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Aging and low-contrast vision: face perception.

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Previous work showed that despite good visual acuity, many healthy older people require more contrast to see gratings of low and intermediate spatial frequencies than do younger observers. Here we report that a daily perceptual activity, which relies on lower spatial frequency information, is also adversely affected: as compared to young individuals, many older individuals require more contrast to detect a face and to discriminate between two faces. Ocular pathology, optical changes within the eyeball, and variation in criterion are ruled out as explanations for the age-related elevation in threshold.

Lower spatial frequencies carry information sufficient for many routine perceptual activities such as face perception, separation of figure from ground, and visual stabilization of posture.[1, 2] At low contrasts, lower frequencies are particularly important because the fine details of a target (high spatial frequencies) become invisible.[3] As a result, in a low-contrast environment the perception of objects depends crucially on detecting more global features (low and intermediate frequencies). Our previous work indicates that many older individuals require higher contrast to see sinusoidal gratings of low and intermediate frequencies than do younger individuals.[4-6] Therefore low-contrast conditions could pose a special problem for the elderly, forcing them to rely on visual mechanisms specialized for processing lower spatial frequencies, precisely those mechanisms of diminished sensitivity. Here we explore this possibility by examining the effects of contrast reduction on face perception for young and old observers.

Materials and methods. We tested two groups of observers: 14 young observers (mean age = 20.5; S.D. = 1.9) and 13 older observers (mean age = 74.2; S.D. = 4.1). Young observers were student volunteers whose most recent eye exams (on average, 10 months before our tests) revealed no ocular pathological conditions. Older observers were healthy active individuals recruited from a senior citizen meeting center. Detailed ophthalmological exams of the older observers of our experiment within 3 months were generally unremarkable. Most older subjects had traces of cataract; three had early senile macular degeneration (SMD); all had intraocular pressures within the normal range (mean = 16.3 mm Hg; S.D. = 3.2). All older observers had normal visual fields when tested with a 1 mm diameter white target on a tangent screen.

Observers' acuities were measured at a distance of 3 m with a Sloan letter chart (120 cd/m^2). Since all subsequent testing was done with binocular viewing, we report only binocular acuities here. Observers wore appropriate corrections during the experiment, their own spectacles or contact lenses or lenses in trial frames. Expressed as minimum angle resolvable, acuities were 0.84 min arc for young observers (S.D. = 0.10) and 0.94 min arc for older observers (S.D. = 0.17). Included in the mean for the older group are the acuities for the three observers with early SMD: 1.09, 1.04, and 1.02 min arc.

The face perception task was divided into two parts, detection and discrimination. To measure detection, eight slides of single faces were rear-projected one at a time onto a translucent screen 115 cm from the subject. Faces were relatively large targets, subtending a visual angle of approximately 5 × 7.4 degrees. The faces were of middle-aged, Caucasian males having no beards, moustaches, eyeglasses, or unusual hairstyles. All males who were photographed wore a gray cloth around their shoulders to prevent the observer from making discriminations based on apparel. Our apparatus consisted of two matched slide projectors positioned so that their beams coincided on the rear-projection screen. Fixed linear polarizers positioned in front of each projector

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produced orthogonal planes of polarization. One projector contained a slide of the target face; the other had a fully opened aperture but no slide. A variable polarizer controlled the contrast of the image on the screen. When light on the screen came only from the projector with the slide, contrast was maximum; when light on the screen came only from the projector with no slide, contrast was zero. Thus the orientation of the polarizer determined the contrast level of the projected face. Contrast is defined as the difference between maximum and minimum luminances divided by the sum of the two. The system was balanced with neutral-density filters, permitting contrast to be varied with minimal variation in average luminance. Mean luminance of the screen when a slide was projected was 17.2 cd/m^2.

In the detection task, each slide was initially presented at zero contrast. Using a remote controller, the observer increased the contrast of the target until "something could just barely be seen on the projection screen." At the end of each trial, the experimenter recorded the orientation of the polarizer, reset the orientation to one that yielded zero contrast, and presented the next slide. The order of slides was randomized across subjects.

In the discrimination task 16 slides were presented, each containing two faces selected from the same set as in the detection task. The two faces (each 5 × 7.4 degrees) were separated horizontally by 2 degrees and were displaced vertically from each other by 2 degrees to eliminate vernier cues. On half the slides, faces were identical; on half they were different. Starting from zero contrast, the observer increased the contrast of the faces until he could judge whether "the faces belonged to the same or different people." The experimenter recorded the orientation of the variable polarizer and the observer's "same-different" judgment. Contrast was then rezeroed and the next slide presented. The order of slides was randomized across observers, with half receiving the detection task first and the other half the discrimination task first.

Results. Mean threshold contrast for each observer in both tasks is portrayed in Fig. 1. Circles in the left panel, labeled *Y* for young, and *O* for old, represent individual observers' detection thresholds; the right panel shows individual thresholds for discrimination. The horizontal dashed lines indicate the means for all data within a column. Since the three older observers with early SMD had thresholds indistinguishable from the rest of the older sample, their results are included in all data analysis.

