AGING VISION IN VISUAL CLUTTER

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Two studies examined the effect of noisy clutter on visual abilities in young, middle-aged and elderly viewers. The first examined contrast perception with and without noise. Without noise, the eldest viewers showed poorest contrast detection under all conditions. Middle-aged viewers were already showing some deficit for the finest details. Addition of noise amplified the aging loss, showing that clutter further magnifies visual disabilities in the elderly viewer. A second study tested dot numerosity estimation, a task that correlates well with situational awareness measures. Younger viewers performed best and oldest viewers worst at all noise levels. However, noise failed to amplify the loss. The results suggest that laboratory studies conducted under ideal conditions underestimate the real-world visual loss in the elderly and lead to inadequate compensatory design.

Most interaction with the environment involves vision. With the aging of the population, human factors design requires increasing attention to the creation of information displays, warnings, etc. that can be readily seen by the older person (Green, 2002). In order to design properly for the elderly, it is necessary to first have a realistic assessment of the extent of age-related visual loss.

However, the effect of aging varies with visual task and conditions. For example Green, Odom, & Chao (1993) found that older viewers exhibited no deficit in orientation discrimination while Odom, Vasquez, Schwartz, & Linberg (1989) reported that elderly viewers had normal vernier acuity. On the other hand, many studies (e .g., Odom, Leys, Yates, Green, & Charlton, 2000) have found a loss in contrast perception, the ability to see the difference in brightness, texture or color between an object and its background. This is the ability that allows perception of edges and contours that define shape and object. In most cases, the critical contrast is *brightness contrast*, a dark object on a bright background or vice versa.

Typical laboratory studies of aging may underestimate the degree of visual disability in the real world because they use simple, uniform targets and backgrounds. Previous visual masking studies (e. g., Cremer & Zeef, 1987; Ho, Scialfa, Caird, & Graw, 2001) have found that the elderly show especially large losses when the scene contains visual clutter and noise.

This has led us to examine the effects of noise on the “normal” contrast perception loss that accompanies aging. We have used the *Ideal Observer* model in a series of studies to test the effects of clutter and noise on vision, situational awareness (Green, Odom, & Yates, 1997) and eye disease (Yates, Leys, Green, Charlton, Reed, & Odom, 1999; Odom, Leys, Yates, Green, & Charlton, 2000). Briefly, the method uses a statistical model specifying the ability of a viewer to use the information available in a scene. The actual test method involves adding “noise” which clutters the scene. In the present case, the noise is random dots of different brightness (distributed by a Gaussian function) that disrupt the smooth and uniform surfaces. In this report, we will not discuss the statistical model in detail, but only the effects of adding noise to an image on contrast perception. Our goal is merely to determine whether noisy clutter will reveal a greater disability in the aging eye and suggest that the visual impairment in the elderly is greater than previously believed.

Lastly, we investigated the age where visual loss begins. Most studies use only a young and an old group. We refined the age range by adding a third group, “middle aged” people in their 40’s. The results show that even at this relatively early age, visual losses are already apparent.

Experiment I: Contrast Perception

Subjects. A total of forty-five young (mean age = 21 years), middle-aged (mean age = 43 years), and older (mean age = 72 years) adults were recruited in the study. Each age group had 15 participants, all with a visual acuity of 20/33 or better at the viewing distance of 1 meter. No participant had visual disease or systemic diseases.

Procedure. In order to determine the "normal" visual loss of aging, we asked viewers to detect gratings of different spatial frequency with no noise. Next, all participants monocularly viewed (1) 7.5 Hz reversing gratings of 0.7 c/deg. at 5 noise levels ranging from 0 to 80% contrast and (2) 5.5 c/deg. stationary gratings at 5 noise levels ranging from 0 to 80% contrast (See Yates, et al, 1999 for full details of the method). Stimuli were presented at the viewing distance of 1 meter. Thresholds were determined by a 4 spatial alternative force-choice method together with a staircase with 1 up, 1 down rule, that is, 50% correct (d'~ 0.84). Prior to the beginning of each task, the subject was given an opportunity to practice the no-added-noise condition. The reversing grating task was preceded by the stationary grating task. The sequence of testing within tasks was fixed. It began with the no added noise condition and progressed through the lower noise levels to higher noise conditions.

