Visual Performance on the Small Letter Contrast Test: Effects of Aging, Low Luminance and Refractive Error

Major Corina van de Pol, O.D., Ph.D., LTC Jeff Rabin, O.D., Ph.D.
U.S. Army Aeromedical Research Laboratory
Ft. Rucker, AL 36362, U.S.A.
Tel: (334)255-6876
Corina.vandepol@se.amedd.army.mil

Summary:
In this study the visual performance of aviators and a myopic, non-aviator group were compared to determine the effects of aging, available light and refractive error. The chart used is a novel chart called the Small Letter Contrast Test (SLCT) which measures sensitivity to contrast at the moderate to high end of the spatial frequency range near the visual acuity thresholds of most normal observers. All three variables influence visual performance on the SLCT, age having a greater effect on low luminance performance and refractive error having comparable effects on SLCT performance regardless of luminance level. High contrast visual acuity remains fairly stable and normal over the age range tested; however it decreases with increasing refractive error.

Introduction:
As the visual system ages there is a decrease in pupil size, an increase in intraocular scatter, and a decline in retinal function. How these changes affect routine daily activities does not generally become evident until well past age 60 even while standard measures of visual performance are still normal. Indeed, aging appears to have little impact on high contrast visual acuity (HCVA) until after age 70 (Haegerstrom-Portnoy, Schneck et al. 1999). The decline in HCVA after this age is generally minimal for normals who do not have age-related ocular changes such as cataracts or retinopathy, with the greatest decline between the ages of 80 and 100. Army aviators are therefore expected to have excellent HCVA, which should remain very stable over the course of a typical career.

Aviators have higher visual demands, however, and performance not measured by HCVA may be affected at a much earlier age. Visual demands in the army aviation environment include significant low contrast and low luminance scenarios that require excellent contrast sensitivity. Studies of the effects of aging on contrast sensitivity have shown a much earlier and more pronounced effect on this function than on HCVA (Owsley, Sekuler et al. 1981; Adams, Wong et al. 1988). A more sensitive measure of visual performance is needed to evaluate subtle visual changes that may affect function.

Another factor affecting performance may be refractive error. Although current standards limit the amount of refractive error for entry into aviation, many aviators develop ametropias during their careers. We were interested in whether low and moderate amounts of refractive error play a role in contrast sensitivity. Earlier studies of the contrast sensitivity function and refractive error have shown that high amounts of spectacle-corrected myopia (e.g. 8 or more diopters) will reduce sensitivity primarily at the higher spatial frequencies (Collins and Carney 1990; Risse, Saint-Blancat et al. 1996).

The purpose of this study was to evaluate the age-related visual performance changes of aviators and to compare these changes to a myopic, non-aviator population using a more sensitive measure of visual performance, the Small Letter Contrast Test (SLCT). The SLCT was developed in response to the need for a more sensitive measure of the visual capabilities of U.S. Army aviator candidates (Rabin 1995). The SLCT uses small 7.4 mm by 7.4 mm letters, equivalent to 20/25 (6/7.5) when presented at 4 meters, in lines of 10, each line decreasing by 0.1 log contrast level.

Rationale:
Operations in space and aviation require superior spatial vision to optimize target detection and obstacle avoidance. As aviators age, the ability to see under low luminance or other visually challenging conditions changes. The ability to adequately measure these changes and to apply appropriate physiological and technological

Paper presented at the RTO HFM Symposium on "Operational Issues of Aging Crewmembers", held in Toulon, France, 11-14 October 1999, and published in RTO MP-33.

counter-measures is critical to optimal performance.

Methods:

The aviation group consisted of 123 aviators and aircrew, ages 22 to 66, with minimal refractive error (0.00 ± 1.0 diopters). The non-aviation group consisted of 76 subjects, ages 22 to 63, with myopia (–6.25 ± 2.5 diopters). Visual performance was assessed using HCVA and contrast sensitivity using the SLCT. The SLCT was presented under two conditions, standard chart luminance of 100 cd/m^2 and low chart luminance achieved using neutral density filters placed in front of the eye for the aviator group and by decreasing chart luminance to 3 cd/m^2 for the non-aviator group. Separate investigators at different research facilities measured the two groups. Visual changes were evaluated in terms of age, luminance level and refractive error within each group and between groups.

