USAARL Report No. 94-17

Vernier Acuity Through Night Vision Goggles

(Reprint)

By

Jeff Rabin

Aircrew Health and Performance Division

April 1994

U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release; distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
USAARL Report No. 94-17

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
U.S. Army Aeromedical Research Laboratory

6b. OFFICE SYMBOL *(If applicable)*
SGRD-UAS-VS

7a. NAME OF MONITORING ORGANIZATION
U.S. Army Medical Research Development, Acquisition and Logistics Command (Provisional)

6c. ADDRESS *(City, State, and ZIP Code)*
P.O. Box 620577
Ft. Rucker, AL 36362-0577

7b. ADDRESS *(City, State, and ZIP Code)*
Fort Detrick
Frederick, MD 21702-5012

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)*

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62787A	3016278 7A879	PE	164

11. TITLE *(Include Security Classification)*
Vernier Acuity through Night Vision Goggles

12. PERSONAL AUTHOR(S)
Jeff Rabin

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM ________ TO ______

14. DATE OF REPORT *(Year, Month, Day)*
1994 April

15. PAGE COUNT
3

16. SUPPLEMENTARY NOTATION
Printed in Optometry and Vision Science, April 1993, Pages 689-691.

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
17	05	
09	01	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Night vision goggles, image intensifiers, vernier acuity, contrast sensitivity

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Night vision goggles (NVG) are being used increasingly in military and civilian environments. Despite the use of these devices, relatively few tests exist to assess visual performance through NVGs. Hyperacuity tasks may provide a sensitive index of performance through night vision devices. In this study, grating vernier acuity was measured through NVGs. As reported previously, a power law relation was observed between vernier acuity and stimulus contrast. Comparison of vernier acuity with and without NVGs indicated that performance is limited by the contrast transfer of the device. Vernier acuity measurements can be used to assess the quality of vision and quantity of contrast transferred through night vision devices.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Chief, Scientific Information Center

22b. TELEPHONE *(Include Area Code)*
(205) 255-6907

22c. OFFICE SYMBOL
SGRD-UAX-SI

DD Form 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

1040-5488/93/7008-0689$03.00/0
OPTOMETRY AND VISION SCIENCE

Vol. 70, No. 8, pp. 689–691

instruments/techniques

Vernier Acuity through Night Vision Goggles

JEFF RABIN*
U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama

ABSTRACT

Night vision goggles (NVG's) are being used increasingly in military and civilian environments. Despite the use of these devices, relatively few tests exist to assess visual performance through NVG's. Hyperacuity tasks may provide a sensitive index of performance through night vision devices. In this study, grating vernier acuity was measured through NVG's. As reported previously, a power law relation was observed between vernier acuity and stimulus contrast. Comparison of vernier acuity with and without NVG's indicated that performance is limited by the contrast transfer of the device. Vernier acuity measurements can be used to assess the quality of vision and quantity of contrast transferred through night vision devices.

Key Words: night vision goggles, image intensifiers, vernier acuity, contrast sensitivity

Military operations are often conducted at night or under conditions of limited visibility. These operations require high levels of performance in environments lacking sufficient ambient illumination to support normal visual function. Image intensifying devices [night vision goggles (NVG's)] amplify ambient illumination, making performance possible under extreme and limited conditions. Despite their usefulness NVG's present a view of the world that is isochromatic and lacking in contrast and detail. It is essential to understand factors which limit vision through NVG's so that performance can be anticipated under various conditions.

Several techniques have been used to assess visual performance of NVG's such as visual acuity, contrast sensitivity, and stereopsis.[1–4] Another approach for evaluating vision through NVG's is vernier acuity—the precision with which two targets can be aligned. Like stereopsis, vernier acuity is a type of "hyperacuity" because, under optimal conditions, it is better than the acuity predicted from the separation between photoreceptors.[5] Research has shown that vernier acuity depends on stimulus contrast.[6–9] Because NVG display contrast is difficult to measure and varies with ambient conditions, evaluation of the contrast dependency of vernier acuity offers an adjunctive approach for assessing the effective contrast to the observer.

