoacuity values at 52, 54, and 78 weeks showed no differences between the groups at any time point (Table 2). Uncorrected stereoacuity at 52 weeks showed a median improvement of 40 seconds of arc when compared with uncorrected values at recruitment. Refractive correction at 54 weeks resulted in a further median improvement of 30 seconds of arc in each group.

The distribution of stereoacuity scores at 54 weeks is shown in Figure 2. At this time point, all patients demonstrated stereoacuity of 400 seconds of arc or better. Although fewer patients in the no-treatment group showed normal levels of stereoacuity, this was not found to be statistically significant (ANOVA for trend; P = 0.172). Subgroup analysis of stereoacuity outcomes by mild and moderate levels of presenting visual acuity showed no differences between groups at 54 weeks in those presenting with mildly reduced visual acuity (ANOVA for trend; P = 0.323). Those presenting with moderate levels of visual acuity deficit and allocated to the no-treatment group showed reduced stereoacuity at 54 weeks (100 seconds of arc) in comparison to those in treatment (70 seconds of arc), but the reduction did not reach statistical significance (ANOVA for trend; P = 0.555). At the 78-week assessment, the difference was no longer apparent, with those allocated to the no-treatment group showing better stereoacuities (50 seconds of arc) than those in both treatment groups (70 seconds of arc; ANOVA for trend; P = 0.316).

Throughout the study period, there was a statistically significant correlation between visual acuity and stereoacuity (Table 3). At recruitment (mean age, 4 years), more children with a moderate visual acuity deficit demonstrated poor stereoacuity (≥100 seconds of arc), however 41% of those with mild visual acuity deficit also demonstrated poor stereoacuity at this point. At 54 weeks (mean age, 5 years, with refractive correction), the relationship was stronger: 75% of those with moderate acuity loss demonstrated poor stereoacuity and 75% of those with mild visual acuity loss demonstrated good stereoacuity. This finding remained consistent at 78 weeks (mean age, 5.5 years).

At recruitment (mean age, 4 years), both age and visual acuity were found to be independently associated with stereoacuity. Although the effect of visual acuity continued, the effect of age was no longer apparent at 54 weeks (mean age, 5 years). The number of children unable to do the test (“negative” responders) decreased over the study period, and their mean age was significantly younger than those demonstrating a positive response (Table 4).

DISCUSSION

Improvement in stereoacuity is considered an important and often inevitable outcome of treatment for reduced visual acuity. Although this belief is derived from a large number of studies that show a correlation between visual acuity and stereoacuity, it may fail to recognize the importance of the nature of the visual acuity deficit. Previous work has shown that a reduction in visual acuity due to refractive blur affects stereoacuity more than a comparable reduction due to amblyopia,4 and the majority of studies describing the relationship between visual and stereo acuity do so by measuring the effect
of artificially induced optical blur. Studies of naturally occurring visual acuity deficit suggest that stereoacuity levels are more significantly affected by the degree of amblyopia than the degree of anisometropia and that improvements in stereoacuity can be gained with treatment. However, there remains little clear evidence of the separate effects of naturally occurring refractive error and amblyopia, especially in patients in whom these are thought to coexist, and there is no previous work analyzing the separate treatment effects.

Our study group is representative of children who fail visual acuity–based preschool vision screening, and the trial was designed as a pragmatic test of treatment effectiveness in this patient group as a whole. For this reason we did not attempt to distinguish between those with reduced visual acuity due to refractive error alone and those with additional amblyopia and to retain the integrity of the control group, we did not correct refractive errors in these patients until the 52-week follow-up. Nonetheless, the randomized trial study design enables us to comment on the separate effects of treatment by refractive correction alone and with occlusion, with reference to spontaneous change as seen in the control group.

Comparison of stereoacuities at 12 months showed no significant difference between the groups. A commensurate gain from baseline was found in all three groups (as measured without refractive correction) and an additional, equal gain was measured after refractive correction.

The median improvement of 40 seconds of arc in both nontreatment and treatment groups over the first 52 weeks of the trial suggests that change in stereoacuity at this age is at least partly attributable to maturation. This is supported by finding an independent association of stereoacuity with age that disappeared during this period and is consistent with maturational effects noted in previous studies of stereoacuity in children. Adultlike performance is thought to be reached at different ages for different stereo tests. On the Randot stereotest a mean value of 30 seconds of arc can be achieved at 6 years, improving to the 20 seconds of arc achieved in adults by 11 years. Refractive correction improved stereoacuity to the level expected in most visually normal children of this age. This limited the possibility of showing any further differences between those who had undergone 12 months of treatment compared with those who had not, but also serves to emphasize the significant impact from refractive correction alone.

Subgroup analysis showed that those presenting with moderately reduced acuity and allocated to no treatment had poorer stereoacuity at 54 weeks (after refractive correction) than those in treatment. Whereas this was not found to be a statistically significant difference, it may be indicative of some treatment benefit at this level of acuity deficit, consistent with the findings for visual acuity in the main trial. This difference was no longer apparent at 78 weeks, 6 months after treatment had been given to this group.

Outcomes may have been influenced by limitations of the Randot test itself. Although it is one of the more accurate stereotests for this age group, measurements are restricted to predetermined levels of disparity. It is possible that actual stereo thresholds fall between these levels but it is unlikely that such differences would be of clinical significance.

