



USAARL Report No. 86-2

**THE EFFECTS OF CYCLOPLEGIA ON THE VISUAL
CONTRAST SENSITIVITY FUNCTION**

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SENSORY RESEARCH DIVISION

February 1986

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAARL Report No. 86-2	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effect of Cycloplegia on the Visual Contrast Sensitivity Function		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) William G. Bachman and Isaac Behar		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Sensory Research Division US Army Aeromedical Research Laboratory Fort Rucker, AL 36362-5000		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 3E162777A879,164
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research and Development Command Fort Detrick Frederick, MD 21701-5012		12. REPORT DATE February 1986
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Contrast Sensitivity Function Cycloplegia Glare Vision		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) See reverse side.		

20. ABSTRACT.

Contrast sensitivity assessment is one of several emergent techniques being considered for inclusion in a visual standards test battery for the Army, particularly for the evaluation of Army aviators. Since a cycloplegic refraction is required for initial selection of candidates for Class I and Class IA flying duty, it is important to determine what effect, if any, cycloplegia has on the contrast sensitivity function. Twelve subjects, officers in preparation for flight training, who had passed a recent Class I flight physical, were tested. Contrast sensitivity functions were obtained under normal ambient conditions and in the presence of a glare source, both under manifest and cycloplegic conditions. Cycloplegia produced a small reduction in contrast sensitivity under normal ambient conditions, and a greater reduction under glare conditions. For both conditions, the cycloplegia effect was greater for the higher spatial frequency gratings than for the lower.

Acknowledgments

The authors wish to acknowledge the valued contributions to this project of LTC Bruce Leibrecht, Ms. Carolyn Johnson, SGT Rosalinda Ibanez, SSG Nonilon Fallaria, and SGT Marshall Smith.

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INTRODUCTION

Contrast sensitivity assessment has become a major tool for evaluating human spatial vision (Schade, 1956; Campbell, 1983). The contrast sensitivity function (CSF) characterizes the threshold sensitivity of the visual system to sinusoidal variations in contrast over a wide range of target sizes or spatial frequencies. The performance of the visual system is measured over an entire range rather than at specific high frequencies as is done in Snellen letter or Landolt C visual acuity determination.

Comerford (1983) stated that the CSF provides several advantages over other vision tests commonly used in clinical practice. First, it provides a measure of the integrity of both central and peripheral vision requiring similar judgments on the part of the patient. Second, for low spatial frequency stimuli, the detection of the grating requires the integration of visual information over a large expanse of the retina. Third, while better acuity generally indicates the patient's ability to see small details in the environment, the CSF also measures the ability to see large details. These details, which are analogous to low frequency sensitivity, provide input to facial recognition, figure-ground judgments, and other important information relating to the ability to function in the environment. Fourth, the CSF is a sensitive indicator of small differences in visual function.

The ability to detect small differences in visual function can have a significant application in the military, especially in the aviation environment. For example, Ginsburg et al. (1982) and Ginsburg, Easterly, and Evans (1983) demonstrated that contrast sensitivity was found to be better than visual acuity for predicting a pilot's performance in detecting small low contrast targets both in aircraft simulators and in the field. Contrast sensitivity testing also is being conducted by NASA on space shuttle flights to determine the effects of low gravity on vision.

Contrast sensitivity testing currently is used in the Army primarily in the area of research. It is used in special medical cases to determine the effect on visual function of eye pathology, e.g., an aviator with a developing cataract. Contrast sensitivity assessment is one of several emergent techniques being considered for inclusion in a visual standards test battery for the Army. This battery would offer the potential for characterizing individual differences not now captured with standard visual testing.

