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**NASA
Technical
Memorandum**

NASA TM-82359



**OCULAR SCREENING TESTS OF ELEMENTARY
SCHOOL CHILDREN**

By John Richardson
Technology Utilization Office

July 1983

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16. ABSTRACT This report presents an analysis of 507 abnormal retinal reflex images taken of Huntsville kindergarten and first grade students. The retinal reflex images were obtained by using an MSFC-developed Generated Retinal Reflex Image System (GRRIS) photorefractor. The system uses a 35 mm camera with a telephoto lens with an electronic flash attachment. Slide images of the eyes were examined for abnormalities. Of a total of 1835 students screened for ocular abnormalities, 507 were found to have abnormal retinal reflexes. The types of ocular abnormalities detected were hyperopia, myopia, astigmatism, esotropia, exotropia, strabismus, and lens obstructions. The report shows that the use of the photorefractor screening system is an effective low-cost means of screening school children for abnormalities.					
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UNUSUAL TERMS

AMETROPIA	Disproportionate discrepancy between the size and refractive powers of the eye, such that images are not brought to a proper focus on the retina; consequently, hypermetropia, myopia, or astigmatism is produced [4]
AMBLYOPIA	Dimness of vision without detectable organic lesion of the eye.
CORNEA	The transparent structure forming the anterior part of the fibrous tunic of the eye.
CYCLOPLEGIA	Paralysis of the ciliary muscle; paralysis of accommodation.
CYCLOPLEGIC	An agent that causes cycloplegia.
DILATE	To enlarge or expatiate.
DIOPTER	The refractive power of a lens with a focal distance of one meter; assumed as a unit of measurement for refractive power.
EMMETROPIA	A state of proper correlation between the refractive system of the eye and the axial length of the eyeball, rays of light entering the eye parallel to the optic axis being brought to a focus exactly on the retina.
ESOTROPIA	Strabismus in which there is manifest deviation of the visual axis of an eye toward that of the other eye.
EXOTROPIA	Strabismus in which there is permanent deviation of the visual axis of one eye away from that of the other.
HYPEROPIA	That error of refraction in which rays of light entering the eye parallel to the optic axis are brought to a focus behind the retina, as a result of the eyeball being too short from front to back (farsightedness).
IRIS	The circular pigmented membrane behind the cornea perforated by the pupil; the most anterior portion of the vascular tunic of the eye, it is made up of a flat bar of circular muscular fibers by which the pupil is dilated.
MYDRIATIC	Dilating the pupil. Any drug that dilates the pupil.
MYOPIA	That error of refraction in which rays of light entering the eye parallel to the optic axis are brought to a focus in front of the retina, as a result of the eyeball being too long from front to back (nearsightedness).

UNUSUAL TERMS (Concluded)

OPHTHALMOLOGIST	A physician who specializes in the diagnosis and medical and surgical treatment of diseases and defects of the eye and related structures.
PTOSIS	1. Propolapse of an organ or part. 2. Drooping of the upper eyelid from paralysis of the third nerve on from sympathetic innervation.
REFRACTION	The act or process of refracting; specifically the determination of the refractive errors of the eye and there correction by glasses.
RETINA	The innermost of the three tunics of the eyeball, surrounding the vitreous body and continuous posteriorly with the optic nerve.
RETINOSCOPY	An objective method for investigating, diagnosing, and evaluating refractive errors of the eye, by projection of a beam of light into the eye and observation of the movement of the illuminated area on the retina surface and the refraction by the eye of the emergent rays.
STRABISMUS	Deviation of the eye which a patient cannot overcome. The visual axes assume a position relative to each other different from that required by the physiological conditions.

NONSTANDARD ABBREVIATIONS

A. S. D.	Alabama School for the Deaf
D	Diopters of refractive errors
E. O. C.	Electro-Optics Consultants, Inc.
GRRIS	Generated retinal reflex image system
LCD	Liquid crystal diode
LED	Light emitting diode
OD	right eye
OS	left eye
U	both eyes

TECHNICAL MEMORANDUM

OCULAR SCREENING TESTS OF ELEMENTARY SCHOOL CHILDREN

I. INTRODUCTION

Dr. S. Hudson Hay, a Huntsville, Alabama, ophthalmologist, was interested in developing a reliable low-cost photorefractor system for the early detection of amblyopia in children by using high technology associated with aerospace applications. Dr. Joe Kerr, President of Electro-Optics Consultants Inc., of Huntsville, Alabama, was contacted by Dr. Hay, who requested assistance in developing an ocular screening system. Dr. Kerr, a retired NASA-MSFC employee, approached the MSFC Technology Utilization Office to determine if MSFC could provide assistance in this area. The Technology Utilization Office proceeded to establish an Engineering Application Project with E.O.C. and Dr. Hay, who acted as the medical consultant on the project. The Generated Retinal Reflex Image System (GRRIS) was developed for the purpose of screening for ocular defects.

The GRRIS photorefractor, basically consisting of a 35 mm camera body, a telephoto lens and an electronic flash, was developed under a NASA-Marshall Space Flight Center Technology Utilization Biomedical Applications Engineering Project, a cost-sharing contract with E.O.C. The prototype concept demonstration system developed uses a 1000 mm mirror telephone lens to record the retinal reflex image of subjects at a distance of 5.5 mm.

The prototype system was used to examine the retinal reflex images of 232 persons. One-hundred-thirty-two students were from the Alabama School for the Deaf of Talledega, Alabama, and one hundred persons were from Dr. Hay's private practice. The system was capable of detecting ametropic and non-ametropic eye abnormalities with an accuracy of ninety percent. Dr. Robert R. Jayroe of the MSFC's Data Systems Laboratory provided digital image processing on many of the ASD retinal reflex images. About 50 percent of the retinal reflex 35 mm slides of the ASD students were digitized on the Data Systems Laboratory, Interactive Data Processing System. "The digitized data was read directly onto computer disks and displayed on a black and white television monitor for analysis. The analysis consisted of selecting a rectangular subportion of the image for histogramming, plotting, and recording the intensity values as they occurred in the image. Spatial and spectral intensity variations were examined and the relative integrated reflex intensities of the left eye were compared to those of the right. While the digitization of these retinal reflexes was readily accomplished and optical aberration of the eyes identified, no significant advantage was determined in using this method. It was slower, less accurate and more expensive than the determination of a trained observer" [1].

