Visual localization: age and practice

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Older people seem to be highly susceptible to the distracting effects of irrelevant or interfering visual stimuli. We studied this susceptibility using visual displays in which observers had to localize the position of a face. When a face appeared in isolation, observers of all ages did equally well; when distracting stimuli surrounded the face, older observers alone performed poorly. Brief periods of practice produce substantial and long-lasting improvement in performance.

INTRODUCTION

Many laboratory studies, drawing on diverse tasks, suggest that older observers' visual performance declines in the presence of irrelevant or distracting stimuli.[1] To determine whether similar problems were also manifest outside the laboratory, Kosnik and his associates surveyed 95 people of various ages to identify their most common, everyday visual problems.[2] About five times more older people than younger people reported difficulties with visual distractors. For example, older people reported particular difficulty trying to locate a friend in a crowd or in trying to read a street sign that was surrounded by other street signs.

We designed a laboratory analog to those situations that older observers describe as "difficult"; we used this analog to probe older and younger observers' paracentral and peripheral vision. Our test measured how well a single randomly positioned target could be localized in the presence of other, distractor stimuli and also when the observer had to perform a concurrent central task. When neither a concurrent central task nor peripheral distractors were present, our observers' task resembled that which is used clinically to measure visual fields[3]; but, with a concurrent central task as well as peripheral distractors, the task resembled ones encountered every day, including tasks that the survey showed were particularly troublesome for older people.

We chose radial localization as our performance measure because previous research showed that this measure is relatively impervious to the optical changes that characterize the aging eye—decreased retinal illuminance and image degradation.[4,5] As a result, age-related differences would not necessarily result from age-related optical changes.

EXPERIMENT 1

Observers

Fifteen young (mean age 25.1 years) and nineteen older observers (mean age 68.8 years) were tested. All were healthy volunteers who were paid for participating; to screen for good ocular health, older observers received a thorough ophthalmological examination. All observers were individually refracted for sharpest vision at our testing distance (57 cm) and wore their best optical correction during testing.

At the test distance younger observers' best corrected binocular acuity (minimum angle resolvable) averaged 0.80 min of arc (SD 0.099); the comparable value for older observers was 1.07 min of arc (SD 0.173). Though our older observers had good acuity (1.07 min of arc is only slightly poorer than 6/6), the difference between age groups was statistically significant ($t = 5.85$, $df = 32$, $p < 0.01$).

Procedures

For comparability with everyday conditions, binocular viewing was used in testing. Every trial consisted of a sequence of four successive computer-controlled displays presented on a large video screen (40° × 40°). The luminance of a target on the display was 2 cd/m^2; the background luminance of the screen was low, 0.03 cd/m^2. Although such levels are below many encountered in everyday conditions, previous work has shown that radial localization is, within broad limits, not affected by light level.[6] Therefore, despite the low luminance levels, we retain good ability to extrapolate to everyday conditions in which we are interested.

In the first display of each trial's sequence, a bright outline box (4° × 5°) was presented, directing the observer's fixation to the center of the screen. After 1 sec, two cartoon likenesses of a human face, each 1.5° × 3°, were added to the screen for 125 msec. One face appeared in the center of the fixation box; the other, the test face, appeared unpredictably, but equally often, at any of 24 different locations in the display, along any of eight meridia (the four cardinal meridia as well as four intermediate, oblique meridia), and at any of three different distances, or eccentricities, from the center of the display: 5°, 10°, or 15°. The 125-msec target display was short enough to ensure that the observer could not initiate and execute a saccadic eye movement while the target was present.[7]

When conditions called for distractor stimuli, the single

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peripheral test face was accompanied by 47 outline boxes of the same size and luminance as the face itself. These outline boxes were distributed uniformly over the central 30° of the display (excepting for the locus of the face).

When a concurrent central task was called for, the expression on the central cartoon face was varied randomly from one trial to the next. By changing the curve of the central face's mouth and eyebrows—making the curve either convex upward or downward—the computer causes the face either to smile or to frown, producing the two expressions equally often but in a random order. When conditions did not require a concurrent central task, the central face was always smiling.

