



**Flicker Detection
Through Night Vision Goggles
(Reprint)**

By

Jeff Rabin

Aircrew Health and Performance Division

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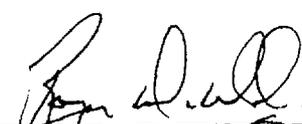
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RICHARD R. LEVINE

LTC, MS

Director, Aircrew Health and Performance Division

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Flicker Detection Through Night Vision Goggles

JEFF RABIN, O.D., Ph.D.

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Visual performance through night vision goggles (NVG's) is commonly assessed with letter charts or other static displays. Few attempts have been made to evaluate dynamic aspects of vision through NVG's. Such information may be used to better predict human performance and guide the development of improved devices. In this study, contrast thresholds for detection of flickering targets were measured through NVG's across a range of ambient conditions. A comparison of measurements with and without NVG's indicated that flicker detection is limited by the contrast and luminance of the NVG display. The contrast limitation is largely independent of stimulus flicker frequency. Increasing the transfer of static contrast and/or luminance through NVG's will also improve dynamic visual performance.

IMAGE INTENSIFYING devices (night vision goggles; NVG's) are being increasingly used in military and civilian environments. NVG's amplify ambient illumination, making it possible to perform under extreme and limited conditions. Despite the efficacy and utility of these devices, NVG's present an isochromatic view of the world limited in contrast and detail. It is important to understand the limitations of these devices so that human performance can be anticipated across a range of environmental conditions. A comprehensive understanding of NVG performance will also guide the development of improved night vision devices.

Although visual performance through NVG's is commonly assessed with letter charts or other static displays (3,4,7,8), little attempt has been made to assess dynamic aspects of vision through night vision devices. Such information may be useful for understanding performance through NVG's under the fluid conditions of an operational environment and the high speeds of aviation. Performance measures with dynamic stimuli may also be used to distinguish between human and electro-optical constraints on processing dynamic information through NVG's.

From the Sensory Research Division, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL.

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Address reprint requests to: MAJ Jeff Rabin, USAARL, Attn: SGRD-UAS-VS, P.O. Box 620577, Ft. Rucker, AL 36362-0577.

In the present study, the minimum contrast necessary to detect flickering targets through NVG's was measured across a range of night sky conditions. A comparison of flicker sensitivity with and without NVG's indicated that flicker detection is limited by the contrast and luminance of the NVG display. The limitation imposed by contrast is independent of flicker frequency. Improved designs which increase the transfer of static contrast through NVG's will also improve dynamic visual performance.

METHODS

Third-generation NVG's contained in the Aviator's Night Vision Imaging System were used in this study. The stimulus was an array of seven Snellen letter "E's" software-generated on a color monitor. Only the red gun of the monitor was used to limit the spectral composition of the display to the spectral range of the NVG's. While NVG's have peak sensitivity in the near infrared (750 nm), little infrared light is emitted by the monitor, making its output between 600-720 nm the primary stimulus. The array of E's was flickered on and off at temporal frequencies of 2, 4, 8, 16, and 32 Hz. Each of the seven letters had a different Weber contrast ranging from 4% to 100% in 0.23 log unit steps, and individual letters were numbered on top. Each letter subtended 75' of arc corresponding to a dominant spatial frequency of 2 cycles/° (20/300 Snellen equivalent). This stimulus size was used since it is near the peak of the spatial contrast sensitivity function at the luminance levels used (1), and would thus provide a sensitive spatial dimension for testing.

Neutral density (ND) filters were used to introduce large changes in stimulation corresponding to different night sky conditions. The irradiance of the night sky in the spectral range of the NVG (600-900 nm) decreases by about 3 log units between full moon and overcast starlight (3,5). To simulate this reduction in ambient stimulation, measurements were obtained with 0, 1, 2, and 3 log units of stimulus attenuation relative to the full moon condition. These four conditions were designated full moon, ¼ moon, starlight, and overcast. The full moon condition was determined by reducing the lumi-

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nance of the monitor with ND filters to the value specified for night sky luminance under full moon conditions [0.01 cd/m^2] (3,5). In addition, photometric measurement of the NVG display in response to different stimulus intensities revealed a range over which the display luminance remained constant and then began to drop with further decrements in stimulus intensity. This decline in NVG display luminance reflects the point at which the automatic brightness control stops operating. Inspection of the display with small increases in intensity above this point revealed a second level (0.9 log units higher) at which visual noise appeared minimized, and further increases in intensity revealed no further improvement in perceived image quality. This point also corresponded to a screen luminance of 0.01 cd/m^2 , and was used as the full moon simulation.

