Recognition Acuity, Grating Acuity, Contrast Sensitivity, and Visual Fields in 6-Year-Old Children

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Objective: To measure monocular distance visual acuity (VA), grating VA, contrast sensitivity, and visual field extent in full-term, 6-year-old children.

Methods: Subjects were 59 healthy full-term children aged 5.8 to 6.3 years who had no ocular abnormalities and no myopia of 1.00 diopter (D) or greater, hyperopia of 4.00 D or greater, astigmatism of 1.50 D or greater, or anisometropia of 1.50 D or greater spherical equivalent or cylinder, as evaluated by a standard eye examination with cycloplegic refraction. All were tested monocularly for recognition acuity (Early Treatment Diabetic Retinopathy Study VA charts), grating acuity (Teller acuity cards), contrast sensitivity (Pelli-Robson contrast sensitivity charts), and visual field extent (white-sphere kinetic perimetry).

Results: Right and left eye values did not differ significantly. Mean values for the right eye were 0.040 logMAR (SD, 0.075 log units) for Early Treatment Diabetic Retinopathy Study VA, 24.5 cycles per degree (SD, 0.3 octaves) for grating acuity, and 1.63 (SD, 0.12 log units) for contrast sensitivity. Mean visual field extent for the inferonasal, superonasal, superotemporal, and inferotemporal meridians was 59.1° (SD, 9.7°), 57.8° (SD, 9.6°), 71.2° (SD, 12.3°), and 100.4° (SD, 6.6°), respectively.

Conclusions: The results provide additional normative monocular data on visual function in 6-year-old children and indicate that their thresholds are less than those of adults for distance recognition VA, grating VA, and contrast sensitivity, but similar to those of adults for white-sphere kinetic perimetry.


Although Early Treatment Diabetic Retinopathy Study (ETDRS) visual acuity (VA) charts and Pelli-Robson contrast sensitivity charts are used as gold standard tests for assessment of adults, only limited normative data are available for 6-year-old children. Three studies have reported mean monocular VA from 0.02 logMAR to 0.10 logMAR in small samples (<30) of 6-year-old children with no ocular pathology or refractive error. For Pelli-Robson charts, 3 studies of children with a mean age of 6 years, 2 with sample sizes greater than 50, have reported mean contrast sensitivity values ranging from 1.59 to 1.85 log units. Teller acuity card assessment of grating VA and white-sphere kinetic perimetry of visual field extent are typically conducted only with infants and children too young to be tested with standard adult techniques. However, 1 study, which unfortunately used linear rather than logarithmic values in their calculations, indicated a mean acuity of 32.4 cycles per degree in 6-year-old children tested with the Teller acuity card procedure. In addition, because white-sphere kinetic perimetry was used for assessment of 5½-year-old children in the multicenter Cryotherapy for Retinopathy of Prematurity Study, 2 studies of normative data have been published. These articles indicated that, although perimetry measurements were variable, mean visual field extent ranged from 45° to 55° in the inferonasal and superonasal quadrants to 80° to 90° in the inferotemporal quadrant.

The purpose of the present study was to collect normative data for ETDRS recognition VA, Teller acuity card grating VA, Pelli-Robson contrast sensitivity, and white-sphere kinetic perimetry assessment of visual field extent in healthy, full-term 6-year-old children, tested according to the protocol used to test 6-year-old preterm children in the Early Treatment for Retinopathy of Prematurity (ETROP) Study. The results provide normative data for 6-year-old children on 4 tests of visual function and also provide comparison data for the 6-year follow-up assessments of preterm children in the ETROP Study.

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METHODS

SUBJECTS

Subjects were 59 children (25 boys and 34 girls) aged between 5 years 10 months and 6 years 4 months who were recruited from birth announcements in the local Tucson, Arizona, newspaper or from a nearby school. Children were primarily non-Hispanic white (93.2%); the remainder were Hispanic. By parental report, none were born more than 19 days before or after their due date.

