Comparison of Recognition and Grating Acuities in Very-Low-Birth-Weight Children With and Without Retinal Residua of Retinopathy of Prematurity

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Purpose. To compare recognition (letter) and resolution (grating) acuity in eyes with and without retinopathy of prematurity (ROP) residua.

Method. Letter acuity measured with the crowded HOTV chart or pocket cards (Good-Lite), and grating acuity measured with the Teller Acuity Card (TAC) procedure, were compared at the 3/12- and 4/12-year follow-up exams in the CRYO-ROP study. Testers were unaware of the retinal status of individual eyes.

Results. Measurable scores for both letter and grating acuity were obtained from 1694 eyes at 3/12 years and 2101 eyes at 4/12 years. Correlation analysis showed that the relation between crowded HOTV and grating acuity scores was best described by a quadratic function, with r² values of 0.57 at 3/12 years and 0.68 at 4/12 years. Difference scores were calculated for each eye by subtracting the log of the HOTV score (converted to cyc/deg based on the convention that 20/20 = 30 cyc/deg) from the log TAC score. Normal eyes showed HOTV acuity that was higher than TAC acuity by an average of 0.37 octave (SD = 0.46, n = 1150) at 3/12 years and 0.27 octave (SD = 0.43, n = 1337) at 4/12 years. HOTV and grating acuity scores were similar to each other in eyes with retinal residua of ROP. Overall, eyes with acuity better than 20/150 to 20/300 tended to show better HOTV than grating acuity, whereas those with acuity below 20/150 to 20/300 generally showed better grating than HOTV acuity.

Conclusions. There is a significant correlation between crowded HOTV letter acuity and TAC grating acuity in young children for normal eyes and eyes with ROP residua. In both groups of eyes, eyes with lower acuity show better grating than letter acuity, whereas eyes with better acuity show slightly higher letter than grating acuity.

nopathy of Prematurity (CRYO-ROP), grating acuity was measured using Teller Acuity Cards in study participants at the 1-, 2-, 3'/2, and 4'/2-year follow-up visits. At the 3'/2 and 4'/2-year follow-up ages, recognition acuity was also tested, using the Crowded HOTV test. Each patient underwent a comprehensive eye examination at each age, and data were recorded concerning presence and severity of retinal residua of ROP.

This article provides a comparison of monocular recognition and grating acuities of eyes with and without retinal residua of ROP in children who participated in the CRYO-ROP study. Based on previous studies of older children and adults with normal eyes, we predicted that eyes without retinal residua of ROP or other abnormalities would show recognition and grating acuities that were similar. We also predicted that eyes with retinal residua of ROP involving the macula would show better grating acuity than recognition acuity, similar to the results reported previously in eyes with other types of macular pathology.

MATERIALS AND METHODS

Subjects
Subjects were 1109 children with birth weights less than 1251 g who were born between January 1, 1986 and November 30, 1987, who were participants in the CRYO-ROP study, and who provided quantifiable recognition acuity and quantifiable grating acuity scores from one or both eyes at one or both of the 3'/2 and 4'/2-year follow-up examinations. All subjects included also had an eye examination by a study ophthalmologist at the age(s) at which acuity data were obtained. Of the 1109 subjects, 148 were participants in the randomized portion and 961 were members of the nonrandomized (natural history) portion of the CRYO-ROP study. All subjects were participants in the study’s long-term follow-up.

The CRYO-ROP study followed the tenets of the Declaration of Helsinki, and informed consent was obtained after the study was explained to parents of participants. Institutional human experimentation committee approval was granted at each study center.

Procedure
Each subject’s monocular recognition acuity was measured with the crowded HOTV test (Good-Lite, Chicago, IL), shown in Figure 1, by a tester who was masked to the ROP status of each eye. Standard test distance was 10 feet, but testing at 5, 2.5, or 1.25 feet was also permitted when the level of vision was too low to allow testing at a more removed test distance. As shown in Figure 1, the HOTV chart is not a logMAR chart, and the individual letters on the “crowded” cards and on the “crowded” (lower) portion of the chart have crowding bars on only two of the four sides of each letter.

