USAARL Report No. 89-16

Visual Acuity with AN/PVS-5A Night Vision Goggles and Simulated Flashblindness Protective Lenses Under Varying Levels of Brightness and Contrast

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July 1989

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United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-5292

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Field	Entry
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. 89-16
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 and Development Command
6c. ADDRESS (City, State, and ZIP Code)	Fort Rucker, AL 36362-5292
7b. ADDRESS (City, State, and ZIP Code)	Fort Detrick Frederick, MD 21701-5012
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	3E162787A879	BG	164

11. TITLE (Include Security Classification) Visual Acuity with AN/PVS-5A Night Vision Goggles and Simulated Flashblindness Protective Lenses Under Varying Levels of Brightness and Contrast

12. PERSONAL AUTHOR(S) Levine, Richard R. and Rash, Clarence E.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
	FROM ____ TO ____	1989 July	18

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
20	06	
23	02	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
PLZT, nuclear flashblindness protection, aircrew eye protection, visual acuity effects

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
Flashblindness protection from tactical nuclear weapons is an issue of current concern in Army aviation. As a countermeasure, the Army is considering incorporating PLZT goggles/material into the overall design of the Aircrew Integrated Helmet System currently under development. Because present generation flashblindness materials permit about 20 percent light transmission in the open state (about the same as the aviator's sunglasses), flying with PLZT under normal daylight conditions is not expected to impact aviator visual performance adversely. For night missions, PLZT would be used in conjunction with image intensification systems (e.g., night vision goggles [NVGs]). Placing PLZT between the NVG and the eyes would leave the sensitivity of the goggle to environmental lighting unaffected; however, the light available to the eyes from the NVG would be reduced by 80 percent. Because reduction of light from the NVG could further degrade acuity (at best, 20/50-20/60 with NVGs), a

Continued

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Chief, Scientific Information Center	(205) 255-6907	SGRD-UAX-SI

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. Abstract (Continued)
study was performed to determine the effects on visual acuity following an 80 percent reduction in goggle luminous output (e.g., from wearing PLZT in its open state). The results of the study demonstrate that visual acuity with NVGs varies as a function of both ambient illumination and target contrast. However, there were no signficant differences in acuity attributable to an 80 percent reduction in NVG output. While these results are encouraging, additional operational testing is required before deciding to incorporate PLZT or any other flashblindness protective material into the aviator's HGU-56/P.

Acknowledgments

Appreciation is expressed to SPC Vincent Reynoso and SGTs Jim Bohling and Kim Ray for providing expert technical assistance in the collection of data. We also thank SSG John S. Martin for his programming assistance and Dr. Isaac Behar for his professional advice and consultative support. Finally, we thank the participants of the study who sat patiently through the hours of testing while maintaining their vigilance throughout.

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Table of contents

List of figures

Introduction

Flashblindness protection from tactical nuclear weapons is an issue of current concern in Army aviation. The U.S. Air Force, as a means of protection, provides its crewmembers with PLZT goggles (Richey, Bower, and Allen, 1980). PLZT is an electro-optical ceramic material made from lead (P), lanthium (L), zirconium (Z), and titanate (T). When placed between a pair of crossed polarizers and provided with a low voltage source, this material can rotate the linearly polarized light transmitted from the first polarizer and pass it through the second -- thus enabling the pilot to see out. However, should the goggles' photosensors detect a sudden change in light intensity (e.g., from a nuclear flash), the voltage to the lenses is reduced/ removed, and within 150 microseconds the system becomes nearly opaque (optical density > 4.0 [Lindsey, 1988]). This "closed" condition protects the aviator during the peak brightness levels associated with the blast-induced flash. Recovery of the material occurs in conjunction with the dissipation of the light source or with the wearer's head (and sensor) facing in a direction away from the source of bright light.

The Army is considering incorporating PLZT goggles/material into the overall design of the Aircrew Integrated Helmet System (HGU-56/P) currently under development. Tactical doctrine would require rotary-wing pilots to don flashblindness protection in areas of possible or expected tactical (i.e., relatively low-yield) nuclear attack. Because current generation flashblindness goggles permit about 20 percent light transmission in their open state (about the same as the current aviator's sunglasses), flying with PLZT under daylight conditions, in the absence of nuclear blast, is not expected to impact aviator visual performance adversely. However, significant decrements in visual performance have been reported during night flights with PLZT (McLean and Rash, 1985) and the ability to pilot rotary-wing aircraft with the material in its closed state, even for short periods, is as yet unknown.

For night missions, PLZT would be used in conjunction with image intensification (I^2) systems. While enhancing visual input under low-light conditions, I^2 systems (e.g., AN/PVS-5 night vision goggles [NVGs]) inherently compromise visual function. NVGs, for example, provide "best" Snellen acuities of only 20/50-20/60. In addition, they restrict field-of-view to approximately 40 degrees, eliminate color cues by presenting a monochromatic (green) image, and degrade depth discrimination at ranges beyond 500 feet (Wiley et al., 1976).