A second-generation prototype (Fig. 1) was developed to reduce the total system length to less than 5.5 m which required approximately 7.6 m of unobstructed floor space to operate the system, to increase system portability, and to increase the resolution of the retinal reflex images.

This prototype was developed under an extension of Contract NAS8-33819 with Electro-Optics Consultants, Inc. This system was approximately 4 m long, could be assembled and disassembled in less than 25 min, and contained an improved 500 mm

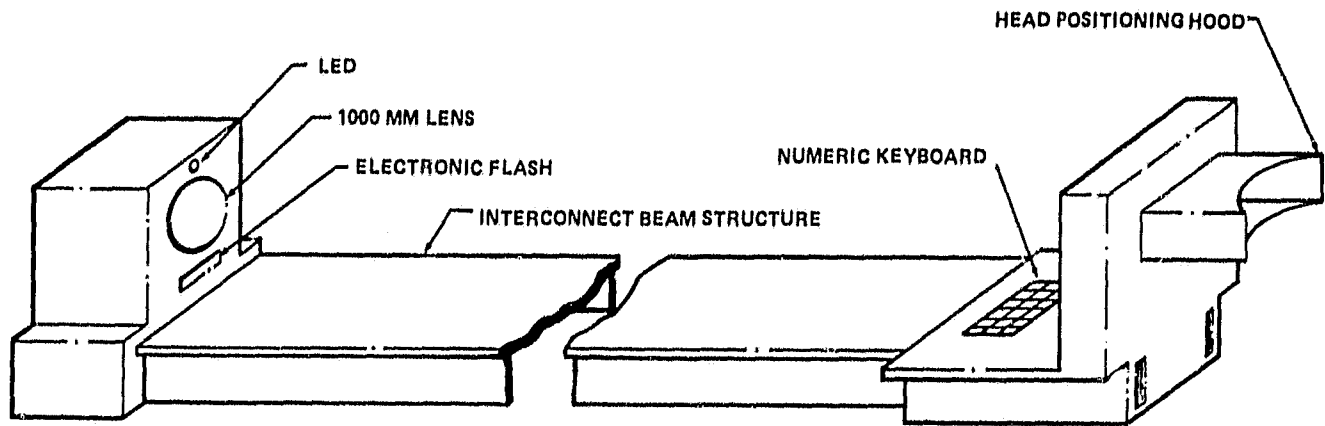


Figure 1. GRRIS photorefractor.

mirror telephoto lens. This 4 m photorefractor system was initially evaluated by Dr. Anthony M. Norcie and Dr. Karla Zadnik, of the Smith-Kettlewell Eye Research Foundation in San Francisco. Norcie and Zadnik used the system to evaluate the eyes of 62 persons, the majority of them less than five years old. All people were refracted with conventional methods (retinoscope, phoropter) for comparison against the 4 m GRRIS photorefractor. The GRRIS photorefractor was able to detect 88 percent of abnormalities found by using conventional retinoscopy methods as shown in Reference 2.

Dr. Hay received a grant from the National Children's Eye Care Foundation through the University of Alabama in Huntsville to study eye mass-screening techniques. A project was initiated by Dr. Hay to photorefract all the Huntsville kindergarten and first grade students using the 4 mm GRRIS photorefractor. The Huntsville Pacesetters Lions Club provided the manpower and logistics to test the students. The project was coordinated by Ms. Cathy Jackson, Dr. Hay's research assistant. Retinal reflex image analysis was provided by Dr. Hay, Ms. Jackson, and the author.

This project involved the largest group of people ever to have been photorefracted with the GRRIS system. In addition, the conventional Snellen (E chart) visual acuity measure was performed at the schools on all the students. All students found to have abnormal retinal reflexes were requested to see a local ophthalmologist for detailed examination to verify ametropic and non-ametropic anomalies detected by photorefraction, which would include a retinoscopy examination. The retinoscopy examination would provide the diopter of refractive error present in all students indicating a hyperopia and myopia eye condition.

II. PRINCIPLES OF OPERATIONS

The human visual system operates on the same principle as a conventional camera system, both having similar components. The retina of the human eye corresponds to the film plane in the camera. Both have a lens system, the camera lens is focused manually, and the eye lens is automatically focused by the ciliary muscle. The amount of light entering the lens is controlled by the aperture in the camera lens, and by the iris in the human eye. The ocular screening system is an instrument capable of testing the human eye system for defects in the retina or lens, and

obstruction in the cornea, anterior chamber, or lens. This is accomplished by making a color photograph of the human eye system. Ocular alignment problems are detected by photographing both eyes simultaneously. The color images of each eye are analyzed for optical or obstruction defects, and both eyes are examined for alignment defects and differences between each eye. Use of color film is critical to the following: (1) detecting minimal refractive errors, (2) determining the difference in refractive error between two eyes, (3) detecting retinal disease, and (4) determining eye alignment defects.

The photorefractor works in principle [2] much like a retinoscope. "It analyzes the retinal reflex produced by an off-axis light source to determine whether an eye is emmetropic or ametropic. In the case of the emmetrope, when light reflecting off the retina is considered as a point source, light rays emerge parallel from the pupil and do not go directly through the camera aperture. This results in the diffuse red appearance of the pupil in a GRRIS photograph of an emmetrope (Fig. 2a).

For the ametropes, light coming from an off-axis retinal point source emerges divergent for the hyperope and convergent for the myope. In the hyperopic eye, the light rays from the top of the pupil pass through the camera's aperture unattenuated, and the upper part of the pupil appears brighter in the photograph (Fig. 2c).

In the myopic eye, light coming off the retina focuses at some point between the eye and the camera (determined by the magnitude of the myopia), and the resultant image is inverted. The light rays from the bottom of the pupil pass through the camera's aperture, and the lower part of the pupil is brighter than the rest of the retinal reflex (Fig. 2b).

