2

Institute Report No. 373

DTIC
ELECTE
MAY 18 1989
S D
D

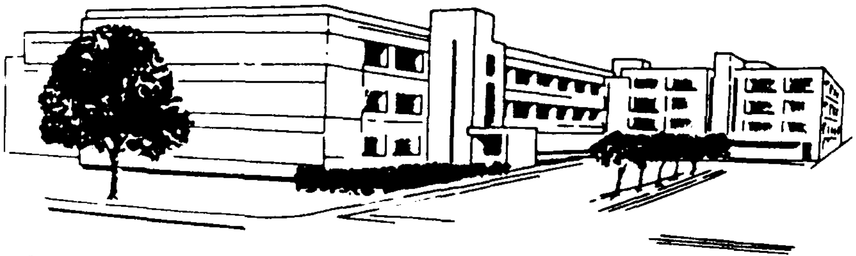
Transient Visual Effects of Prolonged Small Spot Foveal Laser Exposure

Harry Zwick
David O. Robins
and
Nawim Magsood

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

Division of Ocular Hazards

~~January~~ March 1989



LETTERMAN ARMY INSTITUTE OF RESEARCH PRESIDIO OF SAN FRANCISCO CALIFORNIA 94129

Transient Visual Effects of Prolonged Small Spot Foveal Laser Exposure, H. Zwick, et al

Reproduction of this document in whole or in part is prohibited except with the permission of the Commander, Letterman Army Institute of Research, Presidio of San Francisco, California 94129-6800. However, the Defense Technical Information Center is authorized to reproduce the document for United States Government purposes.

Destroy this report when it is no longer needed. Do not return to the originator.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

In conducting the research described in this report, the investigation adhered to the "Guide for the Care and Use of Laboratory Animals," as promulgated by the Committee on Revision of the Guide for Laboratory Animal Facilities and Care, Institute of Laboratory Animal Resources, National Research Council.

This material has been reviewed by Letterman Army Institute of Research and there is no objection to its presentation and/or publication. The opinions or assertions contained herein are the private views of the author(s) and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense. *(AR 360-5)*

Edwin S. Beatrice 11 Apr 89

Edwin S. Beatrice (date)
COL, MC
Commanding

This document has been approved for public release and sale; its distribution is unlimited.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30 1986

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for publication; distribution is unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) Institute Report 373	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Division of Ocular Hazards 6b OFFICE SYMBOL (If applicable) SGRD-ULE-OH	7a NAME OF MONITORING ORGANIZATION Letterman Army Institute of Research
6c. ADDRESS (City, State, and ZIP Code) Letterman Army Institute of Research Presidio of San Francisco, CA 94129-6800	7b ADDRESS (City, State, and ZIP Code) Presidio of San Francisco, CA 94129-6800
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Medical Research and Development Command 8b OFFICE SYMBOL (If applicable) SGRD	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code) Fort Detrick Frederick, MD 21701-5012	10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
61102A	3M61102 BS15	CF	DA0E6078

11 TITLE (Include Security Classification)

(U)Transient Visual Effects of Prolonged Small Spot Foveal Laser Exposure

12 PERSONAL AUTHOR(S)

Harry Zwick, Ph.D.; David O. Robbins, Ph.D.; Nawim Maqsood, B.S.

13a. TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
In-house	FROM Jan 89 TO Mar 89	March 1989	12

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

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

Development of a test of foveal function during and after small spot foveal exposure was the primary objective of this investigation. This objective was accomplished. At retinal damage levels, only a small focal foveal lesion was observed indicating the ability to utilize the fovea during such exposure. Postexposure recovery effects analyzed for target size and contrast conditions suggest retinal and possibly cortical saturation processes.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a NAME OF RESPONSIBLE INDIVIDUAL E.S. Beatrice, COL, MC	22b TELEPHONE (Include Area Code) 415-561-3600	22c OFFICE SYMBOL SGRD-ULZ

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

ABSTRACT

Development of a test of foveal function during and after small spot foveal exposure was the primary objective of this investigation. This objective was accomplished. At retinal damage levels, only a small focal foveal lesion was observed indicating the ability to utilize the fovea during such exposure. Postexposure recovery effects analyzed for target size and contrast conditions suggest retinal and possibly cortical saturation processes.