After completion of recognition acuity testing, the same tester measured monocular grating acuity using the Teller Acuity Card procedure (Vistech, Dayton, OH). Standard test distance was 84 cm, but testing at 55, 38, 19, or 9.5 cm was also permitted, as were nonstandard techniques such as vertical presentation of the cards for patients with nystagmus. The grating on the Teller Acuity Cards ranged from 0.25 to 38 cyc/cm in approximately 0.5-octave steps, with a contrast of approximately 83%.

During each study visit, patients also underwent a comprehensive eye examination, including cycloplegic retinoscopy and a summary rating of the severity of any retinal residua of ROP.

Acuity results were entered into the data analysis only if, before acuity testing, study criteria had been met for correction of refractive error and for occlusion therapy for amblyopia (at least 4 weeks if therapy was ongoing, or at least 75 days if therapy had been prescribed at an earlier study visit). By study criteria, correction of refractive errors was required for 4 weeks before acuity testing, as well as during acuity testing, if at the 3'/2-year examination one or more of the following were found: myopia greater than −3.00 dipters (D), hyperopia > +5.00 D, astigmatism > 2.00 D, or anisometropia > 2.00 D accompanied by amblyopia. At 4'/2 years, correction was required for: myopia greater than −2.00 D, hyperopia > +4.00 D, astigmatism > 1.50 D, or anisometropia > 2.00 D accompanied by amblyopia.

Data Analysis
Data were included from all eyes for which a quantifiable HOTV acuity score and a quantifiable grating acuity score were obtained. Quantifiable grating acuity was defined as acuity measurable with standard Teller Acuity Cards. Eyes testable with only the Low Vision card (which could be held at any distance or moved in an attempt to elicit a response to the 2.2-cm-wide stripes on the card) and eyes that were judged to have only light perception or no light perception did not have acuity that was quantifiable.

For analysis of the effects of retinal residua of ROP, eyes were categorized into groups, based on the most severe residua observed: (1) no posterior pole residua of ROP; (2) abnormal straightening of temporal retinal vessels; (3) macular heterotopia; (4) stage 4A retinal detachment, retinoschisis, or fold in near periphery (sparing fovea); (5) stage 4B retinal detachment, schisis, or retinal fold involving fovea, cataract, or retrolental membrane blocking view of macula; (6)
total retinal detachment or schisis or total retrolental membrane.

For some analyses, only eyes identified as "normal" were used. Eyes in the normal group had none of the following diagnosed at or before the examination during which the acuity data were obtained: aphakia, cataract, corneal clouding, glaucoma, glaucoma surgery, nystagmus, vitrectomy, abnormal straightening of temporal retinal vessels, macular heterotopia, partial or total retinal detachment, retinal fold, or retinoschisis, even when these latter abnormalities did not involve the posterior pole. Eyes were also excluded from the normal group if they were found to have optic atrophy at the last examination completed. Eyes with amblyopia recorded at 3$\frac{1}{2}$ years were excluded from the normal group if they were found to have optic atrophy at the last examination completed. Eyes with amblyopia recorded at 4$\frac{1}{2}$ years were excluded from the normal group if they were found to have optic atrophy at the last examination completed. Eyes with amblyopia recorded at 3$\frac{1}{2}$ years were excluded from the normal group if they were found to have optic atrophy at the last examination completed. Eyes with amblyopia recorded at 4$\frac{1}{2}$ years were excluded from the normal group if they were found to have optic atrophy at the last examination completed. Amblyopia was defined for the 3$\frac{1}{2}$- and 4$\frac{1}{2}$-year CRYO-ROP study visits as fixation that was not maintained, compared to maintained fixation in the fellow eye, in an eye that had a “favorable” structural outcome (normal posterior pole; abnormal angle of temporal vessels; macular heterotopia; or stage 4A retinal detachment, retinoschisis, or fold in the near periphery sparing the fovea). The remaining eyes that were excluded from the normal group were eyes of patients who were unable to pass developmental screening at the last examination completed because this suggested developmental delay or neurologic impairment, both of which have been associated with visual deficits. At 3$\frac{1}{2}$ years, developmental screening was passed if the child could copy a circle at the time of the examination, put on a shirt and shoes by history, and give first and last names at the time of the examination or by history. At 4$\frac{1}{2}$ years, screening was passed if the child, at the time of the examination or by history, could tell what to do if cold, tired, and