Results. Figure 1 shows contrast sensitivities for each age. As would be expected, contrast perception fell with age. While the oldest viewers exhibited a deficit at all spatial frequencies, the age loss was relatively greatest with the thinnest stripes. There was also a slight trend favoring the youngest over the middle-aged viewers at higher frequencies.

Figure 2 shows the effects of noise on contrast thresholds as a function of age. A 3 (age group) by 5 (noise level) repeated-measures analysis of variance was performed on contrast thresholds with age group and noise level as a between-subjects variable and a within-subjects variable, respectively. For the 7.5 Hz reversing gratings, there were significant effects on age, $F(2, 42) = 13.52$, $p < .001$, and noise levels, $F(4, 168) = 211.25$, $p < .001$. In addition, there was a significant interaction between age group and noise level, $F(8, 168) = 2.71$, $p < .01$. A Tukey post-hoc analysis revealed that the elderly had a higher threshold than the young and middle-aged at each noise level, but the young and the middle-aged did not differ on their thresholds. Within each group, the contrast threshold increased with the greater noise level ($F(4, 56) = 118.07$, $p < .001$; $F(4, 56) = 79.72$, $p < .001$; $F(4, 56) = 57.51$, $p < .001$, for the young, the middle-aged, and the old, respectively). The significant interaction between the young and the old indicated that the thresholds of the elderly had a greater increasing rate across the noise levels than the young, $F(4, 112) = 4.39$, $p < .01$. However, the interaction between the old and the middle-aged was not significant, $F(4, 112) = 2.08$, $p = .09$.

Similar results were obtained for the 5.5 c/deg. stationary gratings. There were significant differences among groups, $F(2, 42) = 22.80$, $p < .001$, and the noise levels $F(4, 168) = 173.48$, $p < .001$. There was a significant interaction between age group and noise level, $F(8, 168) = 2.31$, $p < .05$. The older adults had higher thresholds than the young and the middle-aged at all noise levels. The young and the middle-aged did not differ on contrast threshold across all noise levels. Within each group, the contrast threshold increased with greater noise level ($F(4, 56) = 66.00$, $p < .001$; $F(4, 56) = 54.91$, $p < .001$; $F(4, 56) = 58.03$, $p < .001$, for the young, the middle-aged, and the old, respectively). The older adults had a greater increasing rate on threshold across the noise levels compared to the middle-aged, $F(4, 112) = 3.87$, $p < .01$, but to the young, $F(4, 112) = 1.72$, $p = .15$.

Discussion. The results clearly show that while cluttered, noisy environments impair contrast perception in all people, the normal age-related differences on contrast thresholds is magnified under higher noise levels. No difference between the young and the middle-aged on contrast threshold under noise suggests that the effects of clutter only become significant later in the life span. Finally, people in their 40's are already showing reduced contrast perception for at the highest spatial frequencies. Visual loss begins at an age well before most people would be considered "old."

Experiment II: Dot Numerosity

The previous study showed that adding noise magnified the normal contrast perception loss in visual aging. We performed a second experiment in order to determine whether the effect of noise is restricted to contrast perception or would occur in another task. We chose dot numerosity estimation, a particularly interesting task because it correlates well with measures of situational awareness (Endsley and Bolstad, 1994; T. Caretta, cited in Endsley and Bolstad, 1944).

Subjects. The same as described above.

Procedure. The method was identical to that used by Green, Odom, & Yates, T. (1997). The viewer saw two red rectangular boxes (Figure 3) containing differing numbers of black dots on a gray background. Following each 667 msec exposure, the observer responded by pressing the left or right mouse button to signal whether the left or right box had more dots. Observers were tested in a series of two-alternative spatial, forced-choice trials in which task difficulty, the difference in the number of dots in the two rectangles, was modulated by a 3-up, 1-down tracking rule. The standard number of dots (N) was 100. The dot difference (ΔN) between the boxes was then perturbed by adding noise (σ N), i. e., increasing/decreasing dots from each box. The number of noise dots was randomly chosen from a Gaussian distribution with a mean of 0 and a variance of 0, 10 or 15 dots.