Instruments and methods for contrast sensitivity determination have existed almost exclusively in the research environment. Arden (1978) developed the first practical clinical test of contrast sensitivity using gratings printed on plates. A clinical contrast sensitivity screening instrument has been introduced (Ginsburg et al., 1984), as well as an automated refractor which measures contrast sensitivity and displays results digitally as visual acuity (CooperVision Dicon AR5000*). Also now available to the clinician are spatial frequency charts similar to acuity charts which are designed to be used for both distance and near testing (Ginsburg, 1984). Therefore, contrast sensitivity testing is becoming more useful in clinical vision evaluation and screening.

Because of growing acceptance and ease of use, as well as practical importance to Army aviation, contrast sensitivity testing would appear to be an important tool in the evaluation of potential Army aviators. Army Regulation 40-501, Change 34, indicates that a cycloplegic refraction is required for initial selection of candidates for Class I and Class IA flying duty. Cycloplegia, in this case, is defined by Cline, Hoffstetter, and Griffin (1980) as an artificially induced paralysis of the ciliary muscle and the power of accommodation, usually accompanied by a dilated pupil. It is relevant therefore to determine what effect, if any, cycloplegia has on the contrast sensitivity function.

Several previous studies have examined the effects on the CSF by drugs that modify the pupillary or accommodative dynamics. Singh et al. (1981) determined that mydriasis alone without paralysis of accommodation did not affect contrast sensitivity in normal older (50 to 84 years) observers. Baker et al. (1983) found that for subjects who had been given atropine intramuscularly, there was a small loss of sensitivity at the highest tested spatial frequency (20 cycles per degree). Campbell and Green (1965) demonstrated the effect on contrast sensitivity of various artificial pupil sizes under atropinized conditions. Using neutral density filters to compensate for the change in retinal illumination due to the changes in pupil area, they found a progressive reduction of contrast sensitivity as the pupil was made larger. Kay and Morrison (1985) replicated the Campbell and Green study except that changes in retinal illumination associated with changes in pupil size were not compensated for in order to simulate natural viewing. They found that the low spatial frequency portion of the CSF "was only

* See Appendix B

marginally affected by pupil diameter" as well as the high spatial frequency portion which "was also relatively unaffected by pupil diameter."

The contrast sensitivity function measured under normal clinical conditions does not provide information for all situations encountered by a subject in his or her daily environment. Paulsson and Sjostrand (1980) used a bright light glare source introduced into the visual field in order to enhance the effects of intraocular light scattering on the CSF. In the same vein, Carney and Jacobs (1984) stated that the contrast sensitivity function can be sensitized by the presence of a glare source to allow a more accurate determination of any visual loss.

The purpose of this study then was to evaluate the effect of cycloplegia on the contrast sensitivity function. This was done in a manner simulating clinical conditions as closely as possible as well as with the introduction of a glare source. Subjects were candidates for flight training at Fort Rucker, Alabama.

METHOD

Subjects

Twelve subjects were used, 11 males and 1 female. All were aged 22 or 23, except one who was 27. All were officers in preparation for flight training at the Army Aviation Center at Fort Rucker, Alabama, who had passed a recent Class I flight physical, and were free of eye disease. All subjects received an intraocular pressure test (Reichert* noncontact tonometer) and were within normal limits.

Procedures

Subjects were refracted at a distance of three meters using both standard subjective refraction and static retinoscopy to determine spherical and cylindrical components. Refraction was accomplished under both manifest (undilated) and cycloplegic (dilated) conditions. See Table I for the mean optical correction under both conditions. The subjects then wore the best possible optical correction (spectacles) to minimize blur at 3 m for whichever condition was being tested. Optical corrections, to include plano results, were provided using a standard trial frame. All subjects resolved 20/20 or 20/15 with each eye unaided as well as with spectacle corrections. Acuties were measured using the Baylor Video Acuity Tester (B-VAT)* which has a 12" diagonal CRT for video display of target sizes from

20/10 to 20/400. Mean luminance of the screen was held at 26.5 fL which was identical to the mean luminance of the contrast sensitivity testing screen.

Pupil diameters were measured for all subjects. Diameters were measured with a PD rule to the nearest 0.5 mm while the subject viewed the contrast sensitivity display. This was accomplished with and without glare under both undilated and dilated conditions. See Table II for the mean pupillary diameters.