Placing PLZT between an I^2 system such as the NVGs and the eye will leave the sensitivity of the goggles to environmental lighting unaffected. In addition, because PLZT's spectral density is relatively flat over the visible spectrum (Richey, Bower, and Allen, 1980), wearing PLZT (in its open state) should not degrade prevailing color vision. (PLZT's effects on field-of-view and depth-of-field will depend on its physical compatibility with the NVGs.) However, PLZT will reduce the light available from the NVGs to the eye, and these reductions in the already low photopic or mesopic levels of light characteristic of normal NVG output could affect visual acuity adversely.

The Directorate of Combat Developments (DCD), U.S. Army Aviation Center, Fort Rucker, Alabama, requested that the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, evaluate the effects of tandem NVG-PLZT wear on visual function (Appendix A). Additional dialogue with DCD representatives determined that their immediate data needs centered around possible additional visual acuity losses using NVGs with PLZT in its open state. In response to DCD's request, an experiment was performed to determine the effects on visual acuity using NVGs with and without an 80 percent loss of luminous transmission (characteristic of PLZT in its open state) between the NVGs and the eye.

Methods

Subjects: Eight volunteers, seven military and one civilian ranging in age from 22-37, participated in the study. All but one participant had 20/20 or better Snellen acuity without correction; one myopic subject was corrected to 20/20 with contact lenses. All subjects were familiar with the experimental procedures and had prior experience in acuity testing with NVGs.

Apparatus: Subjects were seated in a darkened room 20 feet from a 12" monochrome CRT monitor. (The spectral distribution of the monitor's P-4 phosphor was compatible with the energy sensitivity of the NVGs.) Subjects viewed the CRT through a single pair of AN/PVS-5A night vision goggles mounted on a table in front of the subject (Figure 1). Both the height and the inter-pupillary distance of the NVGs were adjusted individually for each subject. PLZT was simulated using a pair of Kodak Wratten No. 96 neutral density filters*, each having a measured transmittance of approximately 20 percent. The filters were placed in specially constructed rings which attached directly

* See Appendix C

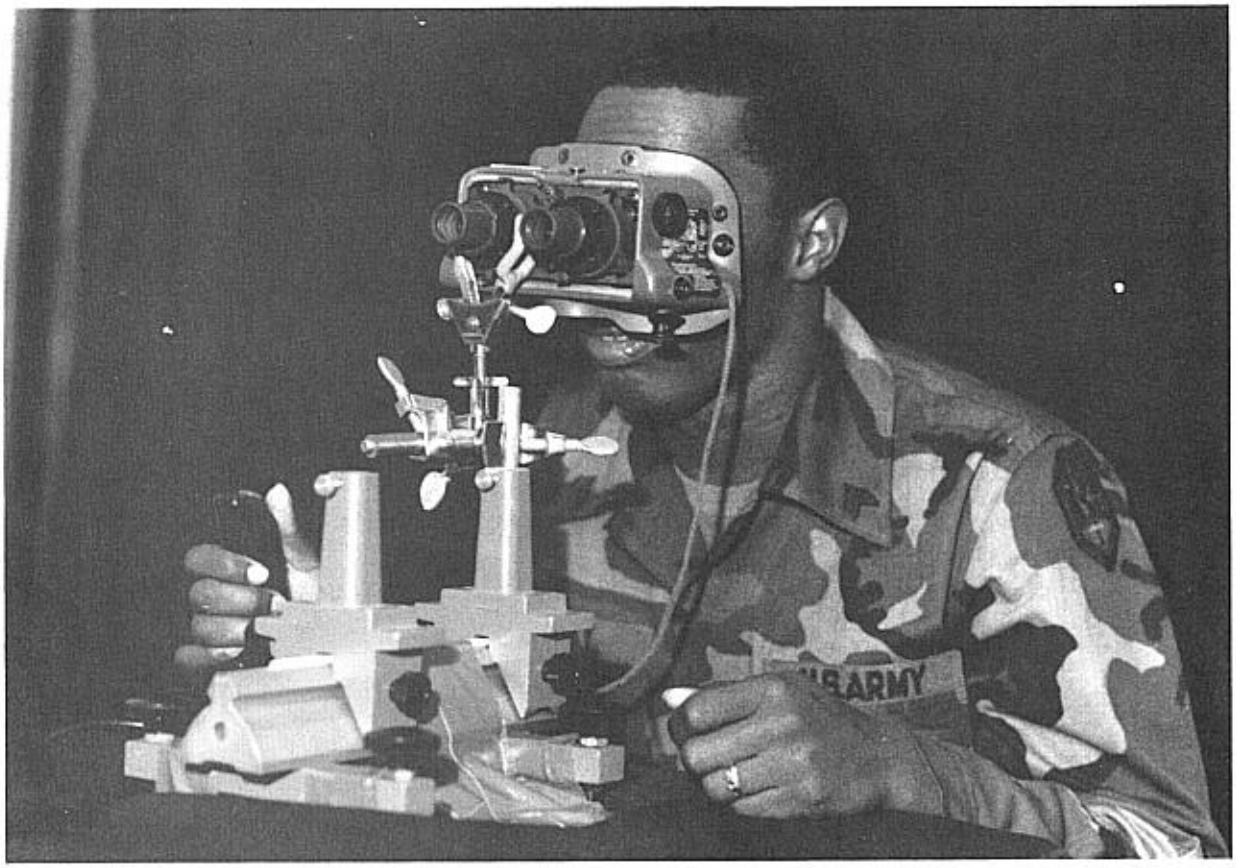

Figure 1. Subject viewing the monitor through the mounted AN/PVS-5A night vision goggles.

onto the oculars of the NVGs (Figure 2). The filters were attached or removed according to a quasi-random schedule of viewing conditions (see below).