DTIC

Accesion For
NTIS CRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification ________
By ________
Distribution /
Availability Codes
Dist | Avail and / or Special
A-1

PREFACE

TABLE OF CONTENTS

BODY OF REPORT

List of Figures

Transient Visual Effects of Prolonged Small Spot Foveal Laser Exposure

INTRODUCTION

In recent experiments, we have evaluated the effects of acute, threshold damage levels of small spot foveal laser exposure. These experiments revealed transient changes in acuity and contrast sensitivity lasting from 10 to 15 minutes postexposure. Following recovery from such effects, normal acuity and contrast sensitivity are not necessarily degraded, although continuous exposure at these levels does result in parafoveal compensation for foveal damage and eventual deficit in fine visual acuity (1,2,3).

The present investigation evaluates small spot foveal exposure for relatively prolonged exposure times. Unlike flash exposure effects, prolonged viewing of laser light may involve low to moderate intensity sources which are viewable for periods from several seconds to tens of minutes. The off-axis intensity of some of these sources may be sufficient to produce transient change during and immediately after exposure. In the practical application of laser sources in medicine and industry, such exposure often occurs in close association with visual task performance. An ophthalmologist performing laser retinal photocoagulation may view a low-level laser aiming beam, which is often split off from the the photocoagulation laser, for several seconds to several minutes. This procedure is repeated many times in clinical laser therapy. Exposure may be centered on the fovea or slightly off the fovea. Physical scientists make use of diffraction patterns from laser sources to characterize materials. Such examination may also require lengthy exposures of foveal and parafoveal retinal areas required by the examination process itself. Alignment lasers used in construction, surveying, and military target designators are additional human tasks that may require foveal and parafoveal prolonged viewing of small spot visible laser sources.

Investigations of prolonged light exposure effects have generally been performed with much larger, extended source test stimuli. Both transient and long term effects of low level prolonged and repetitive exposure may occur (4). Such effects can occur at levels well below those set for extended source Maximum Permissible Exposure (MPE) levels (4).

While previous prolonged laser exposure experiments dealt with the effects of extended source exposure, the present experiments deal with small spot prolonged exposure on or sligtly off the central portion of the retina, the fovea. We have employed levels of exposure slightly above the Maximum Permissiable Exposure (MPE) limit to levels many times below the MPE. These exposure conditions have been investigated for measures of foveal visual acuity and contrast sensitivity.

METHODS

Visual acuity and contrast sensitivity for behaviorally trained rhesus monkeys were measured using Landolt ring acuity methods developed in our laboratory (2). Behavioral training techniques that employed either positive or negative reinforcement had equal success in producing animals with optimum visual acuity and contrast sensitivity. These techniques measure foveal spatial visual processing at the level of the retina and within the visual pathways.

Following stable baseline measurements of visual acuity or contrast sensitivity, animals were exposed to either 514 nm cw or 532 nm repetitively pulsed source (20 pulses per second) minimal retinal spot (50 microns) exposures lasting from 10 to 32 minutes. In both acuity and contrast sensitivity experiments, the animal's task was to detect the gap in a Landolt ring. The laser source was placed coaxial with the Gap in the Landolt ring or just slightly off the center of the gap so that correct detection of the gap required foveal irradiation (6) or slightly parafoveal visual function. In the acuity scenario, the animal's task was to adjust the gap to the smallest size that could be detected in the presence laser source. The laser source was 2 degrees from the center of the Landolt ring gap. Two target contrast ratios of 97 and 60% were employed in acuity experiments. For contrast sensitivity, a fixed gap size was presented and the animal's task was to adjust the luminance of the acuity target so that it was detectable against a 75-foot Lambert background (1,2,3). In these experiments, the laser source was always coaxial with the gap. Contrast sensitivity for a total of seven gap sizes was measured before and after every exposure for each Landolt ring gap size. Contrast sensitivity recovery functions measured at each gap size were used to construct postexposure contrast sensitivity functions.