	Diopters	
	Sphere	Cylinder
Manifest	+0.09	-0.36
Cyclopegic	+0.46	-0.34

TABLE I. Mean optical correction.

	Manifest	Cyclopegic
No glare	4.92	8.08
Glare	3.08	8.08

TABLE II. Mean pupillary diameter.

Cycloplegia was induced using 1 percent Cyclogel* (cyclopentolate) which is a diagnostic parasympatholytic drug administered directly in the eye. Each subject received one drop in each eye followed by a second drop after 5 minutes. Cyclopentolate blocks the responses of the sphincter muscle of the iris and the accommodative muscle of the ciliary body to cholinergic stimulation, producing pupillary dilation (mydriasis) and paralysis of accommodation (cycloplegia).

Contrast Sensitivity Measurement

Testing was conducted in a room in which all surfaces, walls, ceiling, and floor were matte black. Room illumination was provided by four recessed ceiling incandescent lamps adjusted to provide 12 fc at the observer's table. The contrast sensitivity functions were obtained with a Nicolet Optronics CS2000 Contrast Sensitivity Testing System*. The video display had a mean luminance of 26.5 fL, and at the 3-meter viewing distance, subtended 4.4 degrees by 5.6 degrees. For a glare source, the display was surrounded by a high intensity (4300 fL) fluorescent lamp (Aristo DA-17*) which was masked so that no direct light reached the screen. The choice of a surrounding glare source instead of a more commonly used laterally placed small glare source was based on the findings of Miller *et al.* (1972) that the former was less fatiguing and helped the subjects maintain fixation on the centrally located display.

The contrast threshold was measured using a variation of the method of increasing contrast (Ginsburg and Cannon, 1933), which is similar to an ascending method of limits psychophysical procedure. On each trial, the display contrast began near zero and after a variable delay increased under computer control uniformly at a rate at which 50 percent contrast would be reached in 45 s. The subject's task was to depress a response switch immediately upon detecting the emergence of a grating pattern on the display screen. Each subject was tested on 3 separate days, the first of which was for training. For half of the subjects, testing on the second and third day was under manifest and cycloplegic conditions, respectively, while for the remaining subjects the order of conditions was reversed. On the training day, they received verbal instructions followed by 18 practice trials consisting of three trials at each spatial frequency: 0.5, 1, 2, 4, 8, and 16 cpd, in an intermixed random order. This then was repeated with the glare source turned on. On each test day, the subject received five warm-up trials (one trial each at 0.75, 1.5, 3, 6, and 12 cpd in random order) followed by a random series of 36 trials consisting of 6 trials at each of the spatial frequencies 0.5 to 16 cpd. Following a short break, this 41-trial set was repeated with the glare source turned on. For each subject, mean log threshold contrast was calculated for each

combination of conditions: manifest-glare source off, cycloplegic-glare source off, manifest-glare source on, cycloplegic-glare source on.

RESULTS

The mean contrast sensitivity (reciprocal of group mean contrast threshold) as a function of spatial frequency is presented graphically in Figure 1. The upper left panel summarizes the results for the two conditions with the glare source turned off, while the upper right panel summarizes the results with the glare source turned on. For both no glare ($F=5.76$, $df=1,11$, $p<.036$) and glare ($F=9.79$, $df=1,11$, $p<.01$), contrast sensitivity is superior under manifest compared to cycloplegic conditions for all spatial frequencies except the lowest spatial frequency (0.5 cpd) under glare. The log ratios of the mean contrast thresholds for each spatial frequency with