Results. Figure 4 shows the results of the dot efficiency test. There was an age separation at each noise level, with younger always superior to middle aged who, in turn were superior to the oldest viewers. Moreover, performance decreased with increasing noise for all viewers. However, there is no clear evidence that noise magnifies the effect of aging on the ability to perform dot numerosity estimation.

General Conclusion

The study has three main findings. First, older viewers exhibit a visual deficit both with and without noise. The onset of loss occurs in the 40's, a surprisingly early age. Second, noise and clutter magnify the normal contrast perception loss that accompanies aging. This may partly explain why noise impairs the elderly in performing everyday tasks such as reading (Speranza, Daneman & Schneider, 2000). The result further suggests that studies using ideal laboratory conditions underestimate the needs of the elderly in the real world. Third, the dot numerosity experiment task suggests that the elderly may have a deficit task involving situational awareness. One possible explanation is that older viewers have a narrower field-of-view and must make eye movements in order to inspect the entire display. They must then remember the number of dots from one fixation to the next. In contrast, a younger viewer may be able to estimate dots with a single glance. However, the results also show that increasing noise does not magnify the deficit. Perhaps, the random dot positions are themselves so noisy that there is a ceiling effect.

These results also have theoretical significance in localizing the source of the visual loss that accompanies aging. The difference between the two experiments can be understood in terms of the distinction between contrast-variant and contrast- invariant visual tasks. Contrast-variant tasks, as the name implies, depend on the level of contrast. Increasing contrast produces better perception, and the most obvious such task is contrast detection. Contrast-invariant tasks are not greatly dependent on contrast – once an object can be barely seen, further contrast increases do not improve perception. Many form and motion discrimination tasks fall into this category. It seems likely that the elderly are less impaired in contrast-invariant tasks, as they sometimes show no deficit at all (e .g., Green, Odom, & Chao, 1993). This is important because contrast-variant tasks likely reflect the optical quality of the eye while contrast-invariant tasks are an indicator of higher-level neural loss. If true, then the effects of noise on aging will largely be greater for tasks requiring contrast detection and discrimination.

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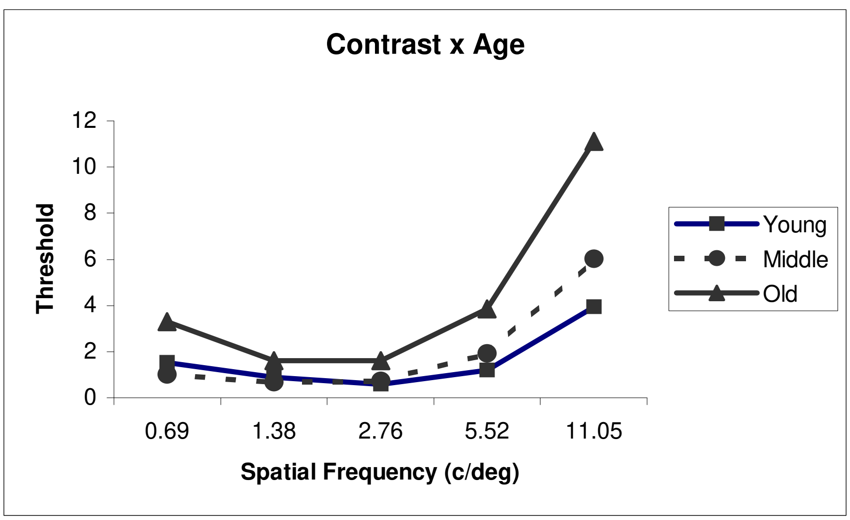

Figure 1. Contrast threshold for age as a function of spatial frequency.