<u>Viewing Conditions</u>:

Background CRT luminance - Background CRT luminances were measured with a Pritchard 1980-A spot photometer* and adjusted to simulate ambient light levels associated with twilight (approximately 1/2 hour past sunset), full moon, or starlight (moonless night; RCA Electro-Optics Handbook, 1974). The monitor display served as the only source of light in the room.

Target/background contrast level - Three contrast ratios (target and background grey levels) -- 90, 30, and 3 percent -- were selected to represent conditions of high, moderate, and low target/background contrast. (Contrast was defined as [target brightness - background brightness]/[target brightness + background brightness]). The target always appeared darker than its surround (Figure 3).

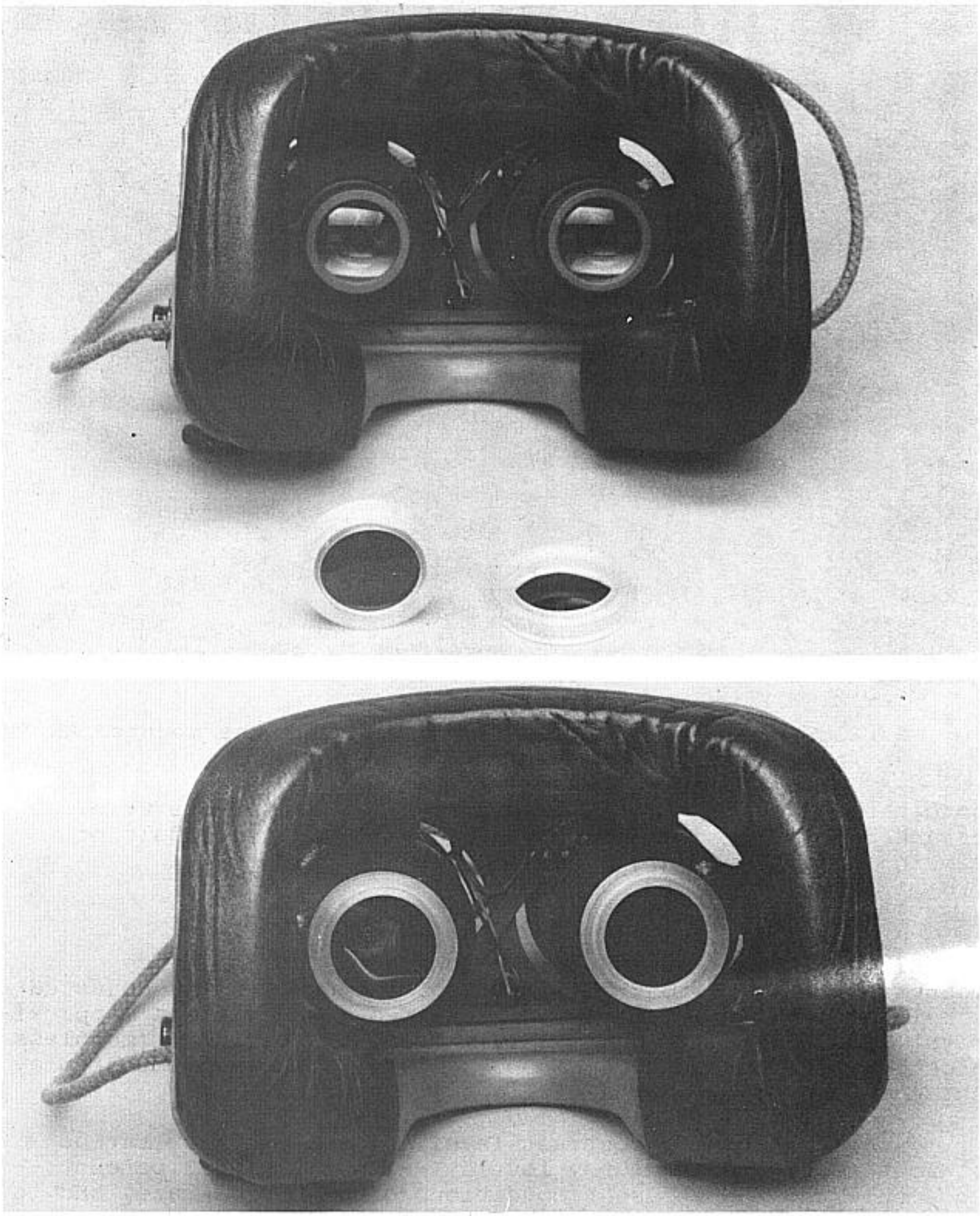

Figure 2. Filter rings unmounted (top) and mounted (bottom) onto the AN/PVS-5A oculars.