The patients analyzed in this study were representative of the population targeted by preschool vision screening programs and therefore did not include children with manifest strabismus >10 prism diopters or children with bilateral visual impairment who would be expected to present because of observed strabismus or symptoms of reduced visual acuity. Our findings suggest that in this target group, stereoacuity is mainly affected by refractive blur, and that delaying correction of refractive error and treatment of any coexisting amblyopia does not result in poorer stereoacuity outcomes.

Stereoacuity testing has been recommended as part of the vision screening assessment, although it has been sug-
Table 3. Stereocuities by Mild and Moderate Levels of Coexisting Visual Deficit at Ages 4, 5, and 5.5 Years

<table>
<thead>
<tr>
<th>Degree of Visual Impairment</th>
<th>&lt;100 sec arc n (%)</th>
<th>≥100 sec arc n (%)</th>
<th>Total</th>
<th>( \chi^2 )</th>
<th>Pearson Correlation Coefficient (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N at Recruitment; age 4</td>
<td>75</td>
<td>79</td>
<td>154</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild: 6/9–6/12</td>
<td>55 (59)</td>
<td>39 (41)</td>
<td>94 (100)</td>
<td>9.292</td>
<td>( r = 0.346 ) (0.001)</td>
</tr>
<tr>
<td>Moderate: 6/18–6/36</td>
<td>20 (33)</td>
<td>40 (67)</td>
<td>60 (100)</td>
<td>0.002</td>
<td>( r = 0.510 ) (&lt;0.001)</td>
</tr>
<tr>
<td>N at 54 weeks; age 5</td>
<td>106</td>
<td>58</td>
<td>164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild: 6/9–6/12</td>
<td>98 (74)</td>
<td>34 (26)</td>
<td>132</td>
<td>27.322</td>
<td>( r = 0.510 ) (&lt;0.001)</td>
</tr>
<tr>
<td>Moderate: 6/18–6/36</td>
<td>8 (25)</td>
<td>24 (75)</td>
<td>32</td>
<td>0.001</td>
<td>( r = 0.510 ) (&lt;0.001)</td>
</tr>
<tr>
<td>N at 78 weeks; age 5.5</td>
<td>112</td>
<td>35</td>
<td>147</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild: 6/9–6/12</td>
<td>107 (83)</td>
<td>22 (17)</td>
<td>129</td>
<td>26.501</td>
<td>( r = 0.420 ) (&lt;0.001)</td>
</tr>
<tr>
<td>Moderate: 6/18–6/36</td>
<td>5 (28)</td>
<td>13 (72)</td>
<td>18</td>
<td>0.001</td>
<td>( r = 0.420 ) (&lt;0.001)</td>
</tr>
</tbody>
</table>

Table 4. Influence of Age on Stereo Test Performance

<table>
<thead>
<tr>
<th>Assessment Point</th>
<th>Pearson Correlation Coefficient (P)</th>
<th>Regression Beta (P)</th>
<th>Negative Responders n (%)</th>
<th>Mean Difference in Age (mo) from Positive Responders (P)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age 4 y (recruitment)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.326 (P &lt; 0.001)</td>
<td>0.286 (P &lt; 0.001)</td>
<td>34/154 (22)</td>
<td>3.1 (P &lt; 0.001)</td>
</tr>
<tr>
<td>VA</td>
<td>0.346 (P &lt; 0.001)</td>
<td>0.306 (P &lt; 0.001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean age 5 y (54 weeks)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.146 (P = 0.062)</td>
<td>0.046 (P = 0.507)</td>
<td>12/164 (7)</td>
<td>0.02 (P = 0.991)</td>
</tr>
<tr>
<td>VA</td>
<td>0.510 (P &lt; 0.001)</td>
<td>0.501 (P &lt; 0.001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean age 5.5 y (78 weeks)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.012 (P = 0.884)</td>
<td>0.103 (P = 0.189)</td>
<td>10/147 (7)</td>
<td>1.45 (P = 0.452)</td>
</tr>
<tr>
<td>VA</td>
<td>0.420 (P &lt; 0.001)</td>
<td>0.446 (P &lt; 0.001)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* By \( \chi^2 \) test.

gested that it does not discriminate well for the screening target condition, unilateral visual impairment.\(^{34,35}\) Although we found a significant correlation between poor stereocuity and moderately reduced visual acuity, stereocuity did not reliably discriminate for reduced visual acuity at the age at which primary vision screening is currently recommended to be undertaken in the United Kingdom (4 years of age).\(^{36}\) In combination with the demonstration of a maturation effect between the mean ages of 4 and 5 years, these data would suggest that incorporating a measurement of stereocuity into preschool vision screening assessment is unlikely to contribute usefully to the measurement of visual function.

**CONCLUSION**

Refractive correction alone improved stereocuity to a normal level in most children with unilateral visual impairment, whose acuity failed preschool vision screening. Deferring treatment for 12 months did not appear to lead to poorer stereocuity outcomes. Conversely, a maturational improvement occurred between the mean ages of 4 and 5 years. Further study may be informative as to whether this effect of refractive correction on stereocuity is demonstrable in older children.

**References**

7. www.academyadmissions.com