The two laser sources employed in this experiment were a cw Argon ion laser source operating at 514 nm and a repetitively pulsed frequency doubled Neodymium (532 nm). For cw Argon laser exposures, corneal irradiances varied from 0.1 to 0.001 milliwatts/cm (2). The ranged from 3 microjoules per pulse to .003 microjoules per pulse for the frequency doubled neodymium source. Exposure durations from 10 to 32 minutes were utilized across both laser conditions. All argon laser exposures were made at 2 degrees off the fovea, while all repetitively pulsed 532 nm exposure were made directly on the fovea.

RESULTS

In Figures 1 and 2, data from animals S1 and S2 exposed to 0.1 mw/cm (2) at 2 degrees off axis from a cw Argon laser (514) are presented. Both animals were exposed for 10 minutes. For this duration, the exposure level is 6 times the MPE.

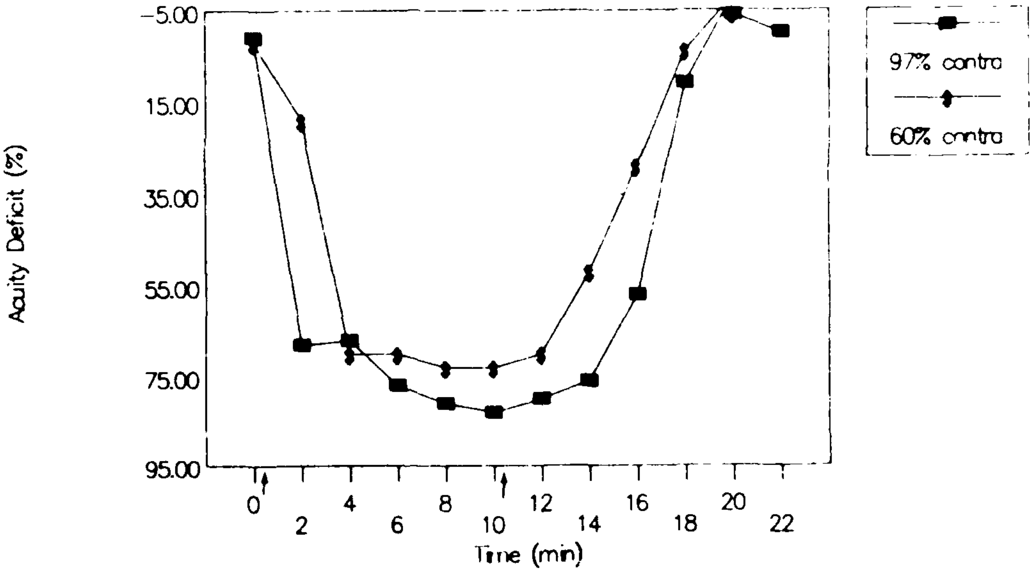


Figure 1. Effect of Argon laser exposure on S1 for two contrast conditions. The first vertical arrow indicates the onset of laser exposure and the second termination of exposure.