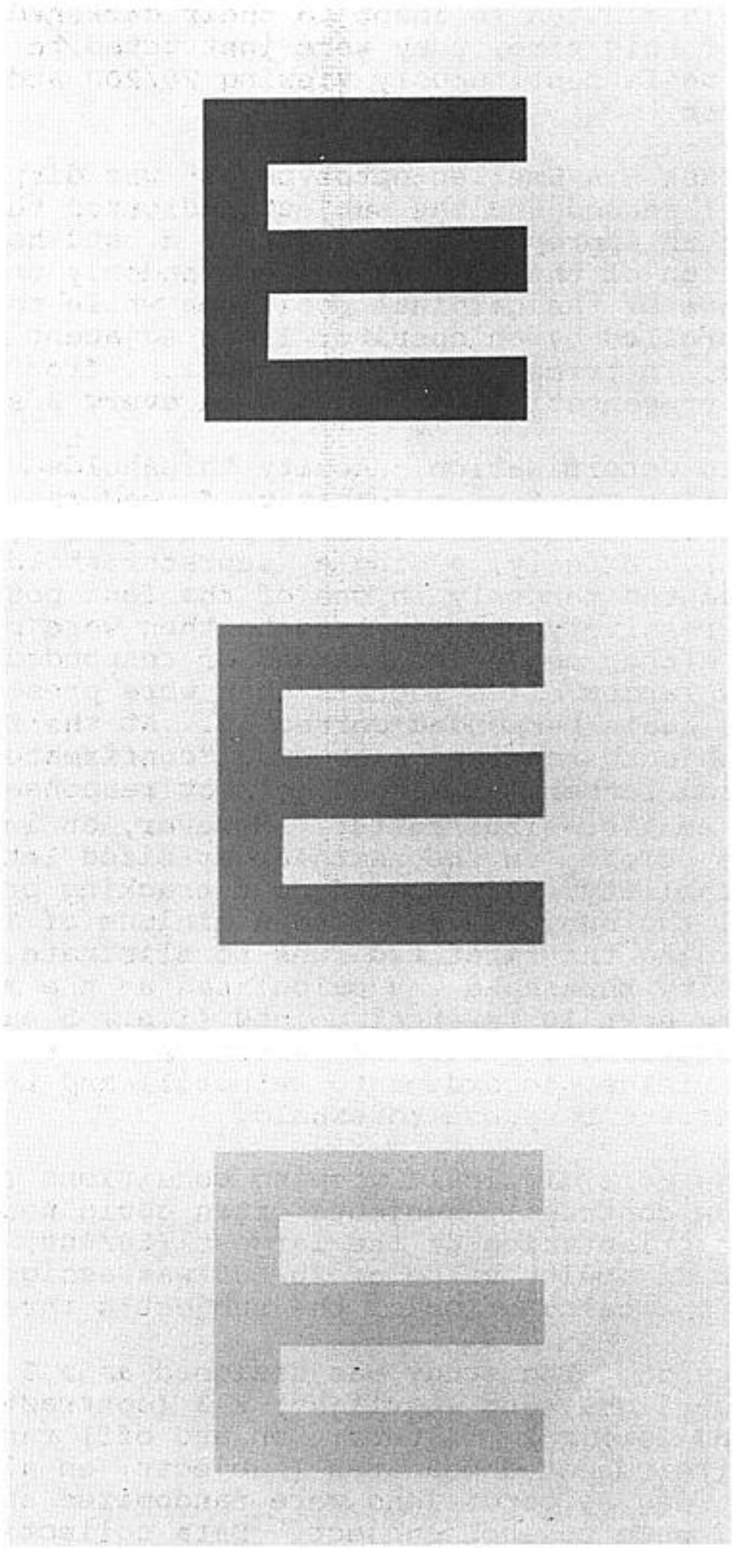

Figure 3. Examples of Snellen Es at contrasts of 90 percent (top), (top), 30 percent (middle), and 3 percent (bottom).

Procedures: Subjects were briefed on their required task and permitted 5-10 minutes to adapt to their darkened surroundings. At the end of this time, they were instructed to focus the tubes of the NVGs while continuously viewing 20/200 and 20/60 targets on the monitor.

Acuity task - A Snellen optotype "E" was displayed on the monitor for 1 second and the subject indicated the orientation of the "E" with an appropriate movement of a hand-held joystick. The orientation of the "E" was varied randomly under computer control in one of the cardinal positions while the size of the "E" was controlled by an operator in an adjacent room. Letter sizes ranged, in terms of Snellen notation, from 20/10 to 20/400. The rate of presentation was about once every 3 seconds.