Results and Discussion:

High Contrast Visual Acuity (Age)

Figure 1 shows the change in HCVA with age for both groups. Loss of high contrast acuity was minimal; less than 0.10 ± 0.08 logMAR loss (approximately 1 line) across the entire age range for both groups. The correlation coefficient for the regression was r = 0.20 for the aviator group and r = 0.33 for the non-aviator group. The difference between groups on the HCVA measure was statistically (0.04 logMAR, p=0.01), but not clinically significant (<1/2 line of acuity).

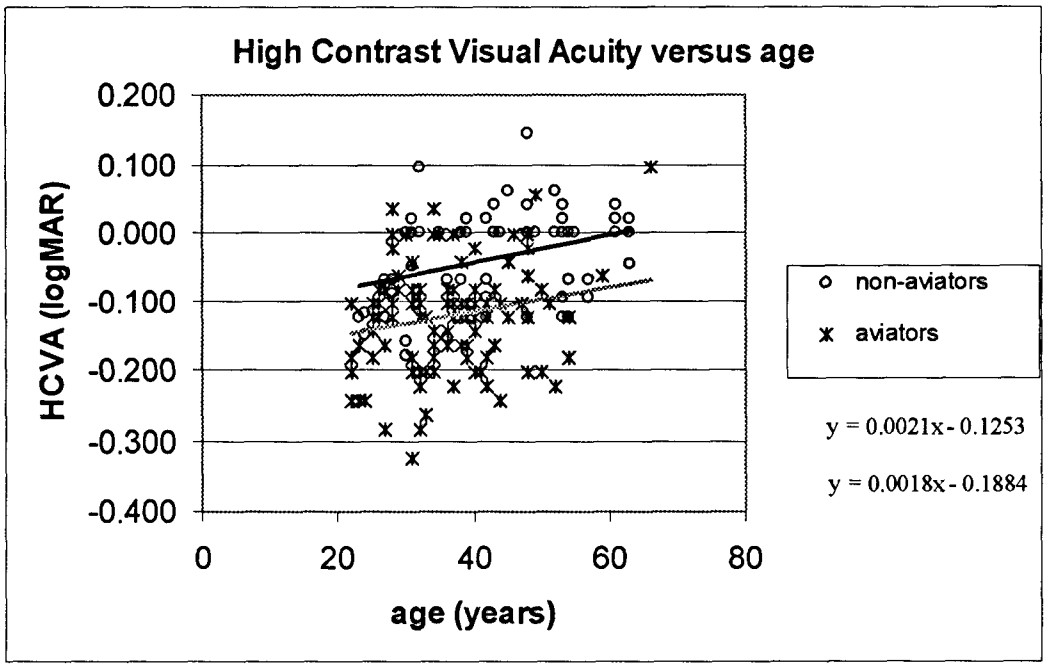

Figure 1: HCVA versus age. More positive values of HCVA (logMAR) indicate a decrease in performance. Regression equations are shown on the graph. The black line represents the non-aviator group and the gray line represents the aviator group. Note the range of performance across the entire age range as well as the overlap between the two groups.

Small Letter Contrast Test (Age and Luminance)

Figure 2 shows the change in SLCT performance under standard luminance conditions as a function of age for both groups. Contrast sensitivity on the SLCT decreased for the aviator group at a rate of 0.032 ± 0.04 logCS (almost 1/3 line) per 10 years under standard luminance conditions, while the decrease was slightly greater for the non-aviator group (0.043 ± 0.05 logCS per 10 years). The correlation coefficients for the linear regressions were r = 0.15 (aviator) and r = 0.24 (non-aviator). The difference in performance level between the two groups was statistically significant (0.11 ± 0.1 logCS, t=4.0, p<0.001), yet there is significant overlap between the groups, especially in the lower age groups.