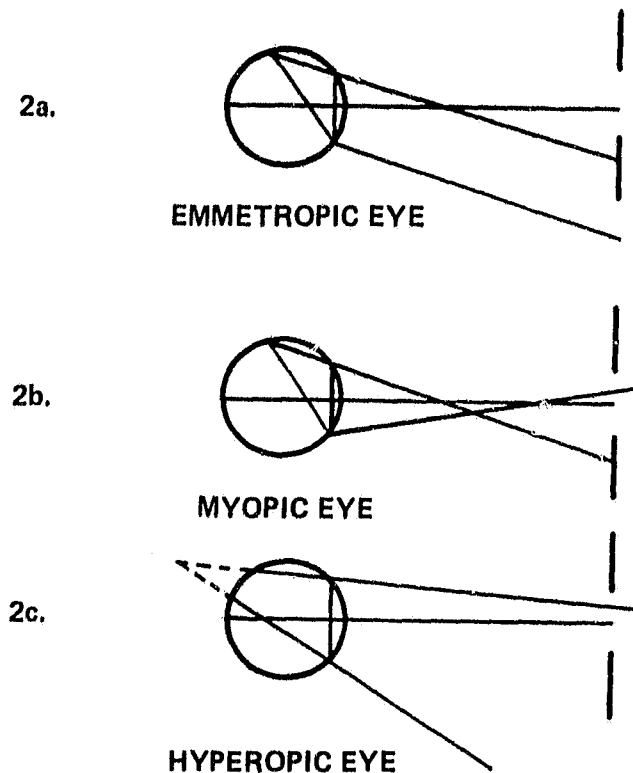


Figure 2. Schematic diagrams of off-axis photorefraction.

III. PROCEDURE

The GRRIS photorefractor was set up in a dark room to facilitate pupil dilation, since cycloplegic agents could not be used. The use of cycloplegic agents would assure large and consistent pupil size; however, such agents must be administered by a professional licensed in the use of diagnostic pharmaceutical agents. This study has shown that sufficient dilation can be achieved in a dark-room environment to obtain satisfactory retinal reflex images.

The students at each school were assigned to a two-alpha, three-digit identification code; e.g., student No. 20 at Jones Valley School was assigned to JV020 identification code. A master log book was maintained listing all students by name and identification code for each school.

Retinal reflex images were recorded on conventional Kodak Ektachrome ASA 64 slide film. The slides were then projected onto a screen for ocular analysis. To obtain a permanent record for comparative analysis and pupil-size measurement, a 4 in. x 5 in. print was obtained from each slide. Ocular abnormalities, classification, pupil size and identification code for each student were recorded and stored in a Hewlett Packard HP-75C portable computing system. Appropriate software for HP-75C was developed for sorting and analyzing data.

IV. EMMETROPIC RETINAL REFLEXES

Table 1 provides an overall summary of the Huntsville kindergarten and first grade screening study. A total of 2938 students were enrolled in the kindergarten and first grades. Parental permission was obtained to photorefract 1835 students; of this number, 1110 were emmetropic, 546 had eye abnormalities, and 178 were not classified because of erroneous data. Emmetropic retinal reflexes of the type shown in Figure 3 accounted for 60 percent of the total population that was photorefracted.

A normal or emmetropic retinal reflex, as represented by student EC24, has three basic characteristics: uniform retinal color between the OD and OS, a corneal reflection that is either centered or slightly convergent (toward the nose) in the retinal reflex, and relatively uniform pupil size when comparing the OD against the OS. The color of the retinal reflex varies by race, and there are some color variations within the races and differences in pupil size. Generally, as shown in Figure 3 (EC24), caucasians have red retinal reflexes, and the blacks have a red-brown or brown retinal reflex (student CO7, Fig. 3).

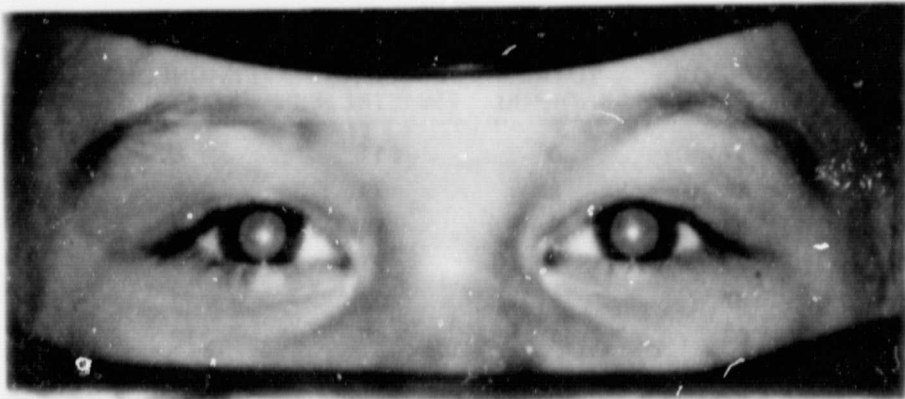
V. GRRIS PHOTOREFRACTOR VERSUS SNELLEN VISUAL ACUITY

The Snellen visual acuity measure, or "E-Chart," is one of the standard tests to measure the visual acuity of students in school systems. The Snellen system has some imperfections. For example, it generally will detect a moderate to high refractive error of myopia and hyperopia. It should be pointed out that the 20/30 line was used for testing the Huntsville school children. Use of the 20/20 line would have generated a higher number of failures. The GRRIS photorefractor is capable of detecting a wider range of refractive error anomalies, +1.00 to greater than +10.00 diopters of hyperopia and -0.75 to greater than -10.00 diopters of myopia. In addition,