Threshold determination - Acuity thresholds were determined by incorporating the four-alternative forced-choice procedure into a Wetherill threshold tracking paradigm (Wetherill and Levitt, 1965). Briefly, a single, suprathreshold (e.g., 20/400), "E" was presented randomly in one of the four possible orientations. Progressively smaller targets then were presented until the subject either ceased to respond or responded incorrectly. Increasingly larger-sized letters then were presented until the subject once again responded correctly. At the first correct response, subjects received a second, "confirmatory" trial with the same-sized letter. A second correct response then resulted in the next smaller-sized letter. However, an incorrect response resulted, as before, in the next larger-sized letter. To ensure threshold stability, this up-and-down tracking procedure continued until the subject exhibited a minimum of 12 reversals. After discarding the first two runs to eliminate start-up effects, acuity threshold was calculated as the mean of the values at the next 10 reversal points (i.e., 5 each, maxima and minima). Requiring two correct responses before reducing the target size yields, according to Wetherill and Levitt, the subject's 70 percent response threshold.

Under the more difficult viewing conditions (e.g., starlight and low contrast), subjects often could not correctly identify the orientation of the largest (20/400) letter. On those trials an acuity value of 20/600 was assigned arbitrarily and used in the calculation of the subject's threshold.

Study design: The study was designed as a 3 (brightness: twilight, moonlight, and starlight) x 3 (contrast: high, moderate, and low) x 2 (filters: on and off) randomized factorial with repeated measures (subjects) on all factors. The 18 possible viewing conditions were randomized and presented exhaustively once to each subject. Data collection was accomplished in three sessions for each subject, with each experimental session lasting about 1 hour.

Results

Figures 4-6 display mean acuities for each contrast level at each level of background illumination. Acuities with NVGs both with and without filters are compared for each light and contrast level condition. The thin vertical bars atop the thicker bars represent the standard deviations of the group means (displayed unidirectionally for clarity of presentation). Acuity is shown both in terms of minimum angle of resolution and its associated Snellen value. (Appendix B presents the same data in a tabular format.)

As can be seen, mean acuities ranged from 20/50 under the most favorable viewing condition (twilight and high contrast) to greater than 20/400 under the poorest. However, from the point of view of the present study, inspection of the data reveals no significant differences in acuity between the "filter" and "no filter" conditions at any combination of brightness and contrast. Thus, over the range of conditions examined, decrements in acuity