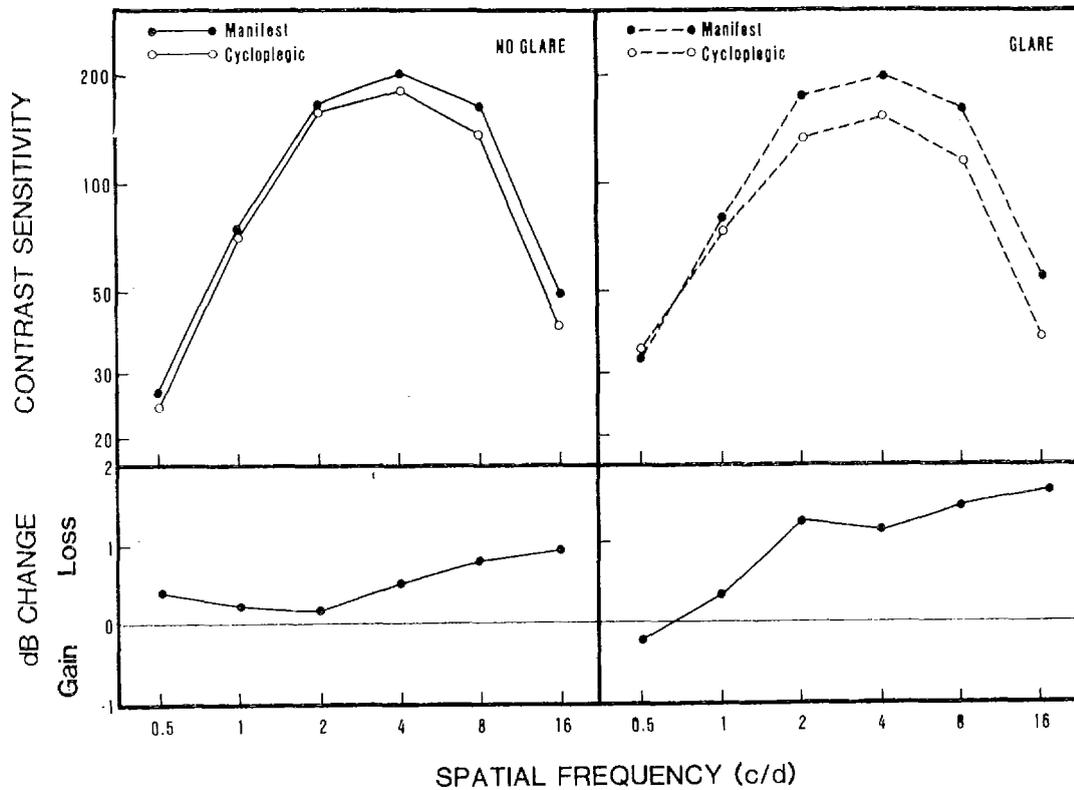


Figure 1. Contrast sensitivity functions (upper panels) and visuograms (lower panels) obtained under manifest and cycloplegic conditions, with and without glare. CSFs for manifest and cycloplegic conditions are directly compared.

and without cycloplegia constitute visuograms (Lundh and Arlinger, 1984), and are plotted in the lower panels of this figure.

In the absence of glare, the loss in contrast sensitivity caused by cycloplegia is minimal for the lower spatial frequencies, but increases monotonically between 2 and 16 cpd. In the presence of glare, the effect of cycloplegia in reducing sensitivity is somewhat greater (except for 0.5 cpd) than it was without glare, and the reduction with increasing spatial frequency is essentially monotonic. An overall repeated measures analysis of variance was performed on these data and a summary table is presented in Appendix A. The main effects of cycloplegic condition ($F=8.92$, $df=1,11$, $p=.012$) and spatial frequency ($F=177.17$, $df=5,55$, $p<.0001$) are highly significant, while the main effect of glare is not significant.

