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10 June 1980

Human Aging and Spatial Vision

Abstract. *The ability to see spatial structures of a wide range of sizes was measured for two groups of observers (mean ages, 18 and 73 years). All observers had good visual acuity. Although older and younger observers did not differ in ability to see targets with fine structure (high spatial frequencies), older observers were only one-third as sensitive to targets with coarse structure (low spatial frequencies) as were younger observers. This difference cannot be attributed to ocular pathology in the older observers or to changes in criterion. Older observers were also less able than younger observers to see moving targets. The reduced sensitivity of the older observers may adversely affect routine perceptual activities, such as face recognition and visually guided postural behavior, that depend upon low spatial frequencies.*

Eye charts quantify visual acuity in terms of the smallest letter that can be seen, but some visual disorders cannot be detected by testing visual acuity (*1*). A comprehensive assessment of spatial vision requires measuring sensitivity to targets over a wide range of sizes (*2*). Since processes associated with aging could selectively affect visual mechanisms that process targets in a particular size range, we compared the vision of two groups differing by more than 50 years in average age. Our older observers displayed a previously unsuspected visual handicap: diminished ability to see large and intermediate-size targets.

The younger observers were 25 undergraduate volunteers (mean age ± standard deviation = 18.5 ± 0.7 years); older observers were ten healthy, active volunteers from a senior citizens' recreation program (73.2 ± 3.8 years). All observers wore a distance correction prescribed within the previous 12 months. Ophthalmological examinations revealed that nine of the older observers were free of ocular pathology that might affect performance in our measurements; the remaining observer, a 74-year-old man, suffered from senile macular degeneration. We measured conventional visual acuity with an Orthorater (Bausch & Lomb); subsequent tests were made with the eye having better acuity. The corrected visual acuity of the younger observers averaged 0.99 (Snellen equivalent, 20/20). Excluding the maculopathic observer, the corrected acuity of the older observers averaged 0.83 (20/24). With his better eye, our maculopathic observer's acuity was 0.4 (20/50).

Stimuli were vertical gratings whose contrast varied as a sinusoidal function of distance along the horizontal axis of a cathode-ray tube. The contrast (*3*) and spatial frequency (cycles per degree) of the gratings were controlled by a small computer. At the viewing distance of 114 cm, the gratings subtended 4.5 by 5.5 deg. Gratings had a mean luminance of 55 cd/m^2 and were surrounded by a large region of the same luminance. With the head steadied by a chin rest and forehead support, each observer fixated a small black dot in the center of the screen.

Contrast thresholds were measured by a method of adjustment for each of several different spatial frequencies: 0.5, 1, 2, 4, 8, and 16 cycle/deg. Gratings flickered in counterphase at either 0.3 or 6 Hz. Threshold for each spatial frequency was defined as the mean of the contrasts at which gratings changed from visible to invisible and vice versa (*4*). Sensitivity was defined as the reciprocal of this threshold value.

For each rate of flicker, the effects of spatial frequency and age were significant, as was the interaction between these two variables (all $P < .01$) (Fig. 1). The difference between the two age groups varied with spatial frequency, with older observers showing diminished sensitivity to low and intermediate spatial frequencies. At the lowest spatial frequencies, the older observers needed three times as much contrast to see the gratings as did the younger observers.

Although the older, maculopathic ob-

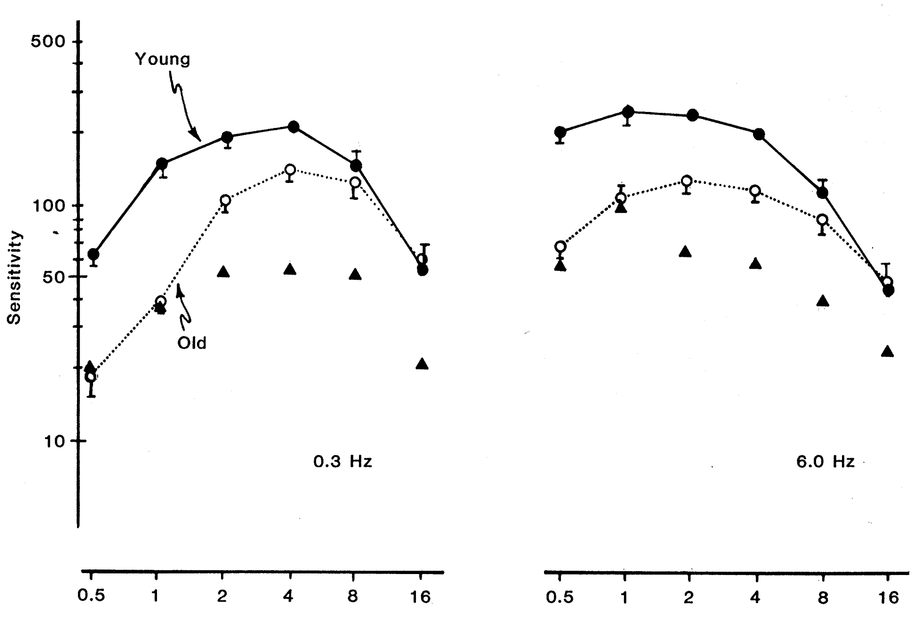

Fig. 1. Contrast sensitivity functions (± standard errors of the mean) of young and old observers for 0.3-Hz flicker and 6.0-Hz flicker. The triangles are for the older, maculopathic observer.