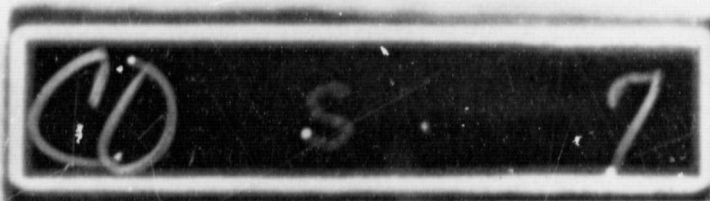
TABLE 1. LIST OF ALL DATA ABNORMALS AND
EMMETROPES BY SCHOOL

<u>SCHOOL</u>	<u>TOTAL STUDENTS</u>	<u>STUDENTS SCREENED</u>	<u>TOTAL ABNORMAL</u>	<u>POTENTIAL EMMETROPES</u>	<u>ERRONEOUS DATA</u>	<u>EMMETROPES</u>
MS	21	17	6	11	0	11
JV	64	37	8	29	3	26
FA	74	25	9	16	6	10
CH	75	36	7	29	7	22
DH	78	37	15	22	1	21
LI	93	63	14	49	12	37
BL	140	47	11	36	2	34
EC	93	54	15	39	4	35
WI	95	69	13	66	3	33
CP	139	83	20	60	3	57
CO	129	96	32	64	11	53
LA	136	54	20	34	2	32
MC	136	73	21	52	8	44
MO	124	99	23	76	13	63
MG	125	91	18	73	14	59
TH	117	96	36	60	4	56
WE	146	85	23	62	6	56
WH	141	123	31	92	13	79
ML	150	72	19	53	3	50
CA	261	192	76	116	12	104
RI	391	263	87	176	31	145
RH	210	123	42	81	15	66
TOTAL	2938	1835	546	1288	178	1110

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EC24 (CAUCASIAN) RETINAL REFLEX



CO 7 (BLACK) RETINAL REFLEX

Figure 3. Emmetropic retinal reflexes.

the GRRIS photorefractor is capable of detecting 0.5D differences between two eyes [1]. The photorefractor is also capable of detecting non-ametropic anomalies, such as strabismus, ptosis, and obstruction in the lens area of the eye, i.e., cataract or tumor.

Table 2 summarizes all schools of the GRRIS photorefractor versus the Snellen visual acuity measurement. Of the 1657 students with valid retinal reflexes, 111 failed the "E-Chart," and 507 were indicated abnormal by the photorefractor, a significant difference. Of the 111 that failed the "E-Chart," 72 were detected by the photorefractor and 39 were missed by the photorefractor. Another way to look at the numbers is that GRRIS missed only 39 (2.3 percent) of the total students having ocular anomalies as compared to the E-Chart visual acuity measure which missed 436 (26 percent) of the total 1696. The 1696 figure includes the 39 that were missed by GRRIS and were classed as emmetropes.

TABLE 2. SUMMARY OF ALL SCHOOLS —
GRRIS VERSUS SNELLEN ANOMALIES

SCHOOL	STUDENTS SCREENED	GRISS AMETROPIC & NON-AMETROPIC ANOMALIES	SNELLEN VISUAL ACTIVITY DATA			
			FAILED "E" CHART	DETECTED BY GRISS	Δ MISSED	TOTAL ABNORMAL
MS	17	6	2	2	0	6
JV	47	8	2	2	0	8
FA	25	9	6	6	0	9
CH	36	7	2	2	0	7
DH	37	14	3	2	1	15
LI	63	11	5	2	3	14
BL	47	11	0	0	0	11
EC	54	14	2	1	1	15
WI	69	12	3	2	1	13
CP	83	18	4	2	2	20
CO	96	31	1	0	1	32
LA	54	19	6	5	1	20
MC	73	17	8	4	4	21
MO	99	22	7	6	1	23
MG	91	17	1	0	1	18
TH	96	30	8	2	6	36
WE	85	23	0	0	0	23
WH	123	25	13	7	6	31
ML	72	19	0	0	0	19
CA	192	75	7	6	1	78
RI	263	80	24	17	7	87
RH	123	39	7	4	3	42
	1657	507	111	72	39	546

VI. AMETROPIC ANOMALIES

Ametropic anomalies accounted for 408 (80 percent) of all the anomalies detected during the study. Ametropic anomalies involve a discrepancy between the size and refractive powers of the eye: myopia, hyperopia, and astigmatism. Figure 4 shows a breakdown of these 408 ametropic anomalies: 198 (49 percent) hyperopia OU, 94 (23 percent) myopia OU, 52 (13 percent) hyperopia OD or OS, 29 (7 percent) myopia OD or OS, 28 (7 percent) myopia/astigmatism OU, and 7 (2 percent) hyperopia/astigmatism OU.

Ametropic students would have problems in school. Hyperopes with moderate to major refractive errors would have problems reading close up, and hyperopes, with moderate to major refractive errors, would have problems reading written information on a blackboard.

The probable reasons the Snellen visual acuity measure failed to detect a higher percentage of abnormalities are that the system is insensitive to minimal hyperopes, and it has difficulty in detecting non-ametropic types of anomalies such as strabismus. On the other hand, the 39 that were missed by GRRIS probably resulted from either latent hyperopia or small pupil size, which masked minimal to moderate myopes and hyperopes.

"The detection of latent hyperopes (hyperopes who can easily accommodate to overcome some or all of their refractive error) is difficult with any technique which measures refractive error. A clinician relies on the results of many visual tests to make this diagnosis, and the use of the cycloplegic agents often confirms the suspicion of high hyperopia [2]."

VII. CLASSIFICATION OF ANOMALIES

It became apparent in this study that it was necessary to establish some sort of defect severity classification to separate minor or minimal refractive errors from large or major refractive errors. Ideally, for precise classification, it would require that each of these students be subjected to cycloplegia and retinoscopy. However, funding was not available for these procedures.