However the interaction of glare and cycloplegic condition, is significant ($F=6.03$, $df=1,11$, $p=.032$), reflecting the greater separation of the manifest and cycloplegic conditions in the presence of glare rather than in its absence. A significant interaction between cycloplegic condition and spatial frequency ($F=2.95$, $df=5,55$, $p=.020$) reflects the greater separation of the manifest and cycloplegic conditions at the higher spatial frequencies than at the lower spatial frequencies. Finally, a significant interaction between glare and spatial frequency ($F=7.74$, $df=5,55$, $p<.0001$) reflects the superior contrast sensitivity in the presence of glare at the lowest spatial frequency (0.5 cpd), but reduced contrast sensitivity in the presence of glare at the intermediate spatial frequencies (2 to 8 cpd), replicating a pattern of results previously found (Behar, 1984).

The comparison of the effects of glare versus no glare is facilitated by the replot of the data in Figure 2. It can be seen that contrast sensitivity is superior in the presence of glare at the lowest spatial frequency (0.5 cpd) when tested under both manifest and cycloplegic conditions. For the remaining spatial frequencies, important differences exist. Under manifest conditions, with the eye in its normal physiological state, no glare sensitivity is evident; contrast sensitivity is equivalent in the presence of the glare source and in its absence. On the other hand, under cycloplegic conditions, considerable glare sensitivity is evident, especially in the middle spatial frequencies (2 to 8 cpd).

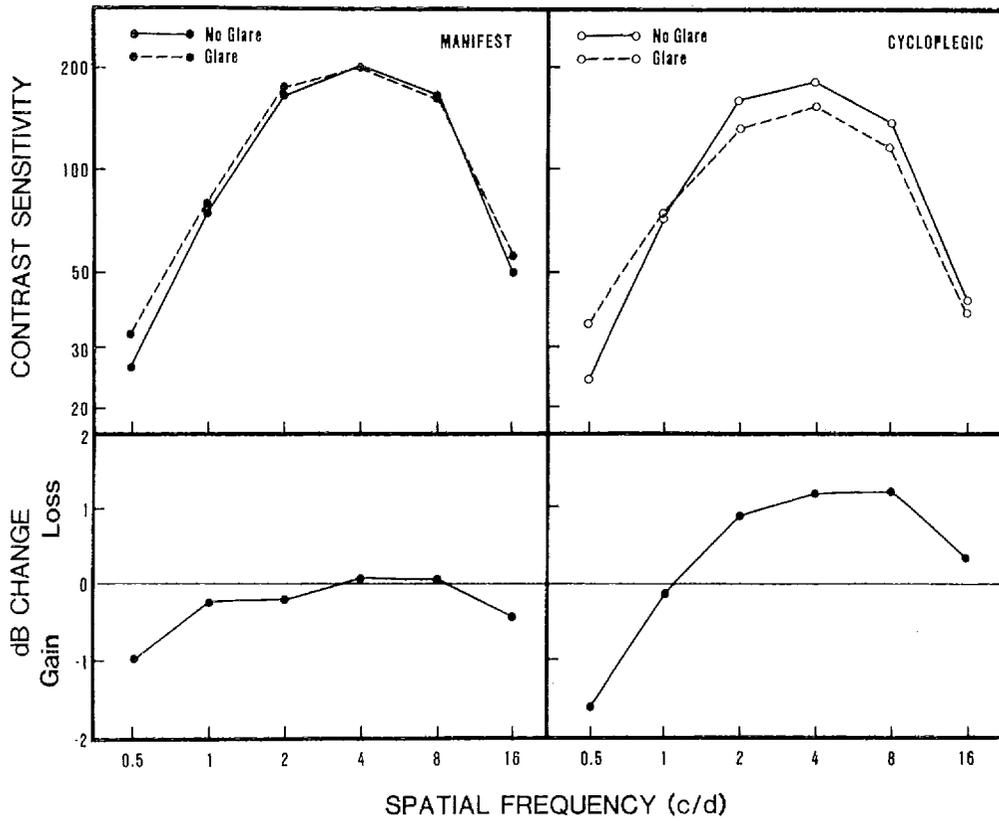


Figure 2. Contrast sensitivity functions (upper panels) and visuograms (lower panels) obtained under manifest and cycloplegic conditions, with and without glare. CSFs for glare and no glare conditions are directly compared.

