Temporal contrast sensitivity in amblyopia

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Temporal contrast sensitivity functions were determined for the normal (20/20) and amblyopic eyes of five strabismic and/or anisometropic amblyopes and for both eyes of two nonamblyopes. In deep amblyopia (20/100+), contrast sensitivity was reduced at all temporal frequencies in the amblyopic eye, whereas no deficit was observed for subjects whose acuity was 20/40 or better. This result indicates that reduced temporal sensitivity is a significant component of strabismic and anisometropic amblyopia. (Invest Ophthalmol Vis Sci 22:98-102, 1982.)

Key words: amblyopia, contrast sensitivity, temporal resolution

Amblyopia is defined as a reduction in visual acuity caused by abnormal binocular interaction and/or form deprivation for which no organic basis can be detected by physical examination of the eye. Recent studies of spatial contrast sensitivity have shown that the amblyopic deficit may extend over a wide range of spatial frequencies and is thus far more debilitating than a simple reduction in acuity. Ancillary investigation of the interaction between spatial and temporal stimulus parameters have suggested to several investigators that unlike spatial vision, the temporal component of vision is only minimally affected in the amblyopic eye of the strabismic or anisometropic amblyope. However, Alpern et al. have demonstrated that critical flicker fusion (CFF) is reduced in the amblyopic eye of strabismic and anisometropic amblyopes at photopic luminance. Although earlier studies in amblyopic CFF had obtained conflicting findings, Alpern clarified the issue by demonstrating that control of pupil size, and hence retinal illuminance, is essential for obtaining valid results.

Because Alpern et al. investigated only high-contrast temporal sensitivity and recent investigators have neglected to control pupil size and hence retinal illuminance, we felt that a more comprehensive and controlled investigation of the temporal sensitivity of amblyopes was essential to a clearer understanding of this deficit. Thus we have examined the temporal contrast sensitivity of several strabismic and anisometropic amblyopes over a wide range of frequencies.

Methods

Subjects. The subjects were students, faculty, and patients from the University of Alabama in Birmingham, School of Optometry, and are detailed in Table I.

Visual acuities of the five amblyopic subjects ranged between 20/30 to 20/400. All subjects had central fixation or less than 1 degree eccentric fixation and were strabismic, anisometropic, or a combination of these.

Apparatus. The visual stimulator consisted of a modified Iconix tachistoscope. The apparatus was modeled after that used by Kelly and relied on approximately his combination of polarizing filters to deliver sine-wave-modulated light varying in frequency and contrast (maximum luminance - minimum luminance/maximum luminance + minimum luminance + minimum luminance)
Table I. Clinical summary of subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Refractive status</th>
<th>Acrivity</th>
<th>Fixation status</th>
<th>Angle of deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amblyopes:</td>
<td></td>
<td></td>
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<tr>
<td>P. A.</td>
<td>27</td>
<td>OD Plano, −1.25 × 105</td>
<td>20/20</td>
<td>Central</td>
<td>40° Constant</td>
</tr>
<tr>
<td>B. C.</td>
<td>26</td>
<td>OD −2.75, −3.50 × 15</td>
<td>20/400</td>
<td>Central</td>
<td>left exotrope</td>
</tr>
<tr>
<td>D. W.</td>
<td>41</td>
<td>OD −1.75, −1.00 × 12</td>
<td>20/156</td>
<td>Central</td>
<td>Orthophoric</td>
</tr>
<tr>
<td>J. B.</td>
<td>35</td>
<td>OD +0.75, −1.50 × 180</td>
<td>20/20</td>
<td>Central</td>
<td>Orthophoric</td>
</tr>
<tr>
<td>K. G</td>
<td>15</td>
<td>OD +1.00, −0.75 × 80</td>
<td>20/20</td>
<td>Central</td>
<td>right exotrope</td>
</tr>
<tr>
<td>Controls:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. C.</td>
<td>25</td>
<td>OD −0.50, sphere</td>
<td>20/20</td>
<td>Central</td>
<td>Orthophoric</td>
</tr>
<tr>
<td>T. L.</td>
<td>27</td>
<td>OD −3.25, −0.75 × 75</td>
<td>20/20</td>
<td>Central</td>
<td>Orthophoric</td>
</tr>
</tbody>
</table>

OD = right eye; OS = left eye.