The GRRIS photorefractor was developed as an ocular screening instrument to be operated by semi-professionals. Currently, only half a dozen professionals and semi-professionals in the Huntsville, Alabama, area are skilled at reading these retinal reflex images. A need existed to establish a comparative inspection example chart that would enable semi-professionals to classify each retinal reflex slide and determine whether or not an ocular abnormality exists. The GRRIS photorefractor is capable of detecting six different types of ocular anomalies as listed below:

A. Ametropic

1. Hyperopia
2. Myopia
3. Astigmatism



DH 16 - MYOPIA OU
TOTAL 94 - 23%



LA 6 - MYOPIA OD OR OS
TOTAL 29 - 7%



LA 39 - HYPEROPIA/ASTIGMATISM OU
TOTAL 7 - 2%



CA 57 - HYPEROPIA OU
TOTAL 198 - 49%



EC 54 - HYPEROPIA OD OR OS
TOTAL 52 - 13%



WE 31 - MYOPIA/ASTIGMATISM OU
TOTAL 28 - 7%

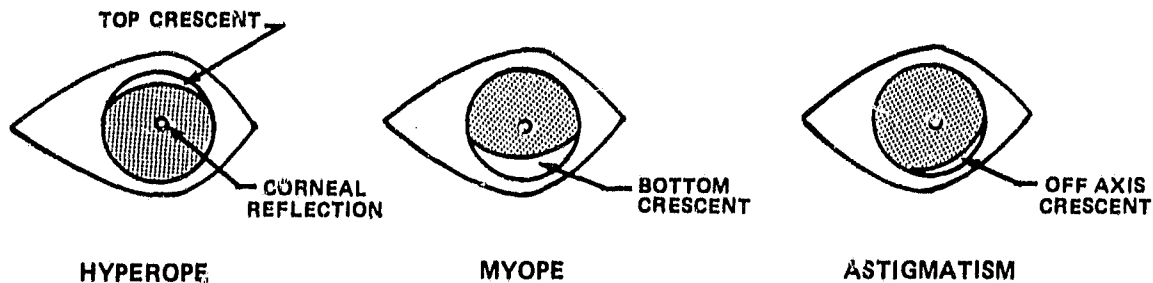
Figure 4. Refractive error anomalies.

B. Non-Ametropic

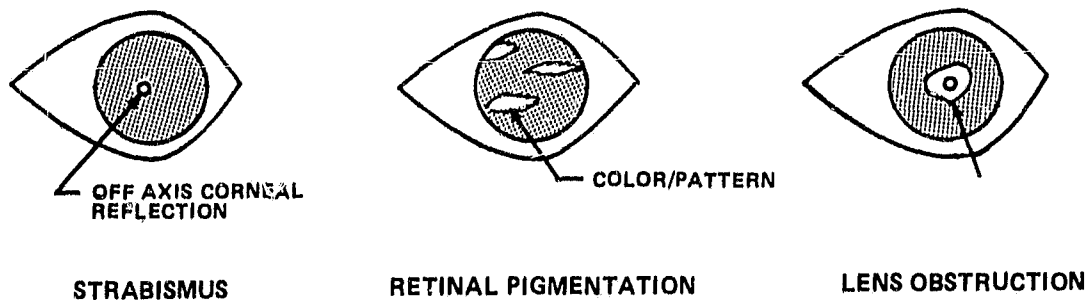
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1. Strabismus
2. Retinal pigmentation/retinal pattern
3. Obstructions in the lens.

Each of the above described ametropic and non-ametropic anomalies has its own type of signature as indicated below.



A. AMETROPIC



B. NON-AMETROPIC

It was the author's intent to establish a relatively simple visual classification scheme that could be readily understood and followed by semi-skilled evaluators. The classification criteria selected were minimal, moderate and major for the ametropic types of anomalies defined below.

<u>CLASS</u>	<u>DESCRIPTION</u>
(1) Major	Any crescent greater than 50 percent of the retinal reflex.
(2) Moderated	A crescent greater than minimal but less than 50 percent of the retinal reflex.
(3) Minimal	A small or partial crescent.

Samples of these three classifications are shown in Figure 5. The projected range of refractive error for each of the classifications was based upon similar ametropes that were verified by retinoscopy examination obtained during the Alabama School for the Deaf and Smith-Kettlewell studies. A breakdown of the 507 abnormal reflexes is as follows: 103 major, 186 moderate, and 218 minimal.

VIII. EFFECT OF PUPIL SIZE ON AMETROPEs

In their study, Norcia and Zadnik [1] made reference to inconsistent pupil sizes and how they affect the GRRIS refractive error indications. They suggest that pupils should be at least 5 mm in diameter in order for a photograph to be a valid measure of refractive error, a conclusion with which the author agrees. Students that were ranked as minimal, and had pupils that were greater than 8 mm in diameter, would probably show as emmetropes with 5 mm diameter pupils.

Consistent pupil sizes of 8 mm or greater can be achieved only by the use of mydriatic drops, which would require 30 to 45 min to achieve maximum dilation of the eyes. The requirement that mydriatic agents can be administered only by a licensed professional would eliminate a major advantage of the GRRIS photorefractor, which was designed to be used by semi-professionals.

The eyes of Huntsville kindergarten and first grade students were photorefracted under a variety of semi-darkened room conditions; i.e., lighting was not uniform from school to school. However, eyes of 5- and 6-year-old children have the ability, in most instances, to dilate sufficiently to obtain an acceptable pupil diameter for subsequent analysis.

The pupil size was measured on each of the 507 ametropic and non-ametropic students. This was accomplished by using one of the slides taken by Norcia and Zadnik that had a strip of centimeter tape affixed to the forehead of a patient. A 4 in. x 5 in. enlarged color print was made of this slide. Two items were measured on the 4 in. x 5 in. print for reference dimension: (1) extrapolation of the centimeter scale on the forehead, and (2) the length of the LCD display where the school and student identification appears. A 4 in. x 5 in. print was made of each of the 507 students, each print having the same LCD dimensions as the reference print. The pupil diameters were then measured by using a template with circles measuring from 2 to 12 mm in diameter.

The distribution of pupil size is shown in Table 3. The range of distribution is from 4 mm to 10 mm and only 3 percent (13) were 5 mm or less in diameter, and 70 percent (357) were 7 to 8 mm in diameter. Pupil size does have an effect on ametropes, as shown in Figure 6. A major ametropia can be detected by GRRIS with only a 4 mm pupil size (student CH22, Fig. 6). Student JV26 (Fig. 6) was photorefracted twice. The pupils in the photo on the left measured 8 mm, and the student was classified as a minimal hyperope; the pupils in the photo on the right measured 9 mm and the student classified as a moderate hyperope. Student JV34 (Fig. 6) was also photorefracted twice. In photo on the left, the pupil measured 6 mm size, and the eyes were classified as emmetropic, and in the photo on the right, the pupils measured 9 mm, and the student was classified as a minimal myope.