Data were excluded from an additional 6 children whose refraction error in 1 or both eyes met 1 or more of the criteria for which spectacle correction was required at age 6 years in the ETROP Study: myopia of 1.00 D or greater (n=1), hyperopia of 4.00 D or greater (n=0), astigmatism of 1.50 D or greater (n=3), or anisometropia of 1.50 D or greater spherical equivalent or cylinder (n=2). Data were also excluded from 1 child whose parent reported that the child had a history of strabismus.

The research followed the tenets of the Declaration of Helsinki, was compliant with the Health Insurance Portability and Accountability Act, and was approved by the institutional review board of the University of Arizona. Parents provided written informed consent and children provided written assent prior to testing.

PROCEDURES

Each child participated in 2 sessions no more than 6 weeks apart that included (1) an eye examination, including cycloplegic refraction that was conducted approximately 30 minutes after administration of 1 drop of proparacaine, 0.5%, and 1 drop of cyclopentolate, 1.0%, in each eye, and (2) a vision-testing session in which recognition VA, grating VA, contrast sensitivity, and visual field extent were measured. The eye examinations were conducted by an optometrist experienced in working with children (J.D.T.), and the vision testing sessions were conducted by the 2 vision testers (D.D.H. and J.W.) who performed all VA, contrast sensitivity, and visual field testing of 6-year-old children in the ETROP Study.

RECOGNITION VA TESTING

Monocular distance VA was tested using ETDRS logMAR charts (Precision Vision, LaSalle, Illinois) mounted in a chart illuminator box, using a procedure described previously.10,12,13,21 Initially, each child completed a binocular pretest, in which he or she identified, by naming or matching to letters on a lap card, at least 9 of 10 large, single ETDRS letters presented at approximately 1 m. If the child passed the pretest, the tester placed an adhesive patch over the left eye and tested the right eye at 4 m, using ETDRS chart number 1. Beginning with the top line on the chart, the child was asked to identify the first 3 letters on each line verbally or by matching. If the child incorrectly identified a letter, he or she was asked to continue reading letters on that line. Testing continued until the child could not identify 3 of the 5 letters on the line correctly. Visual acuity was scored as the last line on which the child identified at least 3 letters correctly. Visual acuity of the left eye was measured with an identical procedure, using ETDRS chart number 2. As recommended for analysis of VA data,19 results were log-transformed prior to analyses.

GRATING ACUITY TESTING

Monocular grating acuity was assessed with the Teller acuity card procedure,9,17,18 using the Teller Acuity Cards II (Stereo Optical Co Inc, Chicago, Illinois) and a Teller acuity card stage (Vistech Consultants Inc, Dayton, Ohio). The luminance of the cards was 10 candelas/m2 or greater. The right eye was tested first, followed by the left.

During testing, the child was seated with his or her eyes 84 cm from the peephole in the acuity card. Initially, the tester, who was masked to the location of the grating on each card, presented the card containing the 2.4 cycles/cm grating and decided, on the basis of the child’s eye movements and pointing response to repeated presentations of the card, whether the child could resolve the grating. If the tester judged that the child could resolve the grating, testing continued with finer and finer gratings until the child showed no evidence of resolving the grating. The tester then repeated testing with the next coarser grating, to confirm that the child could resolve that grating. If the child did not show clear evidence of resolving that grating, coarser gratings were presented, until the tester confirmed the finest grating that the child could resolve; this was recorded as the grating acuity score for that eye. Grating acuity results were log-transformed prior to analysis.

CONTRAST SENSITIVITY TESTING

Each child’s monocular contrast sensitivity was tested using Pelli-Robson contrast sensitivity charts2 (Clement Clarke International, Harlow Essex, England), one chart for the right eye, which was tested first, and a different chart for the left eye. The charts were illuminated uniformly at a luminance of 64 or more candelas/m2. The test distance was 1 m.

Children were asked to identify, or match letters on a lap card to, each letter on the chart, starting with the highest contrast triplet of letters in the upper left corner. Children were encouraged to guess when they thought that they could not identify a letter. Contrast sensitivity for each eye was scored as the log contrast value of the last triplet on which the child correctly identified at least 2 of 3 letters and by the total numbers of letters correctly identified for that eye.