After 125 msec, the entire test display (fixation box plus any targets and distractors) was replaced by spatially random masking noise that obliterated any residual afterimage of the display. Finally, 1 sec later, a radial pattern appeared with eight equally spaced spokes, each labeled with a digit, 1 to 8. This spoke pattern remained visible until the observer made a radial localization judgment by selecting one of the numbers. Four seconds elapsed before the next trial began.

The observer made either one or two responses after each trial, depending on the test condition. Two responses were required for the central task condition: the first response identified the central face's expression, the second identified the radial location of the peripheral face. When no central task was required, the observer made only one response, judging the radial location of the peripheral face. Computer-generated tones gave immediate feedback about response correctness. However, if the central face's expression was judged incorrectly the trial terminated with no additional responses' being permitted. Later in the same set of trials, the aborted trial was re-presented. Trials were grouped in sets of 24, one trial with the peripheral face at each of its 24 possible locations. For each condition, an observer was tested in one 24-trial block. The order of testing with various conditions was randomized for each observer. We promoted attention and high motivation by supplementing observers' hourly pay with 2¢ for each correct response.

Results

The central task proved to be so easy that observers were almost always correct: young observers erred 7.5% of the time, while old observers erred 8.1% of the time. This difference was not statistically significant ($t = 0.98$, $df = 32$, $p > 0.20$).

Our main interest, of course, lay in radial localization. Since initial inspection of the data showed that performance did not vary from one meridian to the next, radial-localization errors were summed over all meridians. Figure 1 portrays the mean results for radial localization of the peripheral face. In each panel, the horizontal axis shows the three