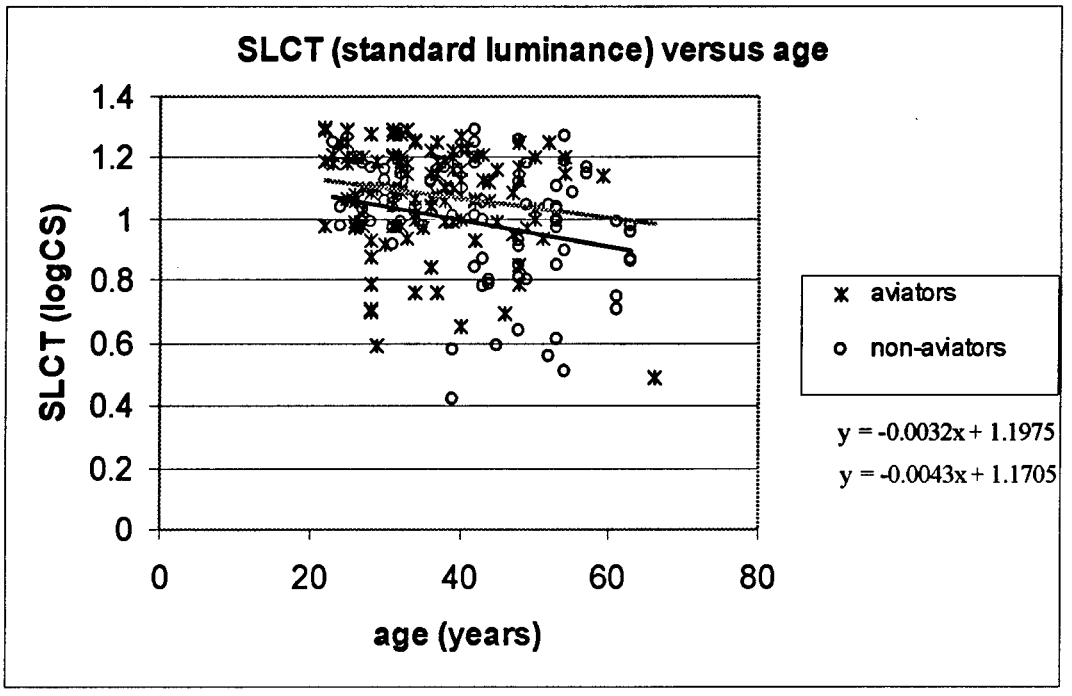

Figure 2: Small Letter Contrast Test performance under standard luminance conditions is plotted versus age. Regression equations are given on the graph. Regression lines are plotted (gray line = aviators, black line = non-aviators).

Figure 3 shows the low luminance SLCT performance with age. CS loss under these conditions was 0.06 ± 0.08 logCS per 10 years for both groups. The correlation coefficents for the regressions were r = 0.31 (aviators) and r = 0.38 (non-aviators). The difference in mean performance level for the two groups was 0.09 ± 0.11 logCS, which is statistically significant (t=3.3, p<0.001). The loss over the age range for both luminance levels was statistically (p<0.001) and clinically significant (1.5 to 2 lines at standard luminance and 2.5 lines at low luminance).