VISUAL FIELD TESTING

Each child’s monocular visual field extent was measured with white-sphere kinetic perimetry, using a 110° double-arc perimeter with arms oriented at 45°, 135°, 225°, and 315°10,12,13,21 The perimeter was positioned in front of a black cloth backdrop, which provided a uniform background. The right eye was tested first, followed by the left.

During testing, the child sat within the perimeter arms, with his or her eyes 36 cm from the intersection of the arms. The tester, who was located behind the black cloth, viewed the child’s face through a small hole in the cloth. At the beginning of each trial, the tester instructed the child to fixate centrally on a 6° white sphere that was located at the intersection of the 4 perimeter arms. When the tester indicated that the child was fixating centrally, an assistant, who was standing behind the child, moved the peripheral target (a 6° white sphere mounted on a black wand) centrally along one of the perimeter arms. Rate of movement was approximately 3° per second, and was standardized through the use of a metronome and marks at 6-cm intervals on the edges of the perimeter arms. When the tester indicated that the child made an eye movement in the direction of the peripheral target, the assistant used the marks on the perimeter arm to measure the distance between the leading edge of the peripheral target and the intersection of the perimeter arms. If the eye movement was not in the direction of the peripheral target, the assistant removed the peripheral target and told the tester to recenter the child’s gaze so that the trial could continue.

Each child completed 12 trials, 3 along each arm, for each eye, presented according to a predetermined, pseudorandom
order. Visual field extent for each arm was scored as the median of the distance measurements for the 3 trials on that arm.

## RESULTS

### RECOGNITION VISUAL ACUITY

Results of ETDRS testing for the right and left eyes are presented in **Figure 1**. Mean VA was 0.040 logMAR (standard deviation [SD], 0.075 log units) for the right eye and 0.057 logMAR (SD, 0.070 log units) for the left eye. A paired t test indicated no significant difference between right and left eye results. Visual acuity was equal in both eyes in 34 children (57.6%). An interocular acuity difference of 1 line was found in 22 children (37.3%), and a 2-line difference was found in 3 children (5.1%).

### GRATING VISUAL ACUITY

Mean grating acuity was 24.5 cycles per degree (SD, 0.3 octaves) for the right eye and 24.3 cycles per degree (SD, 0.3 octaves) for the left. For approximately half of the tests (35 of 59 [59.3%] for the right eye; 32 of 59 [54.2%] for the left eye), the threshold grating was 28 cycles per degree. In most of the other tests (22 of 59 [37.3%] for the right eye; 24 of 59 [40.7%] for the left eye), the threshold grating was 19 cycles per degree, while in a small number of tests (2 of 59 [3.4%] for the right eye; 3 of 59 [5.1%] for the left eye), the threshold grating was 39 cycles per degree. A paired t test indicated no significant difference between right and left eye results. Visual acuity was equal in both eyes in 48 children (81.4%), and an interocular acuity difference of one-half octave (ie, a 1–Teller acuity card difference) was found for 11 children (18.6%).

### CONTRAST SENSITIVITY

Contrast sensitivity results are presented in **Figure 2** for log contrast sensitivity and in **Table 1** for numbers of letters correctly identified. Mean contrast sensitivity was 1.63 (SD, 0.12 log units) for the right eye and 1.65 (SD, 0.06 log units) for the left eye. The mean number of letters correctly identified was 36.4 (SD, 4.2) for the right eye and 36.7 (SD, 3.7) for the left eye. A paired t test indicated no significant difference between right and left eye results.

### VISUAL FIELD EXTENT

Results for white-sphere kinetic perimetry are shown in **Table 2**. Paired t tests indicated no significant difference between right and left eye results. Although the results were quite variable, with SDs for the 4 meridians ranging from 7° to 12°, both eyes showed smaller nasal than temporal field extent, with the largest visual field extent in the inferotemporal meridian.