Flicker sensitivity was measured at a distance of 40 cm from the monitor to the halfway point of the NVG tube. At this distance, the monitor screen filled the NVG field-of-view and stabilized the brightness control mechanism. Using a smaller stimulus field would have made the luminance of the intensified image abnormally high. All measurements were performed monocularly using the subject's right eye and the right tube of a binocular NVG mounted on a table. The left tube was occluded. Except for the monitor, all sources of illumination were extinguished, and the monitor intensity was controlled by placing the ND filters in a filter holder directly against the objective side of the NVG. After 2 min of adaptation to the lowest light level, each subject was tested with an ascending order of night sky illumination and temporal frequencies. On each trial the subject reported the numbers of the letters that appeared to flicker, and also judged whether threshold appeared to lie between two steps in displayed contrast. The lowest contrast seen to flicker was recorded as threshold to the nearest 0.12 log units. The next highest night sky illumination was then presented, and the sequence of five temporal frequencies was repeated until responses were obtained for each of the four night sky conditions. Six subjects (ages 22–37) with normal vision and visual acuity corrected to 20/20 participated in this study.

In separate sessions measurements were obtained from the same subjects with a stimulus that simulated the NVG display at each night sky condition (same luminance and green color). The same seven-letter array was used, but modulated in contrast using only the green gun of the color monitor (P22 phosphor) to simulate the green phosphor (P20) of the NVG display. The display luminance used for each simulated night sky condition was determined by measuring the luminance of the NVG display in response to full field stimulation with each night sky condition (0, 1, 2, and 3 log ND attenuation relative to full moon). Flicker sensitivity was measured on each subject under these simulated conditions in the same manner described for the NVG measurements.

RESULTS

In this study flicker sensitivity was measured as a function of flicker frequency, night sky, and viewing condition (NVG or simulation). A repeated measures

three-way ANOVA revealed significant main effects of flicker frequency ($F_{4,100} = 217, p < 0.0001$), night sky ($F_{3,100} = 310, p < 0.0001$), and viewing condition ($F_{1,100} = 268, p < 0.0001$). The results through NVG's will be considered initially, followed by a comparison of NVG and simulation conditions. A multiple regression model to predict NVG flicker sensitivity from flicker frequency and night sky will then be presented.

Flicker Sensitivity Through NVG's

Fig. 1 shows mean ($\pm 1 \text{ SE}$) log flicker sensitivity through NVG's plotted against stimulus flicker frequency. Values are shown separately for each simulated night sky condition encompassing a 3 log unit range of stimulation. Flicker sensitivity is relatively constant at low and moderate frequencies, but declines at higher frequencies. While sensitivity to flicker is often reduced at both high and low flicker rates (1,6), Kelly (2) found no loss of sensitivity at low frequencies when measured with a moderate stimulus size, as was done in the present study. It is also possible that higher harmonics in the square-wave, flicker stimulus enhanced sensitivity at lower rates of flicker.

Fig. 1 also illustrates that, like visual acuity (3,4,7) and spatial contrast sensitivity (8), flicker sensitivity through NVG's declines with decreasing night sky illumination. This reduction includes the entire range of flicker frequencies, but increases somewhat at higher rates of flicker. Although each night sky condition (full moon to overcast) represents about 1 log unit decrement in stimulation, sensitivity declines in progressively larger decrements with each drop in night sky. This probably reflects the combined effects of lower display luminance and increased electro-optical noise.

Comparison of NVG and Simulated NVG Conditions

The reduction in NVG flicker sensitivity with decreasing night sky illumination could be due to a reduction in display luminance, contrast, or some combination of these factors. To explore this issue, sensitivity through NVG's was compared to that obtained without the device but at the same display luminance and similar color (simulation). Thus, any difference between these two measurements reflects attenuation of sensitivity through NVG's which is unrelated to the luminance of

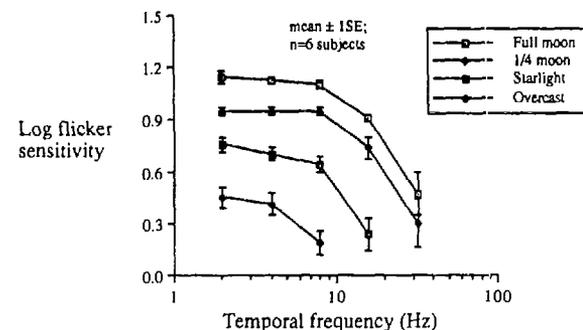


Fig. 1. Mean ($\pm 1 \text{ SE}$) log flicker sensitivity through NVG's is plotted against stimulus temporal frequency for each night sky condition.