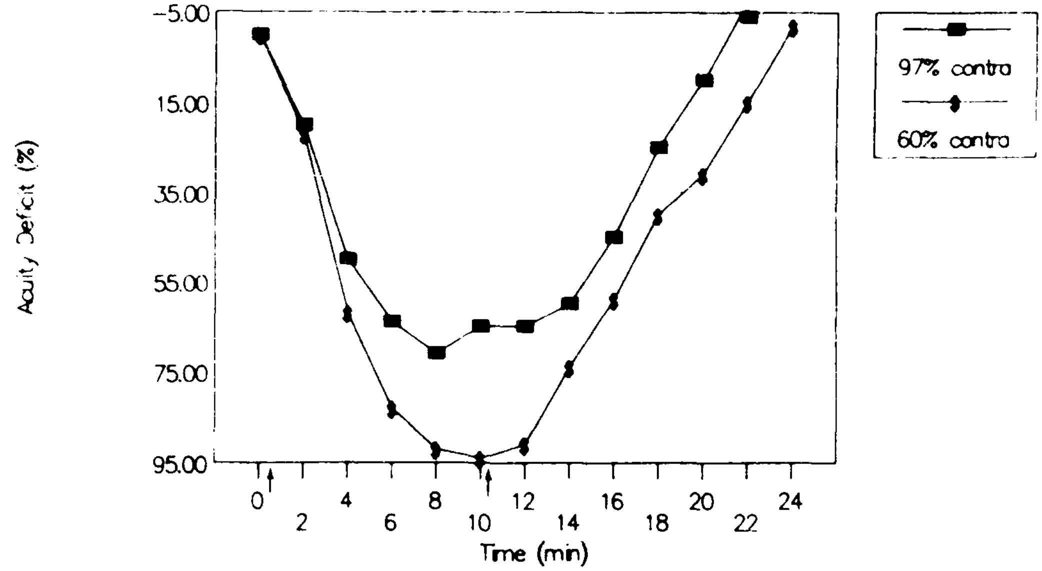


Figure 2. Same as Figure 1 for subject S2.

While the laser source was on, visual acuity deficits between 70 and 80% were obtained. However, maximum acuity deficit did not vary consistently across animals or contrast conditions. While maximum acuity deficit is greater for S1 at the 97% contrast acuity target, this relationship is reversed in S2. Similar inconsistencies were found at the lower exposure level (.001 mw/cm^2) for maximum acuity deficit and acuity target contrast.

On the other hand, initial postacuity recovery is consistent across animals. Upon termination of the laser glare source, initial recovery is more rapid for the lower contrast targets (60%) than for the higher contrast targets (97%). Identical effects were obtained in both animals for the lower exposure level (.001 mw/cm^2).

Postexposure contrast sensitivity following 15 minutes of exposure to a 532 nm repetitively pulsed laser source at 1/10 the MPE (.03 microjoules per pulse) produced effects consistent with the above acuity deficits (Figures 1 and 2). The longest postexposure recovery times were observed for 1.1 and 9.3 min of arc targets. Recovery for these targets never exceeded about 60% of the baseline contrast sensitivity during the exposure session. Full recovery for all baselines was attained on subsequent daily sessions. Contrast sensitivity for the intermediate gap sizes recovered much more rapidly than either the 1.1 or 9.3 min of arc target. The rapid recovery observed at 16.5 min of arc may reflect the fact that this target was larger than exposure spot size of approximately 50 microns.

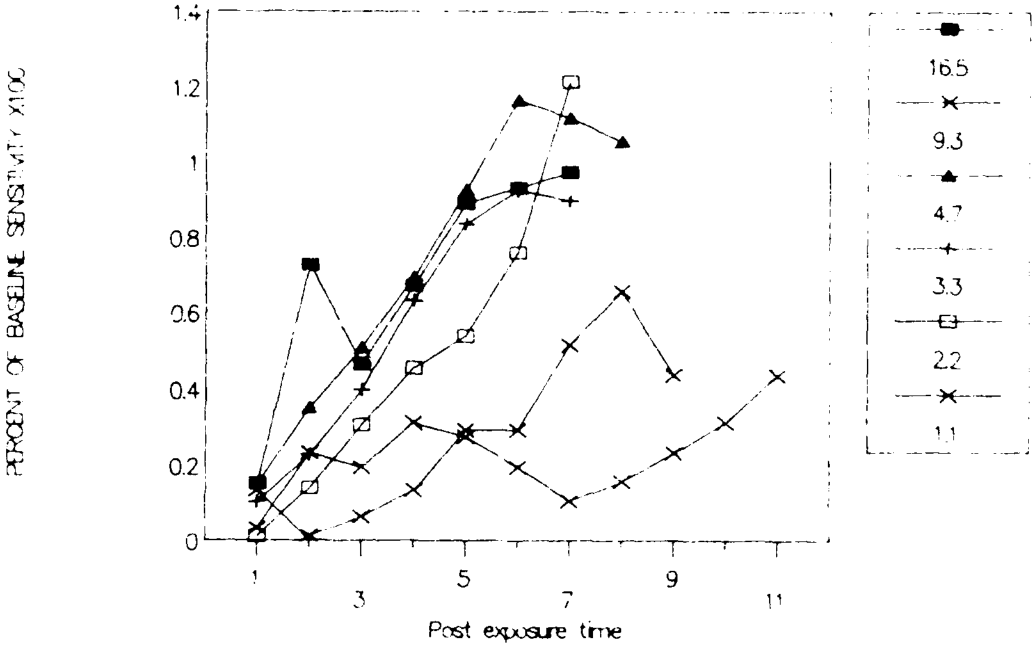


Figure 3. Postexposure contrast sensitivity for Landolt ring gap sizes ranging from 16.5 to 1.1 min of arc.