minimum luminance) and holding time-averaged luminance constant. The tungsten lamps were powered by well-regulated D.C. power supplies (Powermate PXEE-120), and current was continuously monitored. Modulation frequency was monitored by a phototransistor with output displayed on an oscilloscope, and voltage transitions were counted (period) with a Tektronix counter/timer (DC 504). Modulation contrast was controlled by a rotatable polaroid filter (0 to 90 degrees), the position of which predicted modulation contrast within 3% of the $\cos^2 \theta$ while time-averaged luminance remained constant (Tektronix J16 photometer with 1-degree luminance probe J6523). The stimulus field was viewed at a distance of 65 cm on a black background and subtended a visual angle of 1.6 degrees. A relatively small field was used so that the stimulus would be confined to the fovea (even assuming some small drift in fixation), where the amblyopic deficit may be most pronounced. The stimulus luminance was 27.2 cd/m². An entire temporal contrast sensitivity function was determined for both eyes of a subject during a single session. Each subject was tested on at least three different occasions, with each session separated by a minimum of 24 hr. During a single session, testing was completed on one eye and then the other. The first eye tested was alternated across sessions. At every frequency the subject adjusted the contrast from 0% upward until flicker was just detectable, and three determinations were made at each frequency. The sequence of frequencies was increased from low to high until CFF was reached. A 10 min rest period was given between tests of each eye.

Results

The reciprocal of threshold contrast, i.e., contrast sensitivity, was determined as the average of all threshold settings at a particular frequency and was plotted as a function of frequency on a log-log scale. Results are based on the second and third testing sessions of all subjects.

Fig. 1 illustrates the temporal contrast sensitivity functions for both eyes of the highest amblyopes, B. C. (20/156) and P. A. (20/400). The standard deviations of the contrast settings for the two eyes did not overlap except at 8 Hz for Subject B. C. Both amblyopes exhibited central fixation, although P. A.'s fixation was unsteady. B. C. was an anisometropic amblyope, and P. A. was strabismic. The temporal contrast sensitivity deficit appeared to be greater for the
larger loss (P. A.). In both cases the maximum sensitivity for the nonamblyopic eye was at 10 Hz. Also in both subjects the peak contrast sensitivity appeared at 6 Hz for the amblyopic eye. The CFF for both normal eyes was at 27.5 Hz, with a slightly greater decrement in the CFF of P. A.’s amblyopic eye. An analysis of the sensitivity ratio between the amblyopic and normal eye indicated that Subject P. A.’s deficit became progressively larger as temporal frequency increased, whereas Subject B. C.’s deficit was not systematically related to frequency.

Fig. 2 displays the temporal contrast sensitivity functions of three amblyopes with minimal acuity deficits. Subjects K. G. (right eye, 20/30+) and J. B. (left eye, 20/30) demonstrated no difference between their amblyopic and nonamblyopic eyes. Subject D. W. (left eye, 20/40) did demonstrate a slight difference at low and intermediate temporal frequencies, but the standard deviations overlapped at all frequencies.

The results for two normal subjects are represented in Fig. 3. Subject C. G. had almost no variance between the right and left eyes. The peak sensitivity was at 6 Hz with CFF at 25 Hz. Subject T. L. revealed slightly greater variability with a peak sensitivity at 8 Hz and a CFF at 27 Hz.

Discussion

Contrary to the indications from previous studies of spatiotemporal interactions or deLange functions, there appears to be a very significant contrast sensitivity deficit throughout the temporal domain in deep amblyopia. The reason for the discrepancy may be that none of the prior studies controlled for retinal illuminance by controlling pupil size. As Harms has shown, pupillomotor sensitivity is reduced in amblyopic eyes, resulting in a relatively larger pupil, greater retinal illuminance, and a spuriously high CFF. Also the stimulus used in recent studies of amblyopic temporal vision was a flickering grating rather than a simple variation of temporal parameters.

Comparison of the subjects’ clinical signs indicates that the best predictor of temporal contrast sensitivity deficit was acuity deficit. Thus neither fixation nor angle of deviation for the amblyopic eye correlated with temporal resolution. Subjects P. A. and B. C. had central fixation; B. C. had no deviation of the amblyopic eye, yet both evidenced a large temporal deficit. Subject K. G. had eccentric fixation and a right esotropia yet showed no deficit in temporal contrast sensitivity.

Mounting psychophysical and physiological evidence suggests that perception of spatial and temporal aspects of a stimulus are mediated by separate and distinct mechanisms. Because recent investigators have found profound deficits in the spatial contrast...
sensitivity of amblyopes and no apparent deficit in temporal sensitivity, it has been concluded that the mechanism for spatial vision is greatly affected although the temporal mechanism is normal. On the basis of our data, which included the requisite control of retinal illuminance, we feel that amblyopia caused by strabismus or anisometropia is the result of dysfunction in both spatial and temporal mechanisms of vision.

REFERENCES
5. Hess RF, Howell ER, and Kitchin JE: On the relationship between pattern and movement perception...