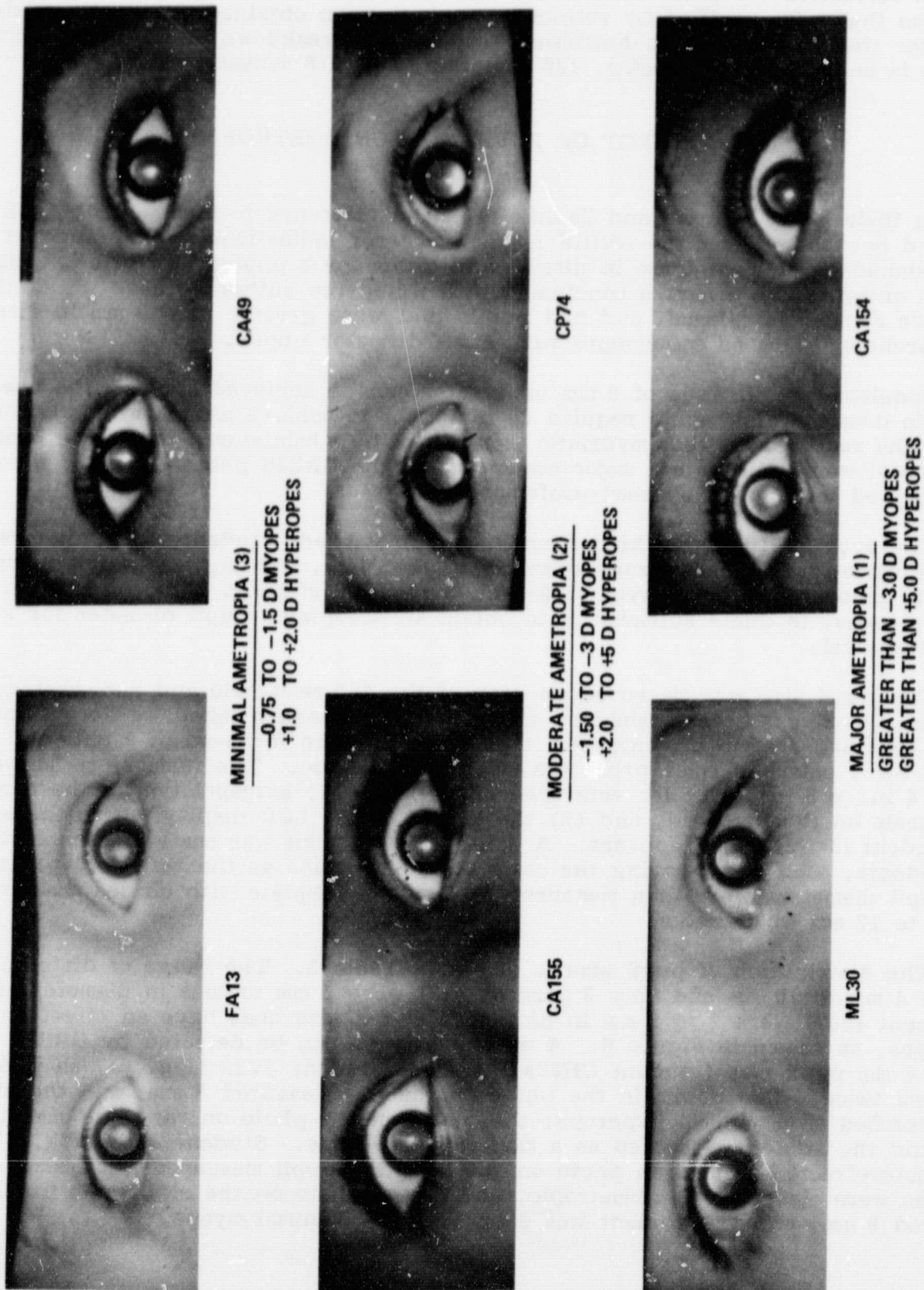
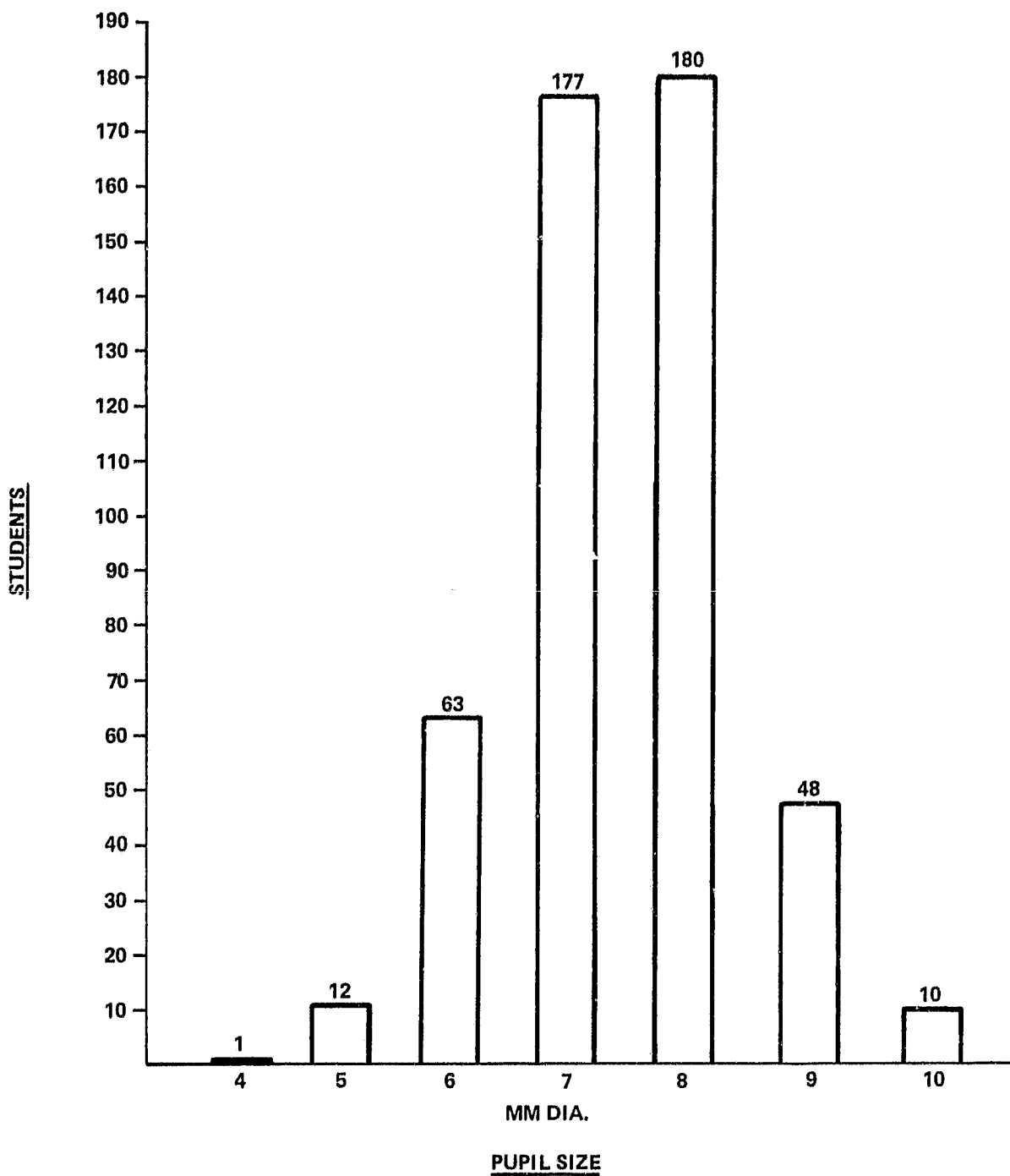