**Figure 1.** Crowded HOTV chart (left) and cards (right) used to measure recognition acuity at 3$\frac{1}{2}$ and 4$\frac{1}{2}$ years in the CRYO-ROP study.
HOTV and Grating Acuity in Preterm Children

A primary goal of this study was to compare HOTV and grating acuity in eyes with retinal residua of ROP. Because it is well documented that grating acuity often overestimates recognition acuity in eyes with amblyopia,

Eyes With ROP Residua

The purpose of this analysis was to compare the distribution of HOTV–grating acuity differences in eyes with retinal residua of ROP with the distribution of differences found for normal eyes. To provide a difference score (HOTV – grating acuity) for each eye, the eye’s grating acuity score in log_{10} cyc/deg was subtracted from that eye’s HOTV acuity score in log_{10} equivalent cyc/deg. The resultant difference was converted to octaves (difference in log_{10} divided by 0.301).

The results showed that the distribution of HOTV–grating acuity differences in eyes with retinal residua of ROP were similar to those found for normal eyes. However, there was a tendency for HOTV acuity to be better than grating acuity, especially in eyes with severe ROP residua.

Frequency Distributions of HOTV–Grating Acuity Differences for Eyes With Retinal Residua of ROP

The frequency distributions of HOTV–grating acuity differences in eyes with retinal residua of ROP are shown in Figure 3 for eyes with abnormally straightened vessels and eyes with macular heterotopia. The distributions of acuity differences are shifted toward the left relative to the distribution for normal eyes. This indicates that in contrast to normal eyes, in which there is a tendency for HOTV acuity to be better than grating acuity, eyes with retinal residua of ROP show approximately equal proportions of eyes in both 3 1/2 and 4 1/2 years (P < 0.001). In the regression equation, grating acuity explained 57% of the variation in the HOTV acuity at 3 1/2 years and 68% of the variation at 4 1/2 years.

Table 1 shows the number of nonamblyopic eyes with retinal residua of ROP for which quantifiable acuity scores were obtained by both HOTV and grating acuity testing procedures. Few eyes with ROP residua more severe than macular heterotopia provided both HOTV and grating acuity results. This is because most eyes with severe ROP residua had vision too poor to be quantified or were from patients who could not perform the matching task required for the HOTV acuity test. Because data were available from so few eyes with ROP residua more severe than macular heterotopia, data from these eyes were not included in further analyses conducted for this study.

RESULTS

Figure 2 shows the overall correlation between HOTV and grating acuity in the 1694 eyes with quantifiable acuity scores at the 3 1/2-year examination (Fig. 2A) and in the 2101 eyes with quantifiable acuity scores at the 4 1/2-year examination (Fig. 2B). Based on the convention that 20/20 letter acuity (recognition of letters with a line width of one arcmin of visual angle) is equivalent to a grating acuity of 30 cyc/deg (resolution of a grating of one arcmin of visual angle), equivalent cyc/deg values for the HOTV results are provided on the right vertical axis. The line at 45° represents perfect agreement between HOTV and grating acuity. A regression analysis showed that the data were fit better by a quadratic function, plotted as the curved line in each figure, than by a linear function. This indicates that the relation between HOTV and grating acuity is dependent on where along the continuum of acuity values the comparison between the two acuity measures is made. The quadratic term in the regression equation was statistically significant at both 3 1/2 and

Hungry, could balance on each foot for more than 3 seconds, and could follow three of four commands to place an object under, on, in front of, and behind a chair. The screening items were selected from the Denver Developmental Screening Test as age-appropriate items that would be relatively unaffected by a child’s visual impairment. Acuity scores were converted to log values for all analyses.
TABLE 1. Number of Nonamblyopic Eyes With Quantifiable Acuity Scores on Crowded HOTV and Teller Acuity Card Testing

<table>
<thead>
<tr>
<th>Group</th>
<th>3½ Years of Age</th>
<th>4½ Years of Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>No posterior pole residua of ROP</td>
<td>1593</td>
<td>1945</td>
</tr>
<tr>
<td>Abnormal straightening of temporal vessels</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>Macular heterotopia</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Stage 4A retinal detachment, retinoschisis, or fold in near periphery (sparring fovea)</td>
<td>2†</td>
<td>2†</td>
</tr>
<tr>
<td>Other favorable*</td>
<td>12†</td>
<td>5†</td>
</tr>
<tr>
<td>Stage 4B retinal detachment, schisis, or fold involving fovea; cataract or retrolental membrane blocking view of macula</td>
<td>3†</td>
<td>5†</td>
</tr>
<tr>
<td>Total retinal detachment or schisis, or total retrolental membrane</td>
<td>0†</td>
<td>0†</td>
</tr>
<tr>
<td>Other unfavorable*</td>
<td>0†</td>
<td>0†</td>
</tr>
<tr>
<td>Unable to grade</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