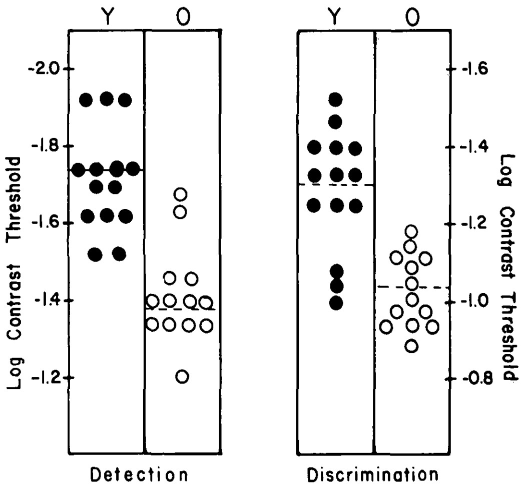

Fig. 1. Mean threshold contrast for each observer for detection and discrimination. To accommodate performance differences between the two tasks, the ordinates for detection and discrimination data cover different ranges. Discrimination trials on which observers made errors were omitted from threshold calculations. Mean error rates for young (*Y*) and old (*O*) were approximately equal. young = 1.6 and old = 2.6.

Note first that older observers needed higher contrast than the young both to detect and to discriminate faces, $F(1,25) = 48.65$, $p < 0.01$. Although there was some individual variation within each group, there was little overlap between the two groups. Control measurements indicated that the diminished retinal illuminance in our older observers—because of senile miosis and increased lenticular density—did not play a major role in the threshold differences between our groups. In fact, reducing retinal illuminance in young observers by means of a 0.5 D neutral-density filter, which approximates retinal illuminance for the average older observer,[7] left face detection thresholds unchanged. This outcome was expected because sensitivity to low spatial frequency targets is constant over comparable decreases.[8] Although reduced retinal illuminance appears to play little role in the older group's higher thresholds for faces, it did account for a large part of their decreased sensitivity to small targets.[9]

We wondered whether the difference between young and older observers' thresholds might result from motivational or criterion differences. To answer this question, we converted the discrimination task into a signal detection task, permitting us to measure visibility without contamination by criterion differences between groups.[10] Each observer was retested with the 16 slides of face pairs, but this time contrast was set 0.2 log units below that particular observer's mean threshold. After each presentation the observer had to specify whether the two faces belonged to the same or different people. Since we had earlier found that the average older person's threshold was 0.3 log units higher than the average young person's threshold, the average older person was tested in the signal detection procedure with faces having twice the contrast used for the average younger person. We first calculated the probability of correctly identifying a pair of faces as different (a "hit") and the probability of misidentifying a pair as different (a "false alarm"). These conditional probabilities were converted into a criterion-independent measure of visibility, d'. The mean d' for older observers was 1.10, that for the younger was 1.04, a difference not statistically significant. Having discounted motivational differences by using d', we have confirmed that pairs of faces will be equally discriminable for both old and young observers when the faces shown to older observers have approximately twice the contrast of those shown to younger observers.

Returning to Fig. 1, note that for both ages, mean threshold for detection was 0.4 log units lower than mean threshold for discrimination, $F(1,25) = 334.49$, $p < 0.01$. A contrast just sufficient for detection does not make visible those details that are presumably important for discrimination. But the 0.4 log unit difference in contrast thresholds for detection and discrimination should not be taken as canonical. Undoubtedly, it depends on the particular sets of pairs used in the discrimination task. For example, the difference between detection and discrimination thresholds would be greater if one had to discriminate between faces drawn from a collection of people closely resembling one another, such as near relatives, than if pairs were drawn from quite dissimilar faces.

Discussion. It is important to note that perceptual difficulties in elderly observers, such as the ones we report, would not have been detected by the most common procedure for assessing visual function: visual acuity tested under conditions of high contrast. Our older observers had good acuity at high contrast yet were significantly impaired relative to young observers in perceiving faces under low contrast. We believe that our measures of face perception reflect different visual abilities from those involved in visual acuity. This view is supported by the fact that although statistically significant ($p < 0.05$), only a small percent of variance (r^2) was shared between the acuity measurements and detection thresholds (22%) and between acuity and discrimination thresholds (17%). These shared variances may be compared to the 70% variance shared between face detection and face discrimination.

Our studies demonstrate that some older persons may have severe difficulties in performing routine perceptual activities in low contrast environments. Ocular pathological conditions (e.g., cataract, glaucoma) and optical factors (e.g., senile miosis, refractive state) can not account for the deficits we report here, suggesting that these deficits have a neural origin. The present data, however, cannot identify the neural locus of this age-related change.

The face perception tasks used here resemble other routine perceptual tasks requiring the differentiation of figure from ground, such as detecting objects in a naturally cluttered environment. Therefore a variety of perceptual activities carried out under low contrast or at low levels of light may be adversely affected in some older people.

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