In the present study, vernier acuity was measured through third-generation NVG's. The red phosphor of a color monitor was used to stimulate the NVG's which have peak spectral sensitivity in the near infrared. Vernier acuity was assessed over a range of stimulus contrasts to characterize the contrast dependency of the response. Measurements were also obtained without the NVG, but at the same display luminance to estimate contrast transfer through the device.

METHODS

The stimulus for testing NVG's was generated on a high-resolution color monitor. Only the red gun of the phosphor was used to limit the spectral composition of the stimulus to the spectral range of NVG's. Although NVG's have peak sensitivity in the near infrared (750 nm), little infrared radiation is emitted by the red gun so its output between 600 to 720 nm forms the primary stimulus. Because the shape of the phosphor spectral output function remains constant with software-controlled changes in monitor intensity, it was possible to introduce accurate changes in contrast to the NVG by varying the red gun intensity in known steps. Neutral density (ND) filters were used to reduce the overall monitor luminance to a value estimated to be between one-quarter moon and starlight conditions.[10] This level was used because it corresponds to a moderate level of stimulation to NVG's and is below the intensity level which activates the NVG automatic brightness control. This made it possible to test at an extended viewing distance without any change in display luminance imposed by the brightness control.

The stimulus for vernier acuity was a 1.4° circular patch of vertical, square-wave grating with a spatial frequency of 6 cpd surrounded by a uniform field of the same mean luminance. This spatial frequency

Received November 24, 1992; revision received April 5, 1993.
*O.D., Ph.D.

was chosen because it is associated with good vernier acuity[8] and is within the spatial bandpass of the NVG for the light level used.[4] In addition, the spatial frequency was high enough to make the effects of higher harmonics in the square-wave stimulus negligible. The top half of the grating was fixed in spatial phase; the horizontal position of the bottom half was adjustable in pixel steps by keyboard control. The subject viewed the grating monocularly with the right eye at a distance of 4.8 m. The method of adjustment was used in which the subject depressed keyboard buttons to shift the bottom half of the grating left or right until it appeared aligned with the top half. After 3 min of adaptation to the mean luminance of the NVG display, 10 alignment settings were made at each of 5 Michelson contrasts ranging from 4 to 66% in 0.3 log unit steps. The contrasts were presented in ascending order to reduce successive adaptation effects. For each contrast the standard deviation of 10 settings was used as the vernier threshold.

In separate sessions, measurements were obtained from the same subjects with a simulation of the NVG display. The same grating stimulus was used, but modulated in contrast using the green gun of the monitor to simulate the green phosphor (P20) of the NVG display. ND filters were used to reduce the monitor luminance to the NVG display luminance used in this study (0.4 ft-L). The same procedures were used as described for the NVG measurements to obtain vernier thresholds for each of the five grating contrasts.

Five subjects participated in this study. Each subject was male, 21 to 22 years of age, and had no refractive error with visual acuities of 6/6 (20/20).

RESULTS

Fig. 1 shows mean (±1 SE) vernier acuity from five subjects plotted against stimulus contrast for NVG and simulated NVG conditions. The NVG test was conducted through the device, whereas the simulation indicates performance without the device, but at the same display luminance and color. In both viewing conditions, vernier acuity improved with stimulus contrast. Although display luminance and color were the same in the two conditions, vernier acuity was consistently reduced when viewing through NVG's (mean decrement = 2.7×). This difference between NVG and simulated conditions, and the improvement in vernier acuity with contrast were statistically significant effects (Friedman two-way analysis of variance; $\chi^2 = 8.0$, $p < 0.005$).

Previous studies reported a power law relation between vernier acuity and contrast.[6-8] The results shown in Fig. 1a are also best described by power law functions with exponents of −0.81 for the NVG condition ($r^2 = 0.92$), and −0.73 for the simulated condition ($r^2 = 0.93$). These values are comparable to those reported in previous studies, and indicate that a 10-fold reduction in contrast will produce a 5 to 7× reduction in vernier performance through NVG's.