Figure 5. Classification of refractive error anomalies.

TABLE 3. PUPIL SIZE DISTRIBUTION

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OF POOR QUALITY





CH 22 - MAJOR - 4 MM PUPILS



JV-A-26 - MINIMAL - 8MM PUPILS



JV26 - MODERATE - 9MM PUPILS



JV 34 - EMMETROPIC - 6MM PUPILS



JV 34 - MINIMAL - 9MM PUPILS

Figure 6. Effect of pupil size on ametropias.

We can assume from Table 3 that the pupil size distribution of the ametropes would be similar for the 1288 students ranked as emmetropes. Therefore, 3 percent or 39 students in that group would have pupil sizes of 5 mm or less, and there is a high probability that any minimal ametropes would not be detected if photorefracted.

IX. NON-AMETROPIC ANOMALIES

Non-ametropic anomalies account for less than 10 percent of the total tested. These anomalies were pupil size, esotropia, retinal pigmentation, exotropia, obstruction and ptosis. Samples are shown in Figure 7.

A 2 mm or greater diameter between the OD and OS-CQ21 (Fig. 7) may not be indicative of an ocular problem; however, it could be a sign of a neurological problem. People having significant pupil size differences should certainly consider an examination by an ophthalmologist. Strabismus LA44 (esotropia) and CP46 (exotropia) (Fig. 7) can be readily detected by observing the location of corneal reflections with respect to the center of the retinal reflex. Retinal pigmentation shown in RI100 (Fig. 7) is another gray area. The retinal pigmentation detected in several of the students at A.S.D. was caused by their mothers having rubella during pregnancy. This condition can also be indicative of some other disease such as diabetes.

Large obstructions, which may be caused by cataracts or tumors, are relatively easy to detect (BL47, Fig. 7). Ptosis, or droopy eye lids, is also easy to detect (WE77, Fig. 7).

Strabismus is essentially a deviation of the eye which a patient cannot overcome: esotropia is a strabismus where the visual axis is toward the other eye, and exotropia where the visual axis is away from the other eye. Detection by photorefraction is dependent upon the position of the corneal reflection with respect to the iris, either centered, or left or right. Since the flash is essentially a point source illumination located just below the camera lens, the corneal reflection is always located near the center of the eye on the visual axis, which is slightly toward the nose. Note the emmetropic eye (Fig. 8) just below the OD eye. The OS eye is shown as esotropic, and the corneal reflection is located near the right edge of the iris (esotropic eye). Conversely, the corneal reflection is located near the left edge of the exotropic eye. Convergent and divergent strabismus, involving both eyes, is also illustrated.

Large angles of strabismus are relatively easy to detect (Fig. 9). The student CA167 has exotropia OD; notice that the corneal reflection is located on the iris. Student CP46 (Fig. 9) has exotropia OS, and the corneal reflection is near the iris.

Small-angles of strabismus are difficult to detect. Student LI13 has esotropia (divergent strabismus); notice that the corneal reflections are only slightly off center. Large angles of esotropia are also detectable by retinal reflex color and the corneal reflection. Kari Kaakinen [3] notes that the corneal reflection became lighter at large angles, 9 to 13 deg, of esotropia. This phenomenon can be seen in the two esotropia samples: ML26 with esotropia OD, and LA44 with esotropia OS.

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CO 21 - PUPIL SIZE
TOTAL 16 - 3%



LA 44 - ESOTROPIA OD OR OS
TOTAL 7 - 1%



RI 100 - RETINAL PIGMENTATION
TOTAL 10 - 2%



CP 46 - EXOTROPIA OD OR OS
TOTAL 5 - 1%



BL 47 - LENS OBSTRUCTION
TOTAL 1 - LESS THAN 1%



WE 77 - PTOSIS
TOTAL 2 - LESS THAN 1%

Figure 7. Non-ametropic anomalies.