* Eyes did not fit into specified categories based on retinal residua of ROP but could be coded by the examining physician as "favorable" or "unfavorable."
† Categories with fewer than 15 eyes were not included in further data analysis.

ROP = retinopathy of prematurity.

which grating acuity is better than HOTV acuity and eyes in which HOTV acuity is better than grating acuity.

The mean difference between HOTV and grating acuity in eyes with abnormally straightened temporal vessels was 0.17 octave (SD = 0.94) at 3½ years, toward grating acuity being better than HOTV acuity, and 0.07 octave (SD = 0.55) at 4½ years, toward HOTV acuity being better than grating acuity. For eyes with macular heterotopia, the mean difference was 0.09 octave (SD = 0.76) at 3½ years and 0.02 octave (SD = 0.76) at 4½ years, both toward grating acuity being better than HOTV acuity. In comparison, at both ages, most normal eyes showed better HOTV acuity than grating acuity, and the average difference between HOTV and grating acuity in normal eyes was 0.37 octave at 3½ years and 0.27 octave at 4½ years.

**Grating and HOTV Acuity as a Predictors of HOTV Versus Grating Acuity Difference in Eyes With Retinal Residua of ROP**

Although in Figure 3 there is a shift to the left in the distributions of difference scores for eyes with ROP residua relative to normal eyes, there are many eyes in the ROP residua groups that show somewhat better HOTV than grating acuity, similar to the results found for normal eyes. The goal of the next analysis was to determine whether there were characteristics of an eye's acuity results that would predict the direction and magnitude of the difference between that eye's HOTV and grating acuity scores.

Figure 4 shows the relation between each eye's grating acuity score and the difference in that eye's HOTV and grating acuities for nonamblyopic eyes with abnormally straightened temporal vessels or macular heterotopia, tested at 3½ years (Fig. 4A) and 4½ years (Fig. 4B). Points falling on the horizontal line show data from eyes with perfect agreement between HOTV and grating acuity, points above the line are from eyes with HOTV acuity better than grating acuity, and points below the line are from eyes with grating acuity better than HOTV acuity. At 3½ years, most points fall above the line, regardless of grating acuity score. At 4½ years, the points are relatively evenly distributed above and below the line, irrespective of grating acuity score.

Figure 5 shows the relation between each eye's HOTV acuity score and the difference between that eye's HOTV and grating acuity scores, for nonamblyopic eyes with abnormally straightened temporal vessels or macular heterotopia tested at 3½ years (Fig. 5A) or 4½ years (Fig. 5B). At both ages, the difference between an eye's HOTV and grating acuity scores appears to be influenced by the eye's HOTV acuity. Most eyes with acuity at the low end of the HOTV acuity range show better grating acuity than HOTV acuity, whereas most eyes with acuity at the upper end of that range show better HOTV than grating acuity. If the data are divided into eyes with HOTV acuity better than 20/100 and eyes with HOTV acuity equal to or worse than 20/100, those with HOTV acuities better than 20/100 showed a mean HOTV–grating acuity difference of 0.08 octave (SD = 0.48) at 3½ years and 0.25 octave.

* This somewhat arbitrary dividing line was chosen for ease of comparison with previously published data (see Discussion).
HOTV and Grating Acuity in Preterm Children

DIFFERENCE (IN OCTAVES) BETWEEN HOTV AND GRATING ACUITY AT 3 1/2 YEARS

DIFFERENCE (IN OCTAVES) BETWEEN HOTV AND GRATING ACUITY AT 4 1/2 YEARS

FIGURE 3. Difference (in octaves) between HOTV and grating acuity in nonamblyopic eyes with abnormally straightened temporal vessels (dashed line) and eyes with macular heterotopia (solid line), compared with eyes classified as normal (stippled area), at 3 1/2 (A) and 4 1/2 (B) years. The distributions of differences are similar for both groups of eyes with retinal residua of retinopathy of prematurity at both ages and are shifted to the left relative to the distribution of acuity differences for the normal eyes.