### COMMENT

The results of the present study add to the literature by providing normative data from 6-year-old children for distance VA measured with ETDRS logMAR charts,1 grating VA measured with Teller acuity cards,9 contrast sensitivity measured with Pelli-Robson charts,2 and visual field extent measured with white-sphere kinetic perimetry.10

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**Table 1. Contrast Sensitivity in 59 Six-Year-Old Children Tested With Pelli-Robson Charts**

<table>
<thead>
<tr>
<th>No. of Letters Correct</th>
<th>No. (%) of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right Eye</td>
</tr>
<tr>
<td>43</td>
<td>1 (1.7)</td>
</tr>
<tr>
<td>42</td>
<td>1 (1.7)</td>
</tr>
<tr>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>3 (5.1)</td>
</tr>
<tr>
<td>39</td>
<td>4 (6.8)</td>
</tr>
<tr>
<td>38</td>
<td>2 (3.4)</td>
</tr>
<tr>
<td>37</td>
<td>6 (10.2)</td>
</tr>
<tr>
<td>36</td>
<td>22 (37.3)</td>
</tr>
<tr>
<td>35</td>
<td>6 (10.2)</td>
</tr>
<tr>
<td>34</td>
<td>6 (10.2)</td>
</tr>
<tr>
<td>33</td>
<td>3 (5.1)</td>
</tr>
<tr>
<td>32</td>
<td>2 (3.4)</td>
</tr>
<tr>
<td>31</td>
<td>1 (1.7)</td>
</tr>
<tr>
<td>30</td>
<td>2 (3.4)</td>
</tr>
</tbody>
</table>
As shown in Table 3, the mean logMAR monocular acuity values of 0.04 for the right eye and 0.06 for the left eye are within the range of mean acuities (0.02-0.10 logMAR) reported in the 3 previous studies that included measurement of ETDRS VA in 6-year-old children. It is more than a line poorer, however, than the mean ETDRS VA of −0.12 to −0.13 logMAR reported for adults. In 3 children (5.1%), the ETDRS interocular acuity difference was greater than the 95% prediction limit of 1.7 lines reported by Dobson et al5 for a sample of 252 five- to 12-year-old children.

The mean values of 24.5 cycles per degree for the right eye and 24.3 cycles per degree for the left eye for grating acuity measured with the Teller acuity card procedure are lower than the value of 32.4 cycles per degree reported by Neu and Sireteanu11 for 6-year-old children. However, this difference is 0.4 octaves, a value only slightly more than 1 SD (0.3 octaves) away from the mean of our sample. Unfortunately, because Neu and Sireteanu calculated means and SDs in their sample in linear rather than logarithmic terms, it is not possible to know how close their values are to those in the current study. The mean value of 24.5 cycles per degree in the 6-year-old children in the present study is, however, 0.7 octaves (0.4 SDs) lower than the range of values (40 cycles per degree and better) reported in studies of monocular grating acuity in adults.25

As shown in Table 4, the mean contrast sensitivity values of 1.63 and 1.65 for the right and left eye, respectively, in the present study are similar to values previously reported in 2 studies of children with a mean age of 6 years6,8 but at the lower end of the range reported in 2 studies in which the sample had a mean age of 8 years but included 6-year-old children.7,26 The mean contrast sensitivity value for 6-year-old children in the present study is also at the lower end of the range reported for adults tested with Pelli-Robson charts; it is approximately one triplet (0.15 log units) worse than the mean values of 1.79 to 1.84 log units reported in normative studies of adults.8,22,23,26

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**Table 2. Summary of White-Sphere Kinetic Perimetry Results**

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Children</th>
<th>Age Range, y</th>
<th>Eye</th>
<th>Degrees, Mean (SD) by Meridian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quinn et al,12 1991</td>
<td>56</td>
<td>Mean, 6.8, 4-10</td>
<td>Right</td>
<td>Inferonasal 55.6 (9.6)</td>
</tr>
<tr>
<td>Wilson et al,13 1991</td>
<td>21</td>
<td>5.3-6</td>
<td>Right</td>
<td>Inferonasal 52.4 (11.6)</td>
</tr>
<tr>
<td>Present study</td>
<td>59</td>
<td>5.8-6.3</td>
<td>Right</td>
<td>Inferonasal 53.6 (8.9)</td>
</tr>
</tbody>
</table>