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server showed a reduced sensitivity at high spatial frequencies that is consistent with his reduced acuity, his performance at lower frequencies is nearly identical to the mean for his age group (Fig. 1). Future work should determine if the effects of other pathologies also interact with the visual effects of aging in an additive fashion.

We wondered whether our results might be due to certain ocular changes commonly associated with aging: cataract, glaucoma, and senile miosis. Two distinct patterns of change in contrast sensitivity have been reported for patients with cataract (*5*). Patients exhibit either (i) a visual loss at intermediate and high spatial frequencies, with normal, unimpaired sensitivity to low frequencies, or (ii) a visual loss at all spatial frequencies. Neither of these patterns resembles the difference between our younger and older observers. Glaucoma (*6*) was also not responsible for the loss at low spatial frequencies; applanation tonometry of our older observers revealed intraocular pressures well within the normal range (15.8 ± 2.6 mm-Hg). We had to consider one other ocular factor: senile miosis, the reduction in pupil size that accompanies aging. Control measurements (*4*) demonstrated that reduced retinal illuminance (the main effect of reduced pupil size) did not affect sensitivity to low spatial frequencies. Therefore, reduced retinal illuminance due to senile miosis did not cause our results.

The age difference shown in Fig. 1 might reflect either a genuine reduction in visual function with age or a simple reluctance of the older observers to say that they saw a grating (*7*). We used a rating scale, signal detection method to separate sensory and criterion factors (*8*), retesting 12 of the 25 younger observers and all 10 of the older ones (*9*). For each we used a 1 cycle/deg grating whose contrast was 1.25 times the threshold contrast previously determined for that observer. If our original threshold estimates were indeed valid, all observers should be about equally successful in detecting the grating. Each session consisted of 100 half-second trials. On half the trials, chosen at random, a grating was presented; on the remaining trials, the screen was homogeneous (60 cd/m^2). The observer used a six-point rating scale to express his judgment that a grating had or had not been presented and his confidence in that judgment. In any session, the gratings were either flickering at 6 Hz or not flickering; the order of testing was randomized. We used standard methods to derive $P(A)$, a measure of sensitivity, and B, a measure of the observer's criterion. Mann-Whitney U tests indicated that the differences between age groups were not significant for either measure. These results also indicate that the age-related differences in our original measurements at low spatial frequencies were not due to differences in criterion; in order to see as well as their younger counterparts, older observers do need approximately three times as much contrast.

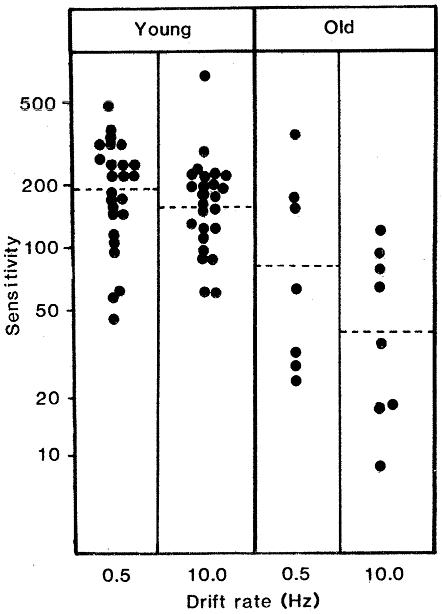

Fig. 2. Contrast sensitivity of young and old observers for 1 cycle/deg gratings drifting at either 0.5 or 10.0 Hz. Dashed lines indicate mean thresholds in each condition.

Human visual mechanisms responsible for the analysis of targets of low spatial frequency also play a role in the detection of many time-varying targets (*10*). As a result, we sought to determine whether older observers, who as a group are less sensitive to low spatial frequencies, would also be less sensitive to moving targets. Thresholds for seeing a 1 cycle/deg grating at two different drift rates, 0.5 and 10.0 Hz, were compared for young and old observers. The order of testing with the two rates was randomized across subjects. There were 8 older observers (75.0 ± 4.8 years; mean decimal acuity, 0.81) and 25 younger observers (20.2 ± 3.1 years; mean decimal acuity, 1.1). About half of the observers in each group had served previously. Thresholds were determined by the method of limits (Fig. 2). Older observers were less sensitive to the moving grating, particularly when it drifted at the higher rate ($P < .001$). The interaction between age and drift rate was also significant ($P < .002$). Thus, older observers less sensitive to gratings of low spatial frequency were also less sensitive to moving targets. This finding may be related to previous reports that older observers have reduced sensitivity to other kinds of temporally modulated targets (*11*).

There are several neural loci (retinal as well as postretinal) and mechanisms that could mediate the observed effects (*4*); since there is as yet no way of choosing among them we shall not speculate here. But whatever its locus and mechanism, the effect may have serious consequences for the perceptual abilities of older humans. For example, recognizing faces and many objects, as well as distinguishing figure from ground, requires low spatial frequency information (*12*). As a result, the older observers' diminished sensitivity to low spatial frequencies may impair their recognition of important features of the visual environment. Likewise, visually guided behavior such as locomotion and postural stabilization may similarly depend on low frequency information (*13*). It is conceivable that postural and locomotor problems of many older people may also be related to their diminished sensitivity to low and intermediate spatial frequencies.

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14 December 1979; revised 22 April 1980