(SD = 0.56) at 4 1/2 years (HOTV acuity better than grating acuity). Eyes with acuities of 20/100 or worse showed a mean HOTV–grating acuity difference of −0.43 octave (SD = 1.13) at 3 1/2 years and −0.48 octave (SD = 0.76) at 4 1/2 years (HOTV acuity worse than grating acuity).

Grating Acuity as a Predictor of HOTV Acuity

Although recognition acuity is the desired measure of acuity, there are some children whose acuity can be measured only with grating stimuli. The data in the present study indicate that the correlation between recognition and grating acuity is high in 3 1/2 and 4 1/2-year-old children. Thus, even though recognition acuity and grating acuity measure different aspects of acuity, it should be possible to use grating acuity results to predict a range of likely HOTV letter acuity results in an individual child.

Table 2 provides the 90% confidence intervals for the HOTV acuity scores that correspond to specific grating acuity results in very-low-birth-weight children with normal eyes (as defined for Fig. 3), and in all remaining eyes for which quantitative measures of HOTV and grating acuity were available. With this table, an eye’s grating acuity measurement can be used to determine, with 90% confidence, the range of HOTV acuity values that would include that eye’s actual HOTV acuity.

DISCUSSION

The results of this study show that there is a significant correlation between letter acuity, measured with the...
TABLE 2. Estimation of Crowded HOTV Acuity From Grating Acuity Measured With the Teller Acuity Card Procedure in 31/2- to 41/2-Year-Old Children

<table>
<thead>
<tr>
<th>Grating Acuity (cyc/deg)</th>
<th>Normal Eyes (N = 2487)</th>
<th>All Other Eyes (N = 1308)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90% conf. (Median)</td>
<td>n</td>
</tr>
<tr>
<td>2.5 or &gt;45</td>
<td>—</td>
<td>18</td>
</tr>
<tr>
<td>2.5 to &lt;45</td>
<td>20/25 to 20/16</td>
<td>57</td>
</tr>
<tr>
<td>2.5 to 3</td>
<td>20/30 to 20/16</td>
<td>565</td>
</tr>
<tr>
<td>1.5 to 2</td>
<td>20/40 to 20/25</td>
<td>1265</td>
</tr>
<tr>
<td>1 to 1.5</td>
<td>20/40 to 20/25</td>
<td>453</td>
</tr>
<tr>
<td>0.5 to 1</td>
<td>20/60 to 20/25</td>
<td>101</td>
</tr>
<tr>
<td>0.5 to &lt;0.5</td>
<td>20/60 to 20/25</td>
<td>18</td>
</tr>
<tr>
<td>0.5 to &lt;0.5</td>
<td>—</td>
<td>5</td>
</tr>
<tr>
<td>0.5 to &lt;0.5</td>
<td>—</td>
<td>1</td>
</tr>
<tr>
<td>0.5 to &lt;0.5</td>
<td>—</td>
<td>0</td>
</tr>
<tr>
<td>0.5 to &lt;0.5</td>
<td>—</td>
<td>1</td>
</tr>
</tbody>
</table>

conf. = confidence interval.

crowded HOTV test, and grating acuity, measured with the Teller Acuity Cards. However, as shown in Figure 2, the best-fit regression line is curvilinear, indicating that for most of the range of measurable acuities, eyes show slightly (<1 octave) better HOTV than grating acuity, whereas at the upper and lower extremes of the acuity range, eyes tend to show better grating acuity than HOTV acuity. Examination of the influence of ROP residua on the agreement between grating and HOTV acuity showed that eyes with abnormally straightened temporal vessels or macular heterotopia were more likely than eyes classified as normal to show better acuity for gratings than for letter targets (Fig. 3). There were insufficient acuity data from eyes with more severe ROP residua to allow comparison of grating and HOTV acuity results in these eyes.

Figures 6, 7, and 8 compare data from the present study with data from previous studies in which it was possible to calculate the average difference between grating and recognition acuity in normal eyes or eyes with ocular pathology. As shown in Figure 6, studies of normal eyes have generally reported an average of less than one-half octave difference between grating and recognition acuity, for both children and adults. In some studies, including the present one, recognition acuity was slightly better than grating acuity, whereas in others grating acuity was slightly better than recognition acuity.