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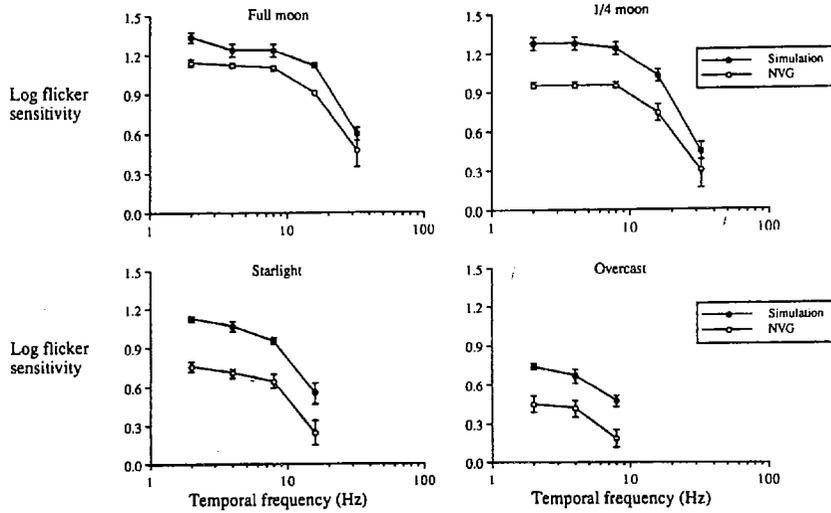


Fig. 2. Mean (± 1 SE) log flicker sensitivity is plotted against temporal frequency for measurements made through NVG's and without NVG's, but at the same display luminance and similar color (simulation). Separate plots are shown for each night sky condition.

the display. Fig. 2 shows mean sensitivity for NVG and simulation conditions plotted against temporal frequency for each night sky. It is clear that sensitivity through NVG's is reduced relative to the simulation at each night sky ($F = 310, p < 0.0001$). Because luminance was the same in the two conditions, other factors, such as contrast reduction from electro-optical noise, are responsible for this reduction in flicker sensitivity.

If dynamic noise limits flicker sensitivity through NVG's, then this effect could vary with stimulus flicker frequency. However, the data in Fig. 2 suggest that the reduction in sensitivity is essentially constant across the range of frequencies tested. This is exemplified in Fig. 3, which shows the NVG mean data (unfilled circles) shifted upward by the difference in sensitivity (simulation - NVG) at the lowest frequency tested. All data conform better to common functions when corrected for this sensitivity difference at the lowest flicker frequency. Thus, attenuation of flicker sensitivity from contrast loss through NVG's is largely independent of stimulus flicker frequency.

While contrast reduction from electrical noise or op-

tics affects flicker sensitivity through NVG's, the luminance of the display can also influence sensitivity. This follows from the fact that sensitivity declines with night sky in the simulated condition in which the only factor varied was luminance. Fig. 4 illustrates the relative contribution of luminance and contrast to the reduction in flicker sensitivity with night sky. Mean sensitivity, averaged across all flicker frequencies, is plotted against night sky level. The reduction in sensitivity due to luminance is demonstrated in the simulated condition, while additional sensitivity loss, presumably from contrast attenuation, is indicated by the separation between NVG and simulation curves. Note that the influence of contrast and luminance attenuation vary with light level. The effect of luminance is more detrimental at very low ambient levels, while contrast loss has a greater effect from full moon to starlight levels.

Prediction of NVG Flicker Sensitivity

To place the results in a more applied context, a multiple regression model was derived to predict NVG

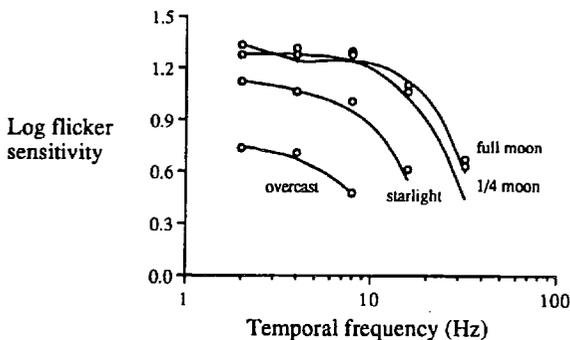


Fig. 3. Log flicker sensitivity is plotted against temporal frequency. The solid curves are interpolated fits to the mean data for the simulation condition. The unfilled symbols are NVG mean data corrected (shifted upward) for the difference in sensitivity (simulation - NVG) at the lowest frequency tested (2 Hz).