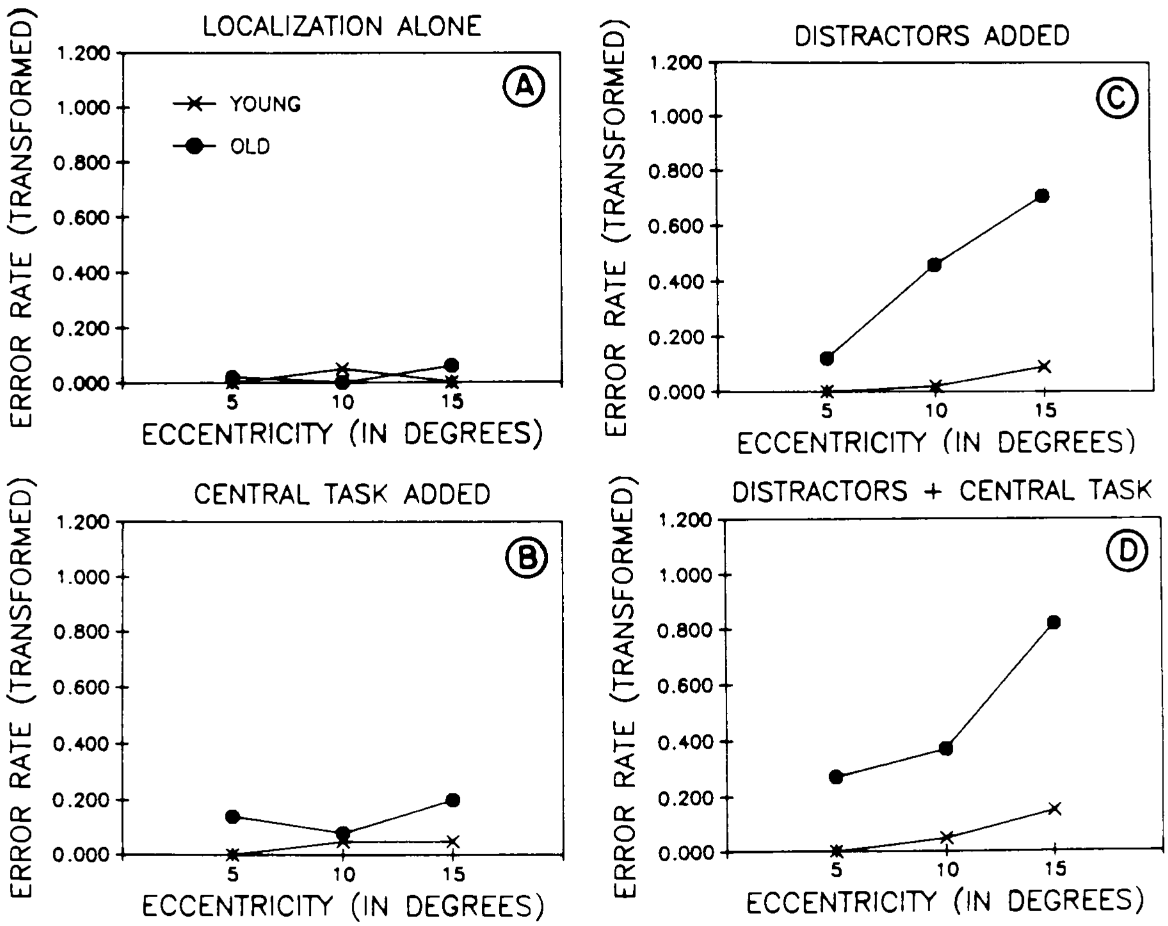

Fig. 1. Radial localization error rate (arc sine transformed) for targets at 5°, 10°, and 15° eccentricity. Data are shown separately for young (×) and old (●) observers. Panel A: performance with no distractor stimuli and no concurrent task. Panel B: performance with a concurrent task. Panel C: performance with distractor stimuli. Panel D: performance with both distractor stimuli and a concurrent task.

different eccentricities at which the peripheral face was presented; the vertical axis represents the mean error rate.

Because our data were proportions (percent correct), they were transformed for statistical analysis by taking the inverse sine of the square root of the percent errors. On this scale, 1.2 corresponds to chance performance (87.5% errors), 0.79 corresponds to 50% errors, 0.52 corresponds to 25% errors, and 0.0 corresponds to 0% errors.

Note first the results for two of the experiment's conditions. Panel A shows that when there was neither a central task nor distractors each group made few localization errors. In fact, young and old observers did not differ in performance (Newman Keuls test, $p > 0.40$). In contrast, Panel D shows that with a central task and peripheral distractors, both groups made more errors, particularly as eccentricity of stimulus presentation increased. Moreover, the combination of central task and distractors affected older observers far more than they did younger observers (Newman Keuls test, $p < 0.01$).

Panels B and C represent intermediate conditions—central task but no distractors (B) and distractors but no central task (C). Although both the central task and the presence of distractors had significant effects on radial localization ($F = 5.36$, $df = 1, 32$, $p < 0.05$; $F = 91.66$, $df = 1, 32$, $p < 0.001$, respectively), Panels B and C show that the distractors exerted a greater effect than did the central task. Moreover, although the central task affected both age groups about equally ($F = 1.91$, $df = 1, 32$, $p > 0.15$), Panel C confirms that distractors affected older observers far more than younger ones ($F = 67.02$, $df = 1, 32$, $p < 0.001$). A comparison of Panels C and D shows that, for older observers, the addition of the central task to the distractors had no greater effect than did the distractors alone.

The increase in error rate at greater eccentricities (Panels B through D) suggests reduced useful vision in the near periphery. Additionally, the growing divergence between the two age groups confirms that this reduction of useful vision is more substantial for older than for younger observers.

We were concerned that the particular impact of distractor stimuli on older observers might have been caused by those observers' slightly poorer visual acuity. Although earlier work suggested that excellent acuity was not important for radial localization,[5] we reconfirmed this with 12 young observers who viewed our displays through various positive lenses, producing different levels of blur. Lenses as strong as +2 diopters sharply increased the number of misjudgments of the central faces' expressions but had no effect on radial localization of the peripheral face, in the midst of distractors or otherwise. So the older observers' slightly reduced visual acuity was probably not the cause of their reduced performance.

Discussion

We should note that all localization errors did not result from a simple failure to *see* the target. If failure to see were their cause, localization errors would be uniformly distributed—with large errors of localization being no less likely than small ones. However, with older observers, more than 41% of all trials, errors were small—with the localization judgment missing by just one radial position (by chance alone, such errors should have constituted 2/7, or 28.6%, of all errors). The preponderance of small errors is confirmed by a chi-square test, $\chi^2 = 10.11$, $p < 0.05$. Thus, on many trials, errors reflect mislocalization rather than failure of detection.