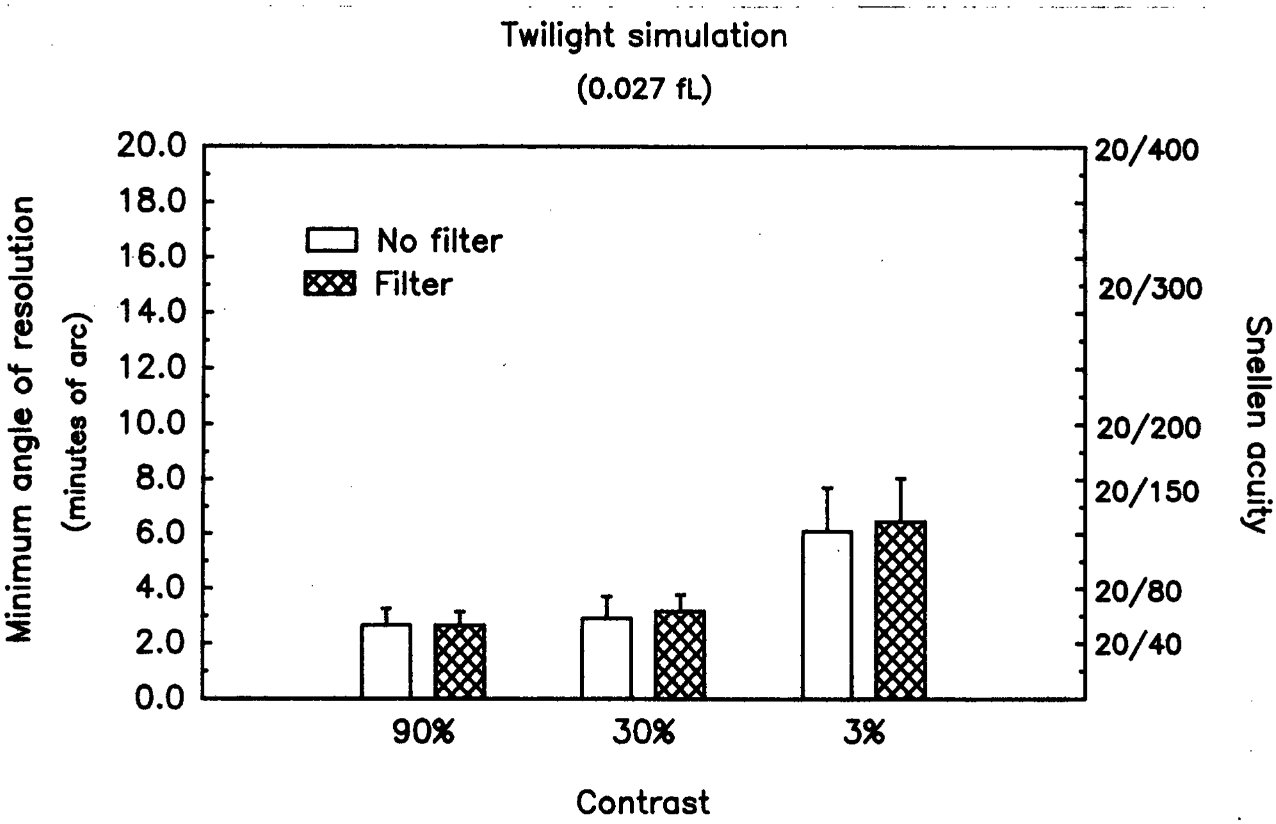

Figure 4. Mean acuities at high, moderate, and low levels of contrast under simulated twilight lighting conditions.

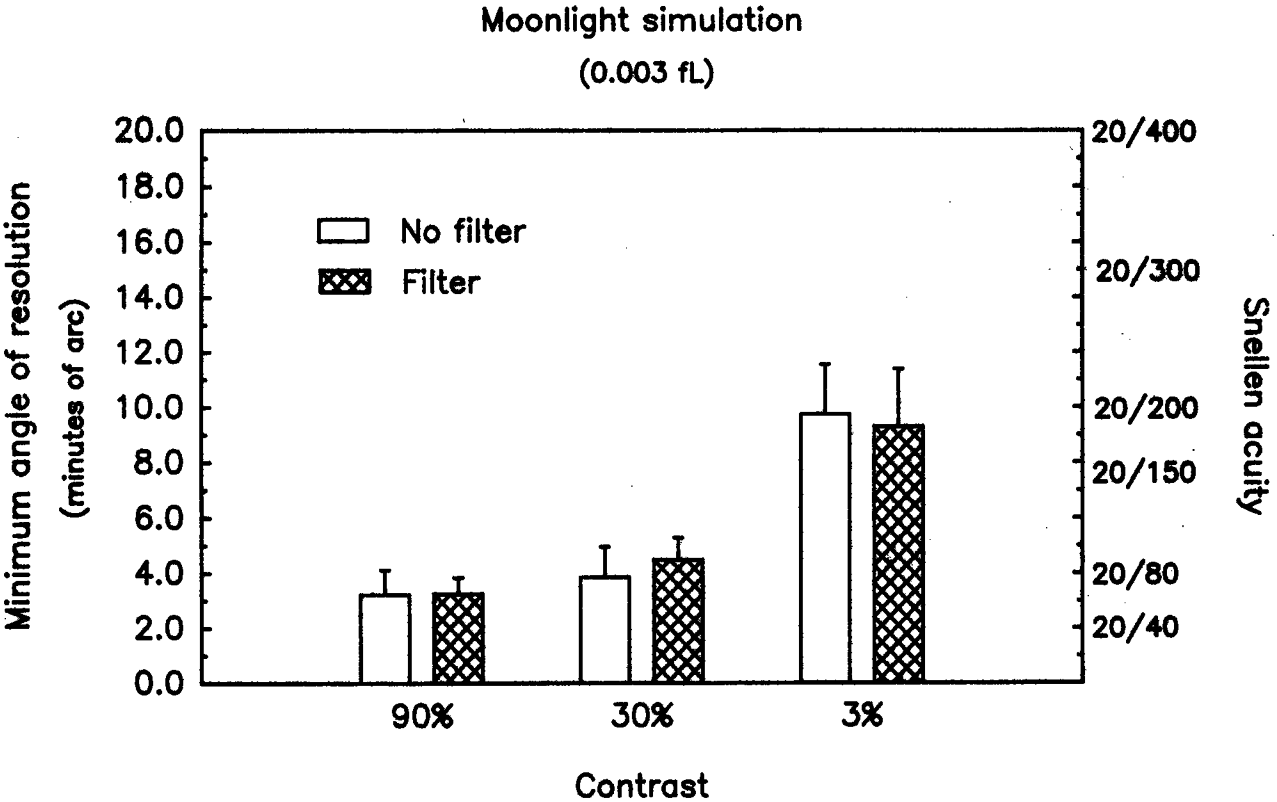

Figure 5. Mean acuities at high, moderate, and low levels of contrast under simulated moonlight lighting conditions.