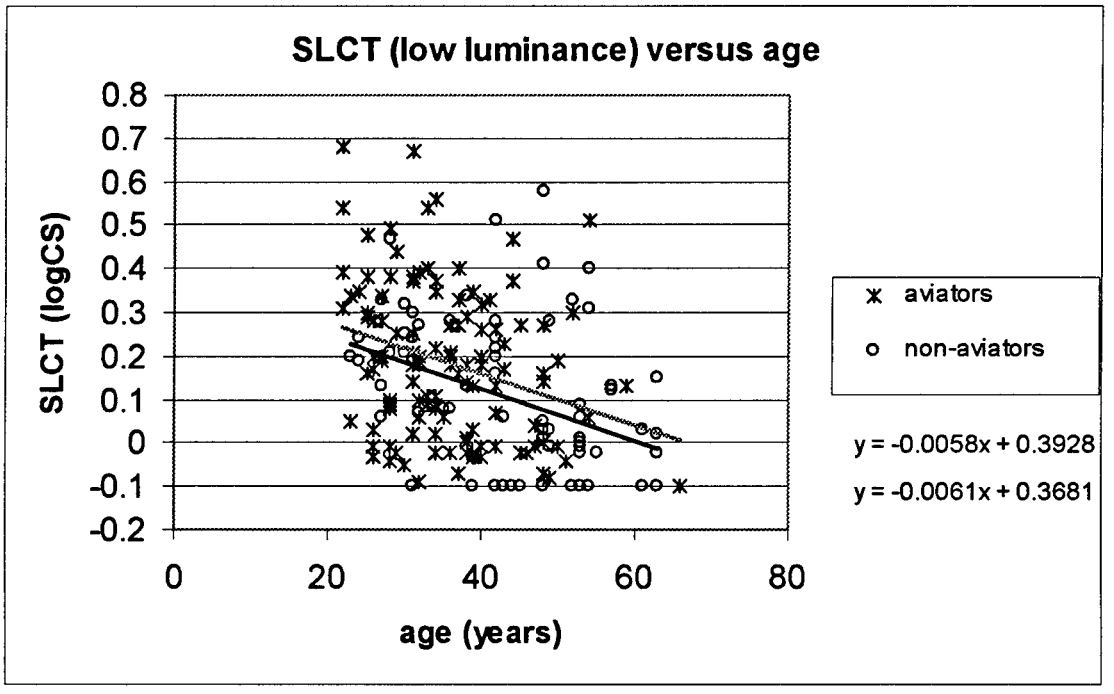

Figure 3: Small Letter Contrast Test performance under low luminance conditions is plotted versus age. Regression lines are plotted (gray line = aviators, black line = non-aviators).

Refractive Error

In Figure 4, performance on the SLCT is plotted as a function of refractive error. Figure 5 shows the effect of refractive error on HCVA. All three measures show a decrease with increasing refractive error. The regression correlations are stronger for the relationship between performance and refractive error than for performance and age. The correlation coefficients were $r = 0.40$ for standard luminance SLCT, $r = 0.30$ for low luminance SLCT and $r = 0.52$ for HCVA. Previous studies have shown that the optical effects of spectacles, specifically spectacle magnification (or minification, as in this case), are largely responsible for decreased visual performance of myopes (Collins and Carney 1990; Risse, Saint-Blancat et al. 1996). The aviators measured in this study were essentially emmetropic and are therefore massed near zero on the graphs, while the non-aviator group spans the range from –3.00 to –14.00 diopters of myopia.

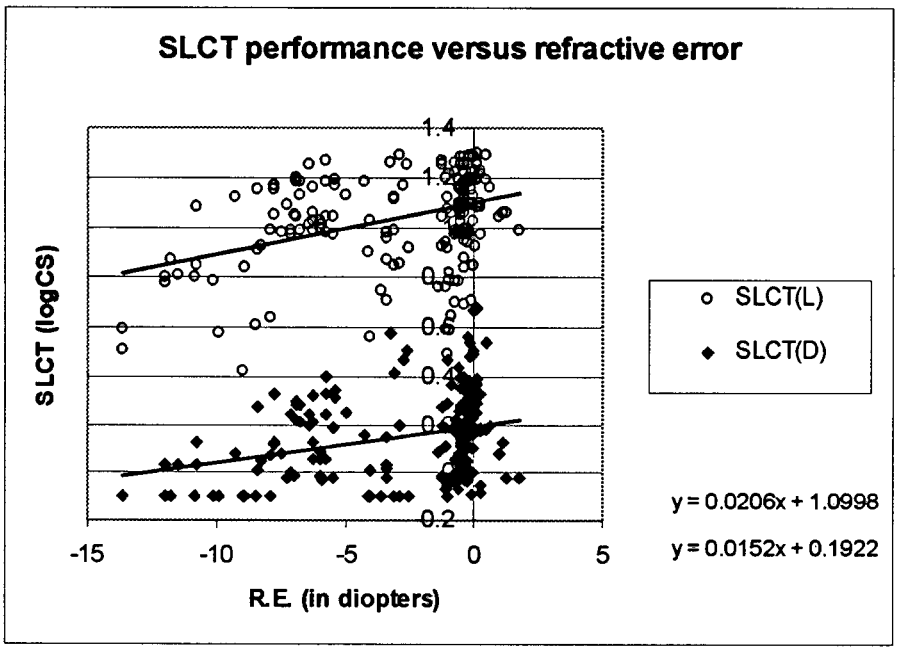

Figure 4: SLCT as a function of refractive error. Regression equations and plots given.