Instability of eye position suggests itself as one simple explanation of the mislocalization errors. If the nervous system failed to take proper account of involuntary fixation changes, one could hypothesize that age-related fixation instabilities might promote localization errors. Although data are not currently available on the fixation stability or accuracy of normal healthy older people, our results militate against the simplest form of this hypothesis. The virtual equality of performance—between young and old observers—when no distractor stimuli are present—suggests that fixation instability *per se* is not the cause of the age-related differences seen in other conditions.

EXPERIMENT 2

With young observers, practice improves various aspects of visual perception,[8,9] including peripheral vision.[10,11] We wondered, then, whether practice would improve older observers' radial localization, and, if it did, how long such improvement would be retained.

Procedures and Results

To examine this question we recruited nine representative observers from our original sample of older observers. These observers practiced in four additional daily sessions, making a total of 72 radial localizations of the peripheral face in each session.

Although performance in all conditions improved significantly over time, improvement was greatest in conditions that initially had been most difficult. Figure 2 shows performance in one of these conditions: radial localization in the presence of peripheral distractors and a central task. Practice steadily improves peripheral localization ($F = 7.95$, $df = 4, 32$, $p < 0.001$) but does not reliably affect any one eccentricity more than any other eccentricity ($F = 1.40$, $df =$

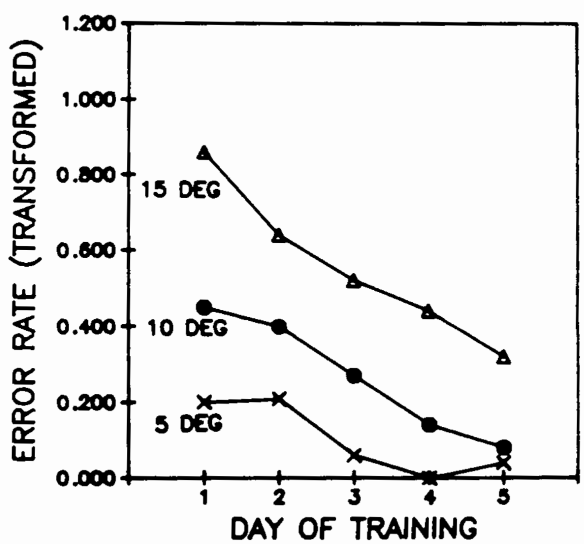

Fig. 2. Radial localization error rate (arc sine transformed) on various days of training. Data are shown separately for targets at three eccentricities: 5° (×), 10° (●), and 15° (Δ).

8, 64, $p > 0.20$). Similar, but less dramatic, results were obtained with other test conditions. Note that the curves in Fig. 2 suggest that, in order to reach asymptotic performance, observers need more practice than provided here.

After rest periods ranging from three to five weeks, the nine older observers were again tested. Performance on the retention test did not differ from performance on the last day of practice, suggesting that virtually all the improvement had endured.

Discussion

Two implications of our study are particularly noteworthy. First, our results seem to embarrass the idea that slowing of perceptual processing is caused by a generalized, age-related slowing of neural processes.[12] In particular, the equality of older and younger observers, at least in one condition of our study, as well as the striking effects produced by small amounts of practice appear to be inconsistent with such a theoretical view.

Although the amount of practice that we provided did not bring the older observers up to the starting level of the younger observers (compare Figs. 1 and 2), practice did have a substantial effect. An unsolicited remark by one older observer dramatizes practice's potency. Though she initially found some conditions to be difficult, two days' practice made the same conditions so much easier that she insisted that we had increased the duration of the test display (we verified that our test display had indeed not changed).

Future research should explore several possible explanations for the effect of practice: one such explanation holds that performance improves as observers learn to suppress particular, distracting stimuli; a second explanation holds that improvement reflects a general increase in efficiency of visual processing.

Finally, our results suggest that clinical tests of vision, which minimize visual distractions, may give unrealistic estimates of the vision available to the elderly under real-life conditions, where visual distractions may be the rule rather than the exception.

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