**Table 3. Summary of Early Treatment Diabetic Retinopathy Study Visual Acuity Results for Children Aged 5 to 6 Years**

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Children</th>
<th>Age Range, y</th>
<th>Eye</th>
<th>Acuity, Mean (SD)</th>
<th>Snellen Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen et al,3 2006</td>
<td>11</td>
<td>Mean, 6.7, 4.8-8.6</td>
<td>Right</td>
<td>0.10 (0.09)</td>
<td>20/25</td>
</tr>
<tr>
<td>Stewart et al,4 2006</td>
<td>27</td>
<td>Mean (SD), 6.1 (0.63)</td>
<td>Right</td>
<td>0.02 (0.05)</td>
<td>20/21</td>
</tr>
<tr>
<td>Dobson et al,5 2009</td>
<td>27</td>
<td>5-6&lt;6</td>
<td>Right</td>
<td>0.13 (0.11)</td>
<td>20/27</td>
</tr>
<tr>
<td>Present study</td>
<td>59</td>
<td>5.8-6.3</td>
<td>Right</td>
<td>0.04 (0.08)</td>
<td>20/22</td>
</tr>
</tbody>
</table>

**Table 4. Summary of Pelli-Robson Contrast Sensitivity Results for Children Aged 5 to 6 Years**

<table>
<thead>
<tr>
<th>Source</th>
<th>No. (%) of Children</th>
<th>Age, Mean (Range), y</th>
<th>Eye</th>
<th>Contrast Sensitivity, Mean (SD), Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dowdeswell et al,6 1995</td>
<td>61</td>
<td>6.2 (5.2-7.5)</td>
<td>Better</td>
<td>1.63 (0.07),1.35-1.80</td>
</tr>
<tr>
<td>Fitzgerald et al,7 1993</td>
<td>122 (73)</td>
<td>8.1 (6-12)</td>
<td>All b&lt;8 y</td>
<td>1.86,1.65-2.10</td>
</tr>
<tr>
<td>Mäntyjärvi and Laitinen,26 2001</td>
<td>15</td>
<td>8.0 (6-9)</td>
<td>Right</td>
<td>1.72 (0.08)</td>
</tr>
<tr>
<td>Leat and Wegmann,8 2004</td>
<td>17</td>
<td>6.7 (6&lt;8)</td>
<td>1 Eye</td>
<td>1.67 a</td>
</tr>
<tr>
<td>Present study</td>
<td>59</td>
<td>5.8-6.3</td>
<td>Right</td>
<td>1.63 (0.12),1.35-1.95</td>
</tr>
</tbody>
</table>

* Ninety-five percent confidence limit, 1.57.
As shown in Table 2, visual field extent values are similar to those reported previously for the inferonasal, supronasal, and superotemporal meridians in 2 studies that included 6-year-old children. However, visual field extent is at least 10° larger for the inferotemporal meridian than values reported in the 2 previous studies. We do not know why this larger value was found, though there may have been procedural differences across studies that contributed to this finding. On all meridians, the mean visual field extent is similar to that for adults tested with a similar procedure.

An important result of the present study is that it provides normative data for full-term, 6-year-old children tested with the recognition VA, grating VA, contrast sensitivity, and visual field protocols used to assess visual outcome in 6-year-old, low-birth-weight children in the ETROP Study, similar to a study conducted by Myers and colleagues to provide normative data for 10-year-old children tested in the Cryotherapy for Retinopathy of Prematurity Study. A strength of the present study is that all children were tested by the well-trained vision testers who conducted testing of the ETROP Study participants. A limitation is that the ethnicity of the sample reflects the population of Tucson, Arizona, which is predominantly white, with a smaller percentage of African Americans than that present in the ETROP Study sample.

However, recent data indicate no significant differences in recognition VA between Hispanic and African American children, and there are no additional data that suggest that there are ethnicity-related differences in grat ing VA, contrast sensitivity, or visual field extent.

In conclusion, the results of the present study indicate the importance of using age-based normative data rather than adult normative data in assessment of visual function in young children. In general, threshold values for healthy, full-term, 6-year-old children with no refractive error and no ocular pathology were poorer than values obtained for healthy adults.

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REFERENCES