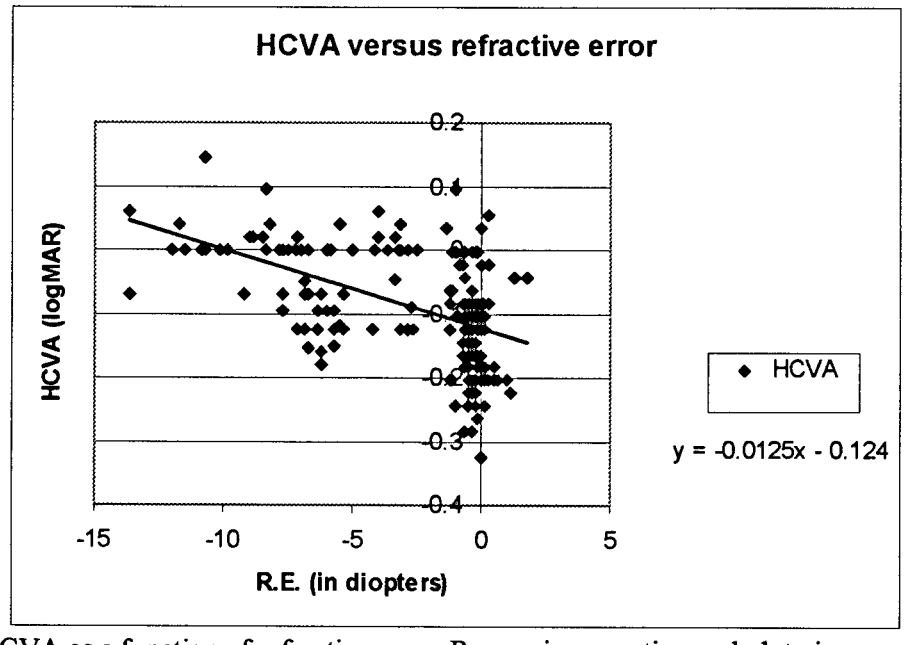

Figure 5: HCVA as a function of refractive error. Regression equation and plot given.

Aging *and* Refractive Error

Using multivariate regression and ANOVA, the effect of age and refractive error on visual performance was evaluated. The regression evaluations are presented in Table 1.

Table 1

Visual Measure	Regression equation	Correlation	ANOVA	Significance
HCVA	0.0022(age)-0.011(r.e.)-0.206	$R = 0.58$	F = 49.4	P < 0.0001
SLCT(standard)	-0.003(age)+0.018(r.e.)+1.22	$R = 0.44$	F = 22.6	P < 0.0001
SLCT(low)	-0.006(age)+0.010(r.e.)+0.40	$R = 0.44$	F = 22.4	P < 0.0001

Conclusions:

From the graphs it is evident that there is a relationship between aging and visual performance as well as refractive error and visual performance. Within each group and for each test there is a wide range of visual performance, however. Using age 40 as an example (see figures 1-3), HCVA ranged from –0.2 to 0.02 logMAR (more than 2 lines on the chart), SLCT standard luminance ranged from 0.65 to 1.25 logCS (6 lines) and SLCT low luminance ranged from –0.1 to 0.35 (4.5 lines). In terms of the significance of measurable changes in vision, HCVA remained within an acceptable range over the age and refractive error of both groups, while more significant decreases in vision were measured on the SLCT, especially after age 40 and above 8 diopters of myopia.

The SLCT is able to detect more significant changes in visual performance with age, refractive error and luminance than high contrast acuity tests. Contrast sensitivity is lower among myopes and under low luminance conditions and it decreases with age. The difference between contrast sensitivity under standard and low luminance conditions also increases with age; indicating aging changes in the visual system will more significantly affect performance under low light conditions. Testing pilot visual performance beyond high contrast will reveal limitations, which may be addressed through improved lighting, instrumentation, sighting devices and cockpit configuration.

References:

Adams, A. J., L. S. Wong, et al. (1988). "Visual acuity changes with age: some new perspectives." Am J Optom Physiol Opt **65**(5): 403-6.

Collins, J. W. and L. G. Carney (1990). "Visual performance in high myopia." Curr Eye Res **9**(3): 217-23.

Haegerstrom-Portnoy, G., M. E. Schneck, et al. (1999). "Seeing into old age: vision function beyond acuity." Optom Vis Sci **76**(3): 141-58.

Owsley, C., R. Sekuler, et al. (1981). "Aging and low-contrast vision: face perception." Invest Ophthalmol Vis Sci **21**(2): 362-5.

Rabin, J. (1995). "Small letter contrast sensitivity: an alternative measure of visual resolution for aviation candidates." Aviat Space Environ Med **66**(1): 56-8.

Risse, J. F., P. Saint-Blancat, et al. (1996). "[Spatial contrast sensitivity in patients with severe myopia]." Journal Francais D Ophtalmologie **19**(4): 271-7.