In Figure 4, a comparison is made between the suppressive and postexposure effects of two animals, S3 and S4. Contrast sensitivity was measured for the 9.3 min of arc target. While S4, exposed at the ED_{50} for single Q-switched exposure (3 microjoules), shows a more rapid and larger sensitivity deficit than S3, exposed at a level 1000 times lower, both animals show similar postexposure recovery times. This similarity in postexposure recovery indicates that the postsuppressive effects are not increased anymore by the production of foveal damage, and that postexposure recovery as well as suppressive effectiveness are mediated by neural rather than frank tissue damage processes. Furthermore, immediate funduscopic examination of S3's fovea revealed a small lesion about 50 microns centered in the foveal region, suggesting that foveal fixation was maintained through out the exposure period (1,2,5).

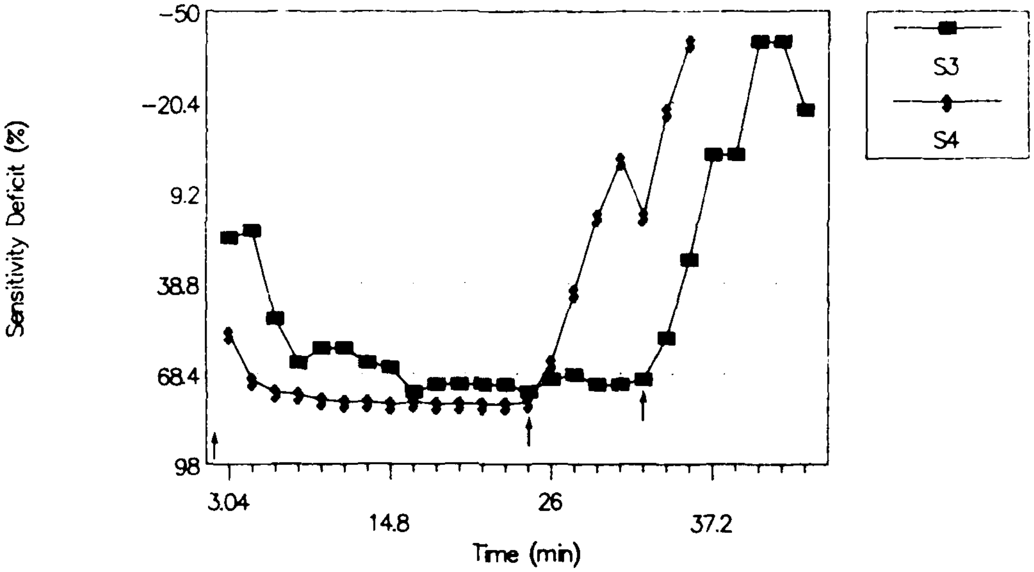


Figure 4. Comparison of exposure effects produced at the ED50 (S4) and MPE/100 (S3).

DISCUSSION

In this investigation, we studied the effects of minimal spot foveal laser exposure on Landolt ring acuity and contrast sensitivity. Previous investigations involved acute laser exposure at levels capable of producing retinal damage. Postexposure changes from such exposure were assumed to result from a combination of retinal edema and photochemical/neural saturation of retinal receptor mechanisms.