Differences between recognition and grating acuity in eyes with a variety of pathologic conditions and in amblyopic eyes, as reported in previous studies, are shown in Figures 7 and 8, respectively. For comparison, data from the present study for nonamblyopic eyes with abnormally straightened temporal vessels or macular heterotopia are shown in Figure 7. Data from the present study for eyes with abnormally straightened temporal vessels or macular heterotopia that had amblyopia at the time of testing are shown in Figure 8. For studies in which data were available, the difference between recognition and grating acuity is plotted separately for eyes with recognition acuity better than 20/100 and for eyes with recognition acuity equal to or worse than 20/100.

Two characteristics of the data are evident in Figures 7 and 8. First, in all studies, eyes with acuity better than 20/100 showed an average difference between recognition and grating acuity of less than one octave.

NORMA EYES

FIGURE 6. Mean difference between recognition and grating acuity for normal eyes of 31/2- and 41/2-year-old children tested in the present study (1), and for normal eyes of children and adults tested in previous studies by Warner et al (2), van Hoo-van Duin and Potter (3), Friendly et al (4), Levi and Klein (5), Volkers et al (6), and White and Loshin (7). Number of eyes represented is shown to the left or right of each bar.
The data reported in the present study were collected as part of the multicenter CRYO-ROP study, not in a specifically designed comparison of recognition and grating acuity. Some aspects of the study design deserve mention. First, the CRYO-ROP study design dictated that acuity be attempted with the HOTV chart or cards before grating acuity was assessed. This was to maximize the likelihood that an HOTV acuity score (the CRYO-ROP study’s primary outcome measure at the 3/6 and 4½-year ages) would be obtained in each eye. Testing each child first with the HOTV test recognition and grating acuity of <1 octave, regardless of whether the acuity deficit was due to ROP residua, macular degeneration, albinism, or amblyopia. Second, except in one study,10 eyes with acuity of 20/100 or worse showed grating acuity that was better than recognition acuity and, in most studies, the average difference between recognition and grating acuity was >1 octave. Thus, the difference between recognition and grating acuity appears to be related more to an eye’s level of recognition acuity than to that eye’s particular pathology.

The difference between recognition and grating acuity vary with an eye’s level of acuity? Recent research indicates that the stimuli used to measure recognition acuity are more sensitive than are grating stimuli to the effects of visual pathology. For example, the periodic nature of grating stimuli may allow them to be detected in diseases that involve spatial undersampling or selective loss of high spatial frequency sensitivity, whereas the nonperiodic nature of letter stimuli makes them potentially more sensitive to the extent of visual loss.27-29 The difference in sensitivity of letter versus grating stimuli to visual pathology could explain two findings of the present study. The first is the finding that eyes with retinal residua of ROP show little difference between HOTV and grating acuity, whereas normal eyes show better HOTV than grating acuity. That is, because grating acuity is degraded less than letter acuity in eyes with retinal residua of ROP, the slight superiority of letter acuity over grating acuity seen in normal eyes is not found in eyes with retinal residua of ROP. Second, the insensitivity of grating acuity to visual pathology could also explain the finding that eyes with pathology severe enough to result in HOTV acuity below 20/150 to 20/300 often show less reduction in grating acuity than in HOTV acuity.

**Limitations**

The data reported in the present study were collected as part of the multicenter CRYO-ROP study, not in a specifically designed comparison of recognition and grating acuity. Some aspects of the study design deserve mention. First, the CRYO-ROP study design dictated that acuity be attempted with the HOTV chart or cards before grating acuity was assessed. This was to maximize the likelihood that an HOTV acuity score (the CRYO-ROP study’s primary outcome measure at the 3½ age and 4½-year ages) would be obtained in each eye. Testing each child first with the HOTV test.
may have resulted in a bias toward lower grating acuities because children may have been fatigued and less cooperative by the time they participated in grating acuity testing.

Another factor that might have influenced the present results is that each child’s recognition and grating acuities were measured by the same tester. Thus, it is possible that the tester’s knowledge of a child’s HOTV results could have influenced the grating acuity value obtained for that child. However, there was no reason for testers to be biased differentially for low versus high acuities, so that the curvilinear relation between HOTV and grating acuity results (Fig. 2) is unlikely to be the result of tester bias.

