Assessment of Acuity in Human Infants Using Face and Grating Stimuli

Susan J. Harris, Ronald M. Hansen, and Anne B. Fulton

In a variety of ocular disorders, square-wave gratings yield more optimistic estimates of visual acuity than more complex stimuli such as letters. However, for clinical vision testing of preverbal patients, square-wave gratings are usually employed in conjunction with preferential looking procedures. We developed a complex stimulus—a schematic face—for use in preferential looking procedures. Using the method of constant stimuli, the acuities of 1-, 3-, and 5-month-old infants with normal eyes were estimated using schematic faces and square-wave gratings. Within each age group, thresholds for face and grating stimuli were not significantly different, but psychometric functions obtained with faces were significantly steeper than those obtained with square-wave gratings. This suggests that complex stimuli such as the schematic face could yield more precise acuity estimates than gratings in some pediatric eye patients. Invest Ophthalmol Vis Sci 25:782-786, 1984

Preferential looking techniques (PL) have enabled studies of visual resolution of grating stimuli by infants and young children. However, in the course of assessment of ophthalmic disorders in older children and adults by PL, it has become apparent that PL grating acuities do not necessarily agree with acuities obtained by standard clinical tests such as Snellen letters and Allen picture cards.2,3 Among patients with some optic nerve diseases, macular lesions or ambylopia, acuities estimated using complex patterns such as Snellen letters or Allen picture cards may be several octaves poorer than grating acuities.3-5 On the other hand, for adults with normal eyes, acuity estimates based on resolution of gratings and those obtained with standard clinical acuity tests are no more disparate than 0.5 octave.3,6

The categories of disorders—amblyopia, macular lesions, and optic nerve diseases—that profoundly depress acuities obtained from older children and adults using standard clinical acuity stimuli are frequently encountered among preverbal pediatric eye patients. Complex stimuli for use in conjunction with PL rather than grating stimuli might make PL more sensitive to these ophthalmological disorders. Therefore, we designed a schematic face of white-on-black line segments having many different orientations. In the present study we have evaluated the complex face pattern as a stimulus for obtaining acuity estimates from 1-, 3-, and 5-month-olds with normal eyes. The face acuities are compared with grating acuities.

Materials and Methods

The basic preferential looking apparatus and procedures have been described in detail previously.1 In brief, the apparatus consisted of a large, gray screen with apertures 9 cm in diameter that were situated 17.5 cm to the left and right of a central 4-mm peephole. A rotating wheel, affixed to the back of the screen, contained four stimuli, each with a paired blank. The stimuli were selected and positioned in the apertures by turning the wheel. The average luminance was 2.4 log cd/m² at the front surface of the screen.

An adult held the infant 31 or 50 cm in front of the screen. Another adult, in this study a parent of the infant, was seated behind the screen and observed the infant through the peephole. This observer reported the position of the patterned stimulus (left or right) based on the infant's head and eye movements. A third adult, the experimenter, presented stimuli, provided feedback to the observer after each trial, and recorded the responses.

The stimuli were (1) schematic face patterns and (2) square-wave gratings. To construct the schematic face patterns, black drafting tape (Chart-pak) segments were placed on gray cardboard; white tape segments, one-half the width of the black, were centered on the black lines (Fig. 1). The contrast of the black and white lines was 86%. The lengths of white line segments were...
adjusted so that, if viewed at a distance by an adult with normal eyes, the faces became invisible when the white-on-black elements could no longer be resolved. For Snellen letters similarly constructed with white lines centered on black lines, resolution and detection thresholds of adults appear to be equivalent. The faces were photographed. For presentation in the PL screen, each face stimulus was paired with a homogeneous gray blank of equal luminance; for adults viewing the screen from a distance at which the elements of the faces could not be resolved, the stimuli matched the blanks. Four different face stimuli were used. The width of the white line segments of the faces was chosen to specify stimulus values; the white lines of the four different faces subtended 29, 14, 11.5, and 5 minutes of arc at 31 cm and 21, 10.5, 8.5, and 4 minutes of arc at 50 cm.