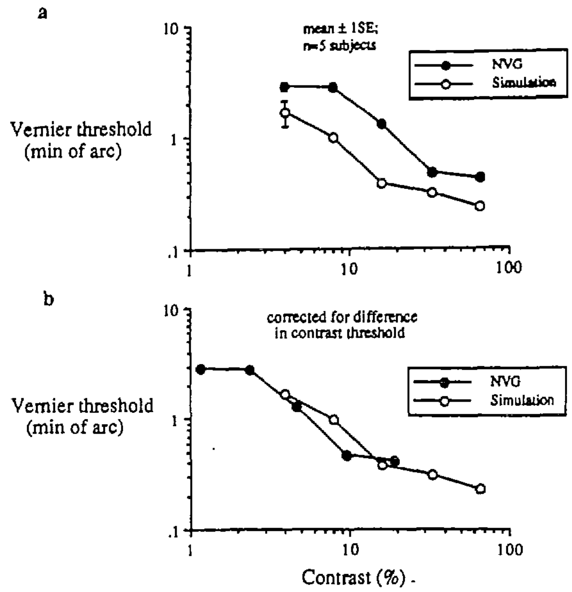

Figure 1. Mean (±1 SE) vernier thresholds from five subjects are plotted against stimulus contrast for NVG and simulated-NVG conditions (a). The same data are plotted in (b), but corrected for the difference in contrast thresholds. This was done by shifting the NVG data leftward along the contrast axis by a factor of 3.4×—the ratio of NVG/simulation detection thresholds.

The fact that vernier acuity was 2 to 3× better in the simulated condition indicates that performance through the NVG was limited by electro-optical properties of the device. This limitation could not be attributed to the luminance or color of the display because they were matched in the two conditions. It is also unlikely that resolution limited performance because the spatial frequency used was lower than the resolution limit of both the NVG and the human visual system. It is more likely that the effective contrast to the observer was attenuated through the NVG, perhaps because of the addition of electro-optical noise. Correction for this contrast reduction should lessen the difference in vernier acuity between NVG and simulated-NVG conditions. Fig. 1b shows mean vernier acuities corrected for the difference in contrast threshold with and without the NVG. All values conform to a common function when corrected for this contrast difference—a factor of 3.4×. Recent studies have also shown that differences in vernier acuity across mechanisms (e.g., luminance vs. color) diminish when contrast is scaled relative to detection threshold.[9, 11] These findings underscore the fundamental importance of system modulation transfer functions for explaining and predicting visual performance.

DISCUSSION

This study quantified vernier performance through NVG's. As shown in previous studies,[6-8] a power law relation was observed between vernier acuity and stimulus contrast. The exponent of this relation (−0.8) was about the same as that reported by Bradley and Skottun[8] using a similar grating stimulus. The dependency of vernier acuity on contrast indicates that stimulus conditions or device factors which reduce contrast through NVG's will impair vernier alignment performance (e.g., targeting tasks). Design features which mitigate against contrast loss are essential for optimal alignment performance through NVG's.

A comparison of vernier acuity through NVG's to measurements obtained without the device but at the same luminance and color revealed substantial differences in vernier acuity. Vernier thresholds through NVG's were an average of 2 to 3× higher than values obtained under comparable conditions of luminance and chromaticity. This reduction in vernier acuity could not be attributed to the brightness, color, or resolution of the NVG display, but could be explained by the difference in contrast sensitivity with and without the NVG. The difference in vernier performance between real and simulated conditions was essentially eliminated by correcting stimulus contrast for threshold differences with and without the NVG device.

Current military standards for image intensifiers include requirements for resolution, gain, and distortion. Vernier acuity offers an additional metric for grading the quality and quantity of vision through NVG's. Subtle distortion or contrast attenuation which may elude detection by standard techniques could reduce vernier acuity through NVG's. This approach will prove useful in the future assessment of night vision devices.

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AUTHOR'S ADDRESS:

Jeff Rabin
U.S. Army Aeromedical Research Laboratory
Attn: SGRD-UAS-VS (MAJ Rabin)
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