Another limitation of the recognition versus grating acuity comparison of the present study is that the measure of recognition acuity used was the crowded HOTV test, not the Landolt C chart or the logMar Snellen letter test, which are the preferred measures of recognition acuity in adults. In the crowded HOTV test, “crowding” bars to the left and right of each letter are intended to make test results with individual letters similar to line acuity results. However, because crowding is on only two sides of each letter rather than on all four sides, as they are in recognition acuity tests of adults, the “crowding” effect could be less with the HOTV test, resulting in an overestimation of acuity in some eyes, especially those with amblyopia. At the 5'/2-year examination in the CRYO-ROP study, recognition acuity is being tested with the ETDRS letter chart (New York Lighthouse, Long Island City, NY), and grating acuity is being tested with the TAC procedure. When testing of the 5'/2-year-olds is complete, a comparison of linear Snellen acuity and grating acuity will be possible.

Two other limitations concern the difference between the highest acuity scores obtainable with the two tests. First, the two tests have a different “best” acuity level. The maximum acuity score on the crowded HOTV test at the standard test distance of 3 meters is 20/16 (equivalent to 37.5 cyc/deg), whereas the maximum acuity score in the TAC procedure at the standard test distance of 84 cm is 57 cyc/deg. Second, it has been reported that adults with normal acuity can detect edge and brightness artifacts in the Teller cards, which can result in overestimation of grating acuity. Thus, comparisons of recognition and grating acuity results at the upper end of the acuity range are constrained in the present study by characteristics of the two tests used. Acuity threshold may have been underestimated in eyes with HOTV acuity better than 20/16 and overestimated in eyes that detect the edge and brightness artifacts in the Teller Acuity Cards.

Finally, although acuity data were included in the analyses only if refractive errors that exceeded CRYO-ROP study criteria were corrected before and at testing, it is possible that a higher prevalence of small uncorrected refractive errors in the ROP residua group than in the normal group contributed to the differences between the two groups seen in Figure 3. That is, optotype stimuli such as those used on the HOTV test are degraded more by blur than are grating stimuli, and therefore the tendency for eyes to show better HOTV than grating acuity might be reduced in eyes with ROP residua that have small uncorrected refractive errors.

Strengths

The present comparison of recognition and grating acuity has a number of strengths, many of which arise from the fact that the comparison was conducted as part of the CRYO-ROP study. First is the large number of eyes in which both recognition and grating acuity were measured. Data are reported for 1694 eyes at 3'/2 years and 2101 eyes at 4'/2 years. A second strength is the broad range of acuity values shown by eyes in the present sample. Although the present sample is skewed, with most of the data points at the upper end of the acuity range, the broad range of acuity values imparts an accuracy to the correlation analysis that would not be present if the eyes tested had a limited, small range of acuity scores, such as might be seen in a normative study.

A third strength of the present study is that testing was conducted in a standardized fashion by a small number of testers (seven), all of whom were trained in the testing techniques by the same individuals and all of whom met twice a year to watch each other conduct the acuity tests and to ensure standardization of testing techniques.

A final strength is that all children in the present study received a comprehensive eye examination as part of the CRYO-ROP study at each follow-up age. The results of the eye examinations were used to document the presence and severity of retinal residua of ROP, as well as other ocular pathologies, and to ensure that children had treatment of amblyopia and correction of refractive errors in accordance with study protocol before acuity testing.

CONCLUSIONS

In conclusion, the result of the present study provide data from a large number of preschool-age children concerning the correlation between recognition acuity and grating acuity in normal eyes and in eyes with retinal residua of ROP. Although recognition and grating acuity are different types of acuity, the results of the present study suggest that correlation between
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the two is high enough, for normal eyes and for eyes with retinal residua of ROP, that it is reasonable to use the present data to provide a table predicting a $3^{1/2}$ to $4^{1/2}$-year-old child's HOTV acuity from his or her grating acuity, and therefore such a table is provided (Table 2). Whether the data in Table 2 are generalizable to children of other ages (e.g., infants) or to different populations (e.g., healthy full-term children, or older children with severe developmental delay) is unknown.

**Key Words**

recognition acuity, grating acuity, infants, children, retinopathy of prematurity

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