The stripes of the square-wave gratings, that had 82.5% contrast, subtended 41.5, 19, 9.5, and 2.5 minutes of arc at 31 cm and 30, 7, 3.5, and 1.5 minutes of arc at 50 cm. Four of the five gratings, that were anticipated to span an infant’s psychometric function, were used to assess each infant. Each grating stimulus was paired with a “blank” that was a very fine grating having 0.5 minute of arc stripes at 31 cm; for adult observers, the blanks matched the stimuli. Stimuli were presented in quasi-random order using the method of constant stimuli; for each stimulus value of both faces and gratings 20 trials were presented.

Subjects were obtained by mailing recruitment letters to parents of infants born at Brigham and Women’s Hospital in Boston. All subjects were born within 7 days of due date. Informed consent was obtained from all before participation.

Infants of three ages, 1-, 3-, and 5-months, were tested in a cross-sectional design. A total of 28 infants performed successfully in two sessions scheduled on separate days. In one test session, face stimuli were used. Grating stimuli were used in the other session. The mean interval between the two sessions was 3 days (SD = 2) for 1-month-olds, 4 days (SD = 2) for 3-month-olds, and 5 days (SD = 4) for 5-month-olds.

Eighteen 3-month-olds, five 1-month-olds, and five 5-month-olds completed testing. Mean ages of infants were as follows: 1-month-olds, 30 days (SD = 3); 3-month-olds, 92 days (SD = 4); and 5-month-olds, 154 days (SD = 5). No subject was more than 9 days from the mean age for the age group on any test date. A thorough ophthalmological examination revealed no abnormalities in any of the 28 subjects. No significant refractive errors were found on retinoscopy after Cyclogyl 1%. The mean spherical equivalents (1-month-olds, +2.38 D (SD = 1.66); 3-month-olds, +2.02 D (SD = 0.92); 5-month-olds, +0.69 D (SD = 1.31) were within two standard deviations of the normal mean for age. The difference in spherical equivalents between right and left eyes did not exceed 0.5 D in any subject.

Four additional subjects participated but were unable to complete testing because of sleepiness or fussiness, or they did not return for the second session. One infant was excluded because cycloplegic retinoscopy revealed 2 D of anisometropia.

To span the psychometric function of each age group from chance performance to 100%, two different test distances, 31 cm and 50 cm, were used. The stimulus aperture subtended 13° at 31 cm and 9° at 50 cm. The 1-month-olds were tested at 31 cm, and the 5-month-olds were tested at 50 cm. It has been shown previously that acuities of 1- and 2-month-olds do not

Table 1. Thresholds (min arc)

<table>
<thead>
<tr>
<th>Age (mos.)</th>
<th>Faces</th>
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<th>Gratings</th>
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<tbody>
<tr>
<td></td>
<td>Probii</td>
<td>Graphical</td>
<td>Probii</td>
<td>Graphical</td>
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<tr>
<td>1</td>
<td>15.8</td>
<td>14.4</td>
<td>21.9</td>
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<td>3</td>
<td>9.0</td>
<td>9.3</td>
<td>7.4</td>
<td>5.7</td>
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<tr>
<td>5</td>
<td>5.5</td>
<td>5.9</td>
<td>5.8</td>
<td>5.3</td>
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</table>
Results

Representative psychometric functions that were obtained using grating and face stimuli are shown in Figure 2. Both grating and face psychometric functions exhibited a monotonic increase from 50%, or chance performance, to about 100%. The thresholds determined by probit analysis agreed well with those determined graphically (Table 1).

The mean thresholds of the psychometric functions for each age group at each test distance are presented in Figure 3 and Table 2. Thresholds of 3-month-olds tested at 31 cm were not significantly different from the results of 3-month-olds tested at 50 cm (faces: t = 0.27, df = 16, NS; gratings: t = -0.18, df = 16, NS). Therefore, the results of 3-month-old infants tested in the two conditions were combined for further analyses.