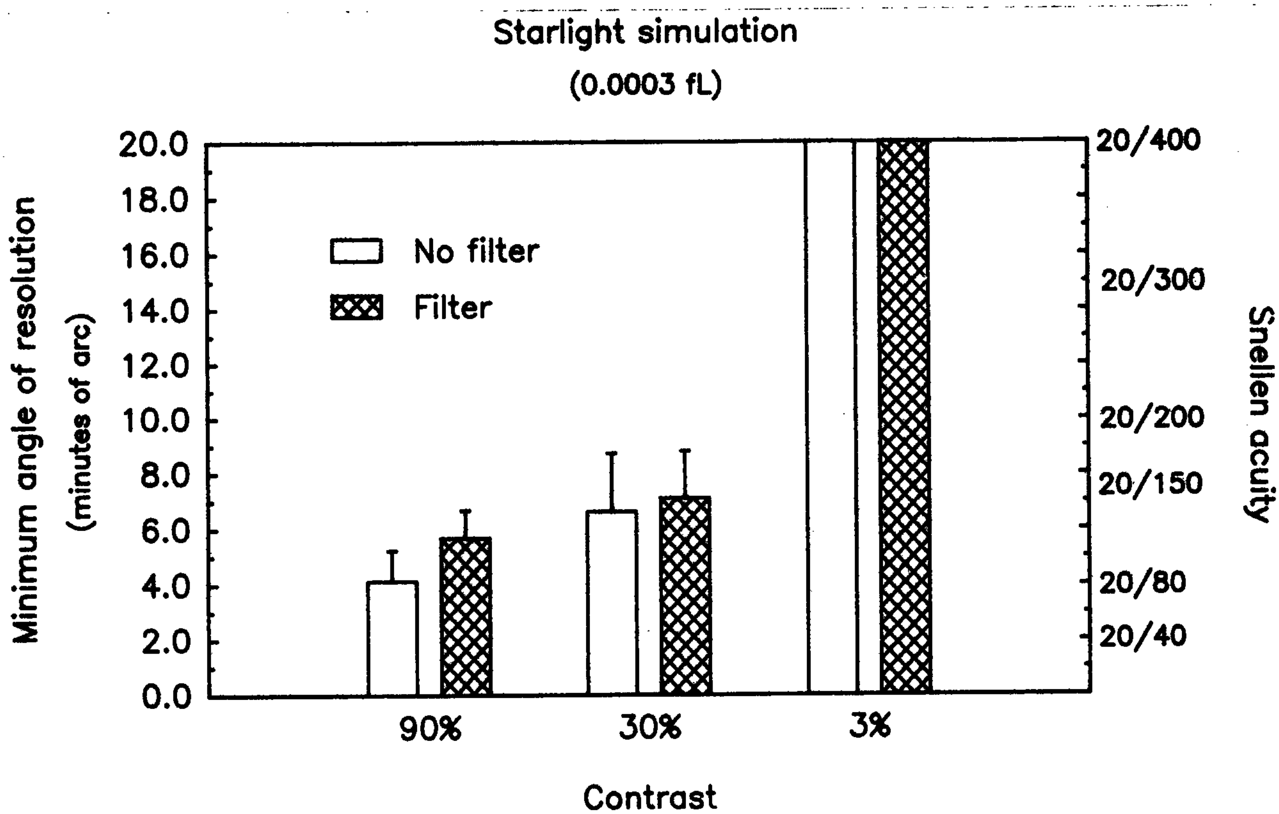

Figure 6. Mean acuities at high, moderate, and low levels of contrast under simulated starlight lighting conditions.

occurred independently of the nearly 80 percent luminous reduction in NVG output which resulted from placing the filter materials over the goggle's oculars.

Discounting the effects of the filters, the data indicate decrements in acuity with decreases either in the level of "ambient" illumination or in the level of target/background contrast. As might be expected, typical "best" AN/PVS-5 acuities (20/50-20/60) were achieved under fairly optimal lighting conditions (i.e., under conditions of relatively high contrast and scene luminance). However, acuity degraded as background brightness decreased from twilight to starlight levels with the most marked decrements (20/125 and worse) exhibited for letters of low (and perhaps the most militarily significant level of) contrast. At the lowest luminance and contrast level (Figure 6), acuity among all subjects degraded beyond measurable levels.

Discussion

The results of this study confirm visual acuity through NVGs may be impaired under light levels less than ideal for optimal NVG resolution, and, in general, for targets of low contrast. However, under typical NVG viewing conditions, no differential effects on visual acuity were found by looking through a filter which reduced the luminous transmission of the goggles by nearly 80 percent. (Although unsupported by improvements in performance, two subjects reported that, under some conditions, the filters actually enhanced viewing by reducing what they regarded as the distracting "flicker" [goggle "noise"] seen in the undifferentiated visual field [empty room] surrounding the video display.) Thus, by itself, an 80 percent reduction in luminous transmission, characteristic of the "open" state of PLZT, should not further impair visual acuity through the AN/PVS-5 night vision goggles.

Before deciding to adopt PLZT for Army aviation, some additional points should be considered. For example, if PLZT can be represented accurately by neutral density filters, then viewing monochromatic NVG imagery via open PLZT should not further degrade available color cues. However, depending upon its physical compatibility with the goggles, PLZT could force the eye further away from the goggles' exit pupil and reduce the already restricted 40-degree visual field and the resultant perception of depth. Thus, even if visual function is preserved, incompatibility of fit between PLZT and NVGs could impair flying ability by constricting the wearer's visual field to the extent that his visual input would be analogous to that of viewing a baseball game through a distant knothole. Therefore, we recommend future testing to incorporate prototype or actual headgear in order to avoid subsequent compatibility problems.