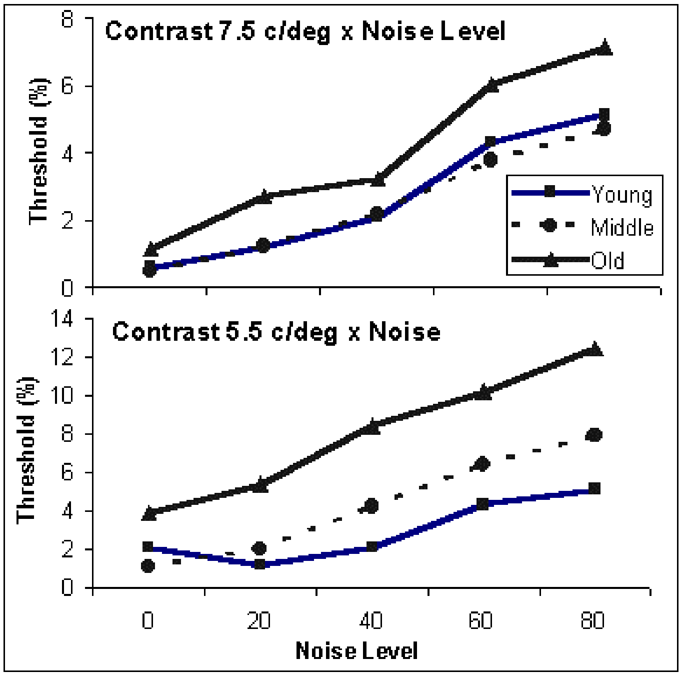

Figure 2. Contrast threshold for age as a function of noise.

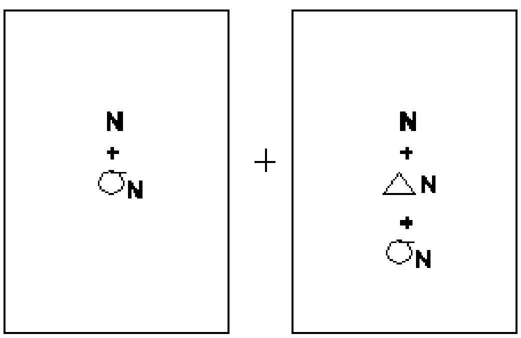

Figure 3. Schematic representations of dot estimation targets.

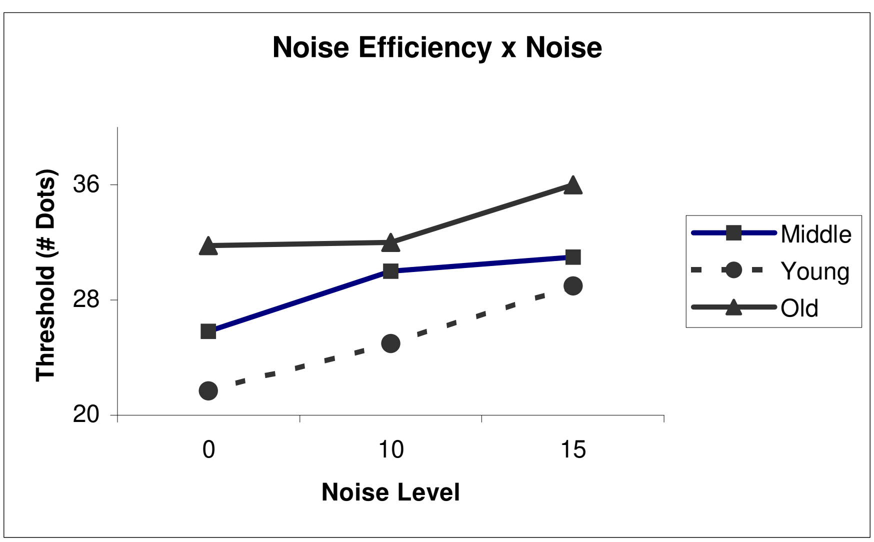

Figure 4. Effects of noise on the dot estimation task for three age groups.