Thresholds for grating and face stimuli were not different within any age group. Results of a two-factor, repeated-measures, design analysis of variance indicated that performance did not differ for the two
Table 2. Summary of acuity results

<table>
<thead>
<tr>
<th>Age (mos.)</th>
<th>N</th>
<th>Test distance</th>
<th>Faces</th>
<th>Gratings</th>
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<td></td>
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<td>Mean</td>
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<td>Range</td>
<td>SD</td>
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<tr>
<td>Thresholds (min arc)</td>
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<tr>
<td>1</td>
<td>5</td>
<td>31 cm</td>
<td>15.8</td>
<td>11.9-18.1</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>31 cm</td>
<td>9.1</td>
<td>5.1-13.6</td>
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<tr>
<td>5</td>
<td>7</td>
<td>50 cm</td>
<td>8.8</td>
<td>5.6-11.1</td>
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<tr>
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<td>5</td>
<td>50 cm</td>
<td>5.5</td>
<td>4.2-7.0</td>
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<tr>
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<td>5</td>
<td>31 cm</td>
<td>1.4</td>
<td>0.8-2.1</td>
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<tr>
<td>3</td>
<td>11</td>
<td>31 cm</td>
<td>1.3</td>
<td>0.9-1.5</td>
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<td>50 cm</td>
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</table>

types of stimuli (F = 3.77, df = 1, 24; NS). However, performance did vary systematically with age: the acuity values for each age group were similar to those found in previous preferential looking studies12 (F = 5.678; df = 2, 25; P < 0.01).

Although thresholds for faces and gratings did not differ, inspection of individual psychometric functions (Fig. 2) suggested that the functions obtained with faces were steeper than those obtained with gratings. The mean slopes for face and grating stimuli are shown in Fig. 4; the range of slope values and standard deviation of each age group are summarized in Table 2. Ninety-three percent (93%) of the subjects had steeper psychometric functions for face stimuli than for gratings. The slopes for grating functions were similar to those previously reported.12 Two-factor, repeated-measures analysis of variance indicated that slopes were significantly steeper for face functions than for functions obtained with gratings at all ages (F = 27.34, df = 1, 24, P < 0.01). Steepness of slope did not vary systematically over the ages studied (F = .934, df = 2, 25, NS).*

Discussion

The results show that, just as with gratings, a monotonic psychometric function can be obtained from 1-, 3-, and 5-month-old infants using the schematic face stimuli. If the width of the white line is chosen empirically as the unit for faces, thresholds for the faces and gratings are not significantly different in any age group. This suggests that the faces are valid stimuli for assessment of young infants' acuity.

The black and white components of the face and grating stimuli are similar (86% vs 82.5% contrast) and the space-average luminances of both faces and gratings equal that of the surrounding PL screen. Therefore, we suspect stimulus features other than differences in contrast and luminance explain the disparity in slopes between the face and grating functions. Possibly the greater complexity of the face stimuli, or selective presentation of spatial frequency information7 lead to the steeper face functions.

* To determine if differences in range and interstimulus intervals influenced the estimates of slopes, the following analysis suggested by an anonymous reviewer was done. The right-most point of each "face" function was shifted to the right to correspond to the stimulus value of the widest stripes; probit analysis was used to estimate the slope of the adjusted face functions. The slopes of the adjusted functions were shallower, but remained significantly steeper than the functions for gratings (t = 4.25, df = 27, P < 0.01).
Steeper slopes imply that smaller differences in stimulus value have a greater effect on performance. Thus, stimuli that yield steeper psychometric functions may yield more precise measures of acuity. Perhaps the steeper face functions can contribute to increased precision and, ultimately, greater specificity in clinical PL testing of young pediatric eye patients with macular abnormalities, optic nerve disease, and amblyopia. Patients in each of these diagnostic categories have been shown to have discrepancies between grating acuities and acuities obtained using the complex stimuli of standard clinical tests.\textsuperscript{2-5}

**Key words:** infant vision, acuity, preferential looking, square-wave gratings, complex stimuli

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**References**