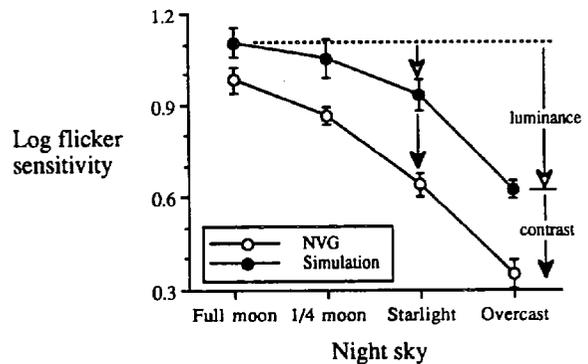


Fig. 4. Mean (± 1 SE) log flicker sensitivity, averaged across all frequencies, is plotted against night sky for NVG and simulation conditions. The vertical arrows indicate attenuating effects of luminance and contrast.

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flicker sensitivity from temporal frequency and night sky for frequencies ≥ 4 Hz. Night sky illumination was used as a quantitative independent variable by assigning each level a value of 0, 1, 2, or 3 corresponding to full moon, $\frac{1}{4}$ moon, starlight, and overcast conditions, respectively. The multiple regression formula derived from these data can be used to estimate flicker sensitivity from temporal frequency and night sky condition:

$$\log \text{ NVG flicker sensitivity} = 1.38 - 0.03(\text{TF}) - 0.31(\text{NS})$$

where TF is temporal frequency (Hz) and NS is night sky illumination (full moon = 0, $\frac{1}{4}$ moon = 1, starlight = 2, overcast = 3). This relation is statistically significant ($F = 217.39$, $p < 0.0001$) accounting for 85% of the variability in NVG temporal contrast sensitivity over a range of ambient stimulation ($r^2 = 0.85$). It is emphasized, however, that night sky illuminations used in this study only approximate real-world conditions.

DISCUSSION

This study illustrates the profile of flicker sensitivity through NVG's. As reported previously (2,6), flicker sensitivity declines at frequencies greater than 10 Hz. Under optimal stimulus conditions, the maximum rate of flicker detected through NVG's was only slightly less than the frequency detected without the device, but presented at the same luminance. Thus, with optimal stimulation, NVG's do not significantly limit one's ability to detect high rates of flicker.

A reduction in night sky illumination produced a decrease in flicker sensitivity through NVG's over a range of flicker rates. This decline in sensitivity was slightly greater at higher flicker rates, and became larger as night sky illumination was reduced. The transition from full moon to starlight produced a two-fold reduction in maximum detectable flicker rate (44 Hz to 19 Hz), and a four-fold reduction in flicker sensitivity. This indicates that the contrast of a flickering target which is just de-

tectable through NVG's under full moon illumination would have to be increased 4 \times for the flicker to be detected under starlight. The regression equation derived from our findings estimates NVG flicker sensitivity from flicker frequency and night sky. Field measurements will be needed to substantiate the accuracy of this equation.

A comparison of NVG flicker sensitivity to measures obtained without NVG's, but at the same display luminance, revealed differences which diminished after correction at the lowest rate of flicker. This indicated that NVG's attenuate contrast per se, but have no adverse effect on the transfer of specific temporal frequencies. Effects of lower display luminance on sensitivity were also noted. Future designs which increase the transfer of static contrast and luminance through NVG's should also improve dynamic visual performance.

REFERENCES

1. De Valois RL, De Valois KK. Spatial vision. New York: Oxford University Press, 1988.
2. Kelly DH. Spatio-temporal frequency characteristics of color-vision mechanisms. *J. Opt. Soc. Am.* 1974; 64:983-9.
3. Kotulak JC, Rash CE. Visual acuity with second and third generation night vision goggles obtained from a new method of night sky simulation across a wide range of target contrasts. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. 1992; USAARL Report No. 92-9.
4. Levine RR, Rash CE. Attenuating the output of the AN/PVS-5A night vision goggles and its effects on visual acuity. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. 1989; USAARL Report No. 89-24.
5. RCA Electro-Optics Handbook. Electro-optics handbook technical series EOH-11. Lancaster: RCA Corp., 1974.
6. Robson JG. Spatial and temporal contrast sensitivity functions of the human visual system. *J. Opt. Soc. Am.* 1966; 56:1141-2.
7. Wiley RW. Visual acuity and stereopsis with night vision goggles. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. 1989; USAARL Report No. 89-9.
8. Wiley RW, Holly FF. Vision with the AN/PVS-5 night vision goggle. (Agardograph) Neuilly-sur-Seine, France: AGARD, 1976; 191:C7.1-C.12.