In the present experiments, levels from just slightly above to many times below the Maximum Permissible Exposure were utilized for exposure durations ranging from 10 to 32 minutes. Both acuity and contrast sensitivity were immediately affected by onset of exposure and resulted in stable period of depression of 70 to 90% acuity or contrast sensitivity deficit. The capability of a minimal spot foveal exposure to suppress visual acuity or contrast sensitivity, thus, depends upon the duration of foveal exposure. We conclude that amount of exposure is a critical variable for demonstrating the presence of the photochemical/neural components involved in the visual process. As pulse width becomes extremely short, < 20 ns, the visual system's photochemical/neural response may become foreshortened, allowing domination of morphological processes at higher exposure energy levels to shape the postexposure visual response (1,2).

Full recovery always occurred upon termination of exposure but appeared to be more severe at levels well below retinal damage levels, suggesting that foveal processes involve saturation of photochemical/neural mechanisms. The comparison shown in Figure 4 indicates that foveal retinal damage does not prolong recovery any more than much lower exposure levels. Furthermore, the longest initial delays in recovery occurred for high contrast, minimal size targets, suggesting that perhaps not only retinal neural mechanisms become saturated but mechanisms involving edge and size as well. The latter involve cortical rather than retinal neuronal mechanisms.

Measurements of Landolt ring contrast sensitivity (Figure 3) extend the range of effects over the spatial frequency domain. Visual acuity measurements involve high frequency (small gaps) high contrast test targets. Contrast sensitivity measurments represent the minimal contrast levels for different spatial frequencies. In Figure 3 the longest recovery for the smallest gap size (1.1 min of arc) is consistent with acuity measurements in Figures 1 and 2 for high contrast targets which required longer initial recovery relative to moderate contrast targets. Larger acuity gap sizes that require lower contrast levels for discrimination tend to recover more rapidly with the exception of the 9.3 min of arc gap, which recovers more rapidly than the minimum gap but much more slowly than the intermediate and largest gap size. Possibly the tendency of larger gap sizes to recovery more slowly measured in minimal spot flash experiments using contrast sensitivity measurements is reflected (1,2). Thus, contrast sensitivity measurement supports the acuity finding of Figures 1 and 2, suggesting that similar effects may occur for larger targets where contrast demands are increasing. Because the largest target subtends an area nearly twice the size of the 9.3 min of arc target, this target may evoke more parafoveal retinal receptors that are less affected by direct exposure to the foveal laser source.

Because visual acuity and contrast sensitivity measured with Landolt ring targets yield very focal and foveal measures of spatial vision, the practical significance of large deficits in visual acuity regarding occupational visual performance and laser safety should be evaluated most carefully. A 90% deficit in Landolt ring visual acuity relates only to a decrement in foveal function. It produces a 70 micron retinal spot, thus, leaving a large unaffected parafoveal and paramacula area. Yet, visual acuity deficits were produced by levels of exposure well below damage levels and at 2 degrees off the central fovea.

The manner in which foveal vision interrelates with visual performance, the dependency of visual performance on foveal, and non-foveal visual function is of paramount importance. If a visual task does not require foveal vision, then changes observed here will have little effect on one's ability to perform during such exposure. If the task requires a high degree of foveal vision, then some decrement in task performance will be observed during exposure. For the latter conditions, changes in laser safety guidelines may be required. Unfortunately, little is known presently about the relationship of visual function measures such as acuity and contrast sensitivity to visual task performance measures.

CONCLUSION

Development of a test of foveal function during and after small spot foveal exposure was the primary objective of this investigation. This objective was accomplished. At retinal damage levels (Figure 4), only a small focal foveal lesion was observed indicating the ability to utilize the fovea during such exposure. Postexposure recovery effects analyzed for target size and contrast conditions suggest retinal and possibly cortical saturation processes. New experiments will determine the exposure duration limits, if they exist, beyond which foveal function becomes permanently suppressed. The relationship of visual function measures required to obtained evidence of altered foveal processing associated with such exposure and visual performance measures is a neglected area of research. Knowledge of the relationship between visual function and visual performance measures will make laser safety evaluations of such exposures more meaningful.

REFERENCES

1. Zwick H, Bloom KR, Lund DJ, Beatrice ES. Laser ocular flash effects. In: Proceedings of 1982 Army Science Conference. West Point, New York, 1982.

2. Zwick H, Bedell Hr, Bloom KR, Spectral deficits in visual acuity due to laser irradiation. In: Proceedings of the 8th Army Science Conference. West Point, 1972.