DISCUSSION

The purpose of this study was to evaluate the effect of cycloplegia on the contrast sensitivity function in a group that is required to have a cycloplegic refraction in order to pass a flight physical. The results indicate that there is a small, but significant loss of sensitivity under dilated conditions and that this loss is magnified by the introduction of glare. Since subjects wore corrections for the test viewing distance, these reductions can be attributed primarily to differences in pupil size in the various conditions. An increase in the size of the pupil increases retinal illuminance, thus would be expected to improve contrast sensitivity especially to higher spatial frequencies (Owsley et al., 1985; Wright and Drasdo, 1985). On the other hand, the larger pupil suffers greater levels of aberrations and reduced depth of field resulting in impairment of contrast sensitivity (Campbell and Gubisch, 1966). When both factors were allowed to operate in opposition, as in the present study, in that of Kay and Morrison (1985), and in that of Singh et al. (1981), relatively small changes in the CSF were found. Singh's subjects were between the ages of 50 and 84 years, so would be expected to have reduced pupils associated with senile meiosis (Said and Sawires, 1972). The mydriatic induced dilated pupil in these subjects resulted in a very large increase in retinal illumination that should favor an improvement in the CSF; however, the degradation in retinal image quality accompanying the larger pupil evidently exactly canceled the illumination advantage leaving the CSF unchanged. In the present study, since the subjects were only in their 20s, the increase in retinal illumination was considerably less, so the more potent factor was the reduction in retinal image quality, resulting in a small net impairment of the CSF.

CONCLUSIONS

If the contrast sensitivity function is to be obtained during the flight physical, it should be obtained prior to the administration of cycloplegia. If the CSF is determined after cycloplegia, then it is most important to avoid viewing with a glare source in the field of view (such as a desk lamp or uncovered window) in order to avoid a biased assessment.

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Appendix A

REPEATED MEASURES ANOVA SUMMARY TABLE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.	GREENHOUSE GEISSER PROB.	HUYNH FELDT PROB.
1	MEAN ERROR	1079.16514 2.96705	1 11	1079.16514 0.26973	4000.89	0.0000		
2	CYCLO ERROR	0.36894 0.45490	1 11	0.36894 0.04135	8.92	0.0124		
3	GLARE ERROR	0.00451 0.21687	1 11	0.00451 0.01972	0.23	0.6417		
4	CG ERROR	0.03777 0.06893	1 11	0.03777 0.00627	6.03	0.0320		
5	SPAFREQ ERROR	25.35698 1.57436	5 55	5.07140 0.02862	177.17	0.0000	0.0000	0.0000
6	CS ERROR	0.13308 0.49622	5 55	0.02662 0.00902	2.95	0.0193	0.0452	0.0252
7	GS ERROR	0.25264 0.37224	5 55	0.05053 0.00677	7.47	0.0000	0.0013	0.0003
8	CGS ERROR	0.05753 0.30885	5 55	0.01151 0.00562	2.05	0.0959	0.1354	0.1137

ERROR TERM

EPSILON FACTORS FOR DEGREES OF FREEDOM ADJUSTMENT

	GREENHOUSE-GEISSER	HUYNH-FELDT
5	0.3804	0.4573
6	0.6175	0.8860
7	0.5082	0.6737
8	0.5263	0.7068

APPENDIX B

Alcon Laboratories, Inc.
P. O. Box 1959
6201 South Freeway
Fort Worth, TX 76134

Aristro Grid Lamp Products, Inc.
65 Harbor Road
Fort Washington, NY 11050

CooperVision Diagnostics
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San Diego, CA 92121

Mentor O & O Inc.
South Shore Park
Hingham, MA 02043

Nicolet Biomedical Division
5225-4 Verona Road
P. O. Box 4287
Madison, WI 53711-0287

Reichert Scientific Instruments
P. O. Box 123
Buffalo, NY 14240