Our study also has assumed generally benign environmental and meteorological conditions, i.e., an airframe unaffected by the destructive potential within the actual blast envelope. Unless hardened against the blast's long-range electromagnetic pulse, resultant voltage or current surges could damage or disable vulnerable opto-electronic assemblies in the NVGs leaving viewing through PLZT alone as the only possible visual path. Thus, any consideration of PLZT's potential effects on vision must be divided, conceptually at least, into those associated with the visual interpretation of the NVG image and those related to visual performance in the absence of fully operational NVGs (i.e., with PLZT alone).

Aviator visual performance using PLZT alone will depend on environmental considerations as well as the specific visual task at hand. While not expected to cause problems under bright ambient illumination, PLZT's effects under low-light conditions, in the absence of test data, only can be surmised. Previous work from this Laboratory has shown unacceptable impairments in acuity under low-light conditions in individuals wearing lenses which reduced visual transmittance by 70 percent (Wiley, 1987). Furthermore, preliminary testing by this Laboratory (McLean and Rash, 1985) and by the Air Force (Templin and Thornton, 1978) suggest that viewing through PLZT under low-light conditions may both impair visual performance and degrade tactical flying ability. The degree to which PLZT may impair low-light performance of visual-based tasks, to include those tasks requiring the aviator to look "under" or around nonoperational NVGs, clearly needs investigation.

An accurate assessment of the effects of PLZT on aviator performance will require operational and task specific flight testing. Needed to be addressed are questions that consider mission profile, ambient light level, meteorological conditions, blast characteristics, separation distance, and aviator experience. From the standpoint of hardware, the effects of various forms of pyrotechnics need to be investigated in order to discern how PLZT's light sensors will respond under varying conditions of rapid illumination change. (Indeed, even the intermittent flicker caused by normal rotor blade rotation can, under certain lighting conditions, effectively trigger PLZT [McLean and Rash, 1985]). Also needed to be addressed are questions associated with cockpit lighting. Current cockpit lighting configurations are not compatible with NVGs and must be operated at low level settings to minimize NVG degradation. A requirement to view instrument and indicator lights through PLZT will necessitate a higher light level setting and thereby reduce NVG performance. The aviator's ability to see his outside environment could thus be impaired and his aircraft rendered more vulnerable to enemy detection and localization.

Recommendations

The data from this study suggest PLZT in its open state can be used with NVGs without significantly impairing visual acuity. We are concerned greatly, however, both about flying with PLZT alone under low-light conditions and with PLZT-NVG compatibility. We cannot at this time offer an unqualified recommendation to incorporate PLZT into the HGU/56P. We recommend additional operational testing of PLZT material, especially with actual or prototype headgear.

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Appendix A

DCD request memorandum

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
ATZQ-CDM-C (70-11)	Evaluation of Visual Transmittance While Wearing Night Vision Goggles (NVG) and Nuclear Flashblindness Goggles

TO	FROM	DATE	CMT 1
Cdr, USAARL	Dir, DCD		

Mr. Birringer/ncw/5272

1. The protection of the unaided eye against the effects of small tactical nuclear weapons (flashblindness) on the modern battlefield is an issue of concern for Army aviators. DCD is having difficulty defining the effects of reduced transmissivity of nuclear flash-blindness goggles (PLZT) in terms of operational capability. This is particularly critical when aircraft are flying NOE at night and when pilots are wearing NVGs.

2. Request USAARL conduct an evaluation and analysis of the effects of visual transmittance through PLZT goggles worn in conjunction with NVGs. DCD will use this information to support or eliminate the operational capability currently required of the Aircrew Integrated Helmet (HGU-56/P). The HGU-56/P is currently in advanced development.

3. Also, request you provide a recommendation based on the analysis by 22 Nov 88.

4. DCD POC for this action is Mr. Birringer, extensions 5272/5071.

for Harold J Becker LTC

THEODORE T. SENDAK
Colonel, Aviation
Director of Combat Developments

DA FORM 2496 PREVIOUS EDITIONS WILL BE USED

Appendix B

Mean visual acuity with AN/PVS-5A night vision goggles with and without simulated flashblindness protective lenses under varying levels of brightness and contrast

	Minimum angle of resolution*		Snellen acuity**	
	No filter	Filter	No filter	Filter
Twilight				
High contrast	2.66	2.65	20/50-	20/50-
Moderate "	2.91	3.17	20/60	20/60
Low "	6.10	6.45	20/100-	20/150+
Moonlight				
High contrast	3.23	3.25	20/60-	20/60-
Moderate "	3.86	4.49	20/80	20/80-
Low "	9.74	9.28	20/200	20/200
Starlight				
High contrast	4.15	5.69	20/100	20/100-
Moderate "	6.63	7.11	20/150+	20/150
Low "	26.25	20.59	20/400-	20/400

* Minutes of arc
** Approximate Snellen equivalent based upon letter sizes actually presented to the subjects.

Appendix C

Manufacturers' list

Eastman Kodak Company
Rochester, NY 14650

Photo Research
3000 North Hollywood Way
Burbank, CA 91505