3. Zwick H, Bloom KR, Beatrice ES. Visual change associated with punctate foveal damage. In: Court LA, Duchene A, Courant D, eds. First International Symposium on Laser Biological Effects and Exposure Limits. Paris, France: Lasers et Normes de Protection, 1986:246-256.

4. Zwick H, Stuck BE, Beatrice ES. Low-level effects on visual processing. In: Proceedings of Society of Photo-Optical Instrumentation Engineers, 1980:55-62.

5. Robbins DO, Zwick H, Holst GC. A method for producing foveal retinal lesions. Behav Res Meth Instr 1973;5: 457-461.

OFFICIAL DISTRIBUTION LIST

Commander
USAMRDC
ATTN:SGRD-PLC/MG Russell
ATTN:SGRD-PLC/COL Lam
SGRD-RMS/Ms. Madigan
Fort Detrick, MD 21701-5000

Director
Defense Technical Information
ATTN:DTIC-DDA (2 copies)
Cameron Station
Alexandria, VA 22314

Commander
US Army SMO
ATTN:AMXCM-EO/MAJ Dedmond
2800 Powder Mill Road
Adelphi, MD 20783

Commander
USAMSAA
ATTN: DRXSY-CSD/P. Baers
ATTN: DRXST-GWD/F. Campbell
Aberdeen Proving Ground
Maryland 21010

Commander
ATTN: AFWAL/MLPJ/G. Kepple
Wright Patterson AFB
Ohio 45433

Commander
US AEHA
ATTN: HSHB-RL/D. Sliney
Aberdeen Proving Ground
Maryland 21010

Dr. John Ewen
PO Box 1925
Washington, DC 20013

Commander
HQ, USAMMDA
ATTN: SGRD-UMA/Channing
Fort Detrick
Frederick, MD 21701-5012

Commander
ATTN:AFAMRL/HEF/R. Susnik
Wright Patterson AFB
Ohio 45433

Headquarters
Department of the Army
ATTN: DASG-TLO
Washington, DC 20310

Commander
CACDA/ATZL-OPS-SE
ATTN: MAJ J.C. Johnson
Fort Leavenworth
Kansas 66027

Director
NADC
ATTN: Code 601B/Dr. Chisum
Warminster, PA 18974-5000

Commander
NMRDC
ATTN: Code 43
National Naval Med Center
Bethesda, MD 20814

Commander
USAF SAM
ATTN: RZW/Dr. Farrer
ATTN: RZW/LTC Cartledge
Brooks AFB, Texas 78235

Official Distribution List, cont.

Director
AMSAA
ATTN: AMXSY-CR/Mr. Brand
Aberdeen Proving Ground
Maryland 21005

Commander
USA Aviation Systems Command
ATTN: AMCPM-ALSE/H. Lee
4300 Goodfellow Blvd
St. Louis, MO 63120

Director
Defense Intelligence Agency
ATTN: DT-5A/Hal Hock
Pentagon
Washington, DC 20301

Commander
USA Aeromedical Research Lab
ATTN: COL La Mothe
Ft. Rucker, AL 36330-5000

Director
EWL/RSTA Center
ATTN: AMSEL-EW-C/J. Allen
Ft Monmouth, NJ 07703-5303

Director
USA HEL
ATTN: AMXHE-IS/D. Giordano
Aberdeen Proving Ground
Maryland 21005-5001

Director
US Army AMMRC
ATTN: AMXMR-O/Fitzpatrick
Watertown, MA 02172-0001

Director
Armed Forces Medical
Intelligence Center
ATTN: AFMIC-SA/MAJ Downs
Fort Detrick
Maryland 21701-5004

Director
DTD Directorate
ATTN: EOGWCM-CCM/Kasparek
White Sands Missile Range
New Mexico 88002-5519

Commander
HQ TRADOC
ATTN: ATCD-ML/J. Gray
Ft. Monroe, VA 23651-5000

Commander
LAIR
ATTN: SGRD-ULZ (1 copy)
SGRD-IR (10 copies)
PSF, CA 94129-6800