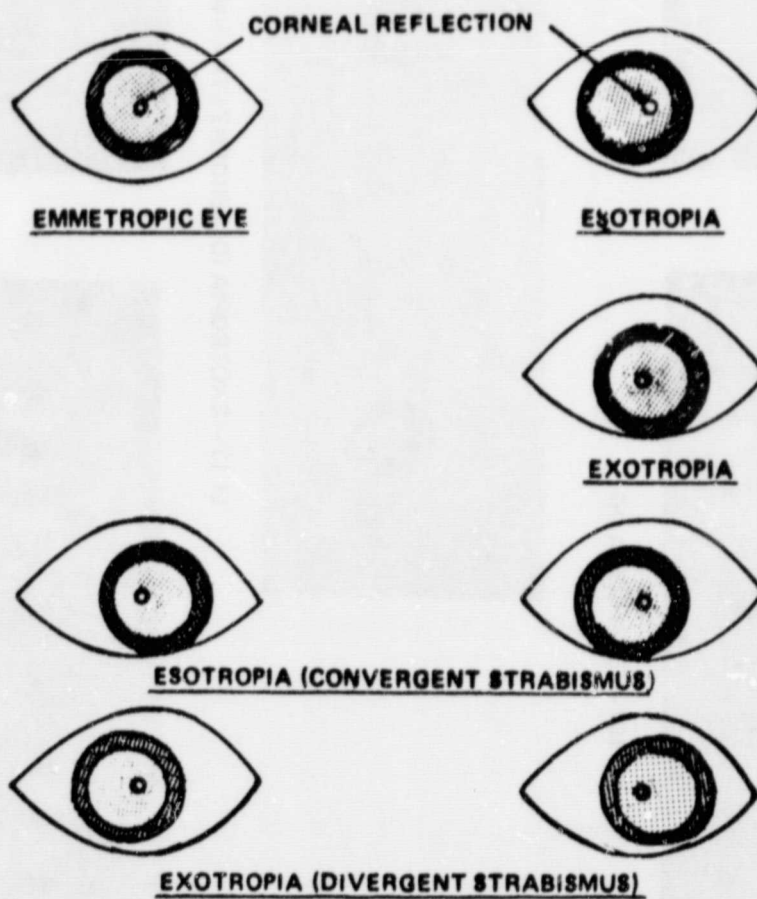
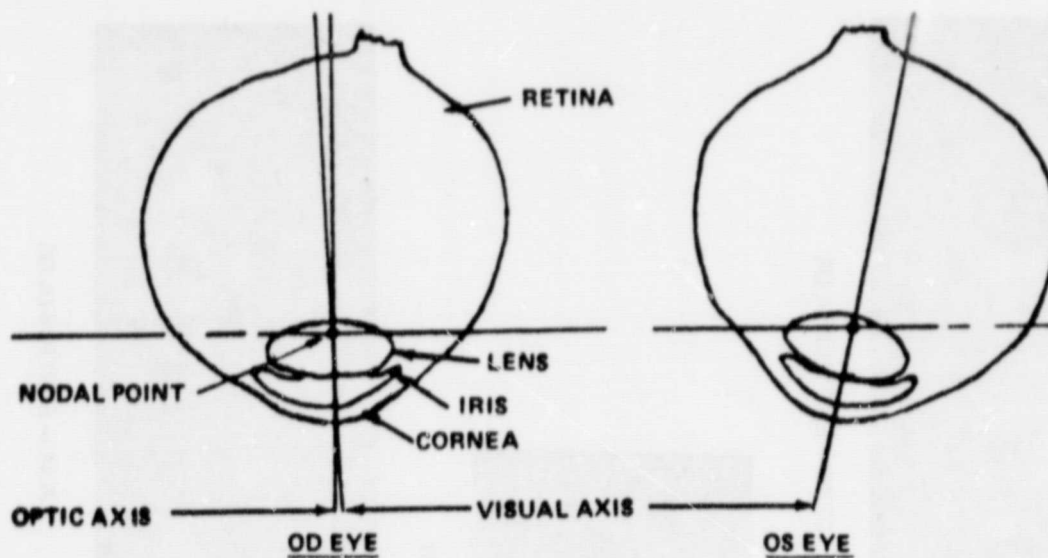


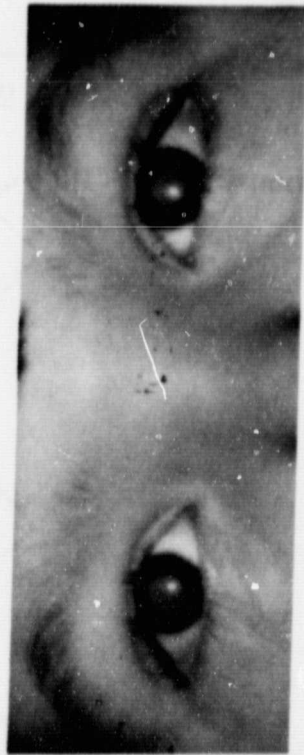
Figure 8. Strabismus.



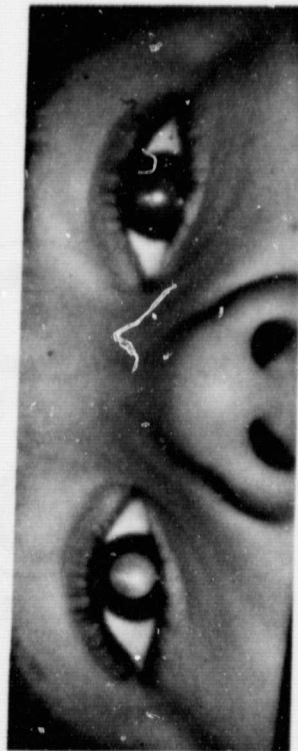
CA 167 - EXOTROPIA OD



CP 46 - EXOTROPIA OS



LJ 13 - EXOTROPIA (DIVERGENT STRABISMUS)



ML 26 - EXOTROPIA OD



LA 44 - ESOTROPIA OS

Figure 9. Strabismus anomalies.

X. RETINAL REFLEX COLOR DIFFERENCES

Retinal reflex color differences between eyes are caused by several factors, namely pupil size differences, eye alignment with respect to the lens and flash, and refractive error. Most retinal reflex color differences are caused by pupil size and eye alignment abnormalities.

A. Pupil Size

Figure 10 shows a sample of how pupil size affects the retinal reflex color. Student RI180 has 4 mm pupils and the color is a dark red. The 4 mm pupils are restricting the amount of light from the flash. Student RI8 has large 10 mm pupils which allows the maximum amount of light to enter the eyes and the reflex color is bright red. Student WH53 has an 8 mm OD pupil and a 7 mm OS pupil. The OS reflex is obviously darker than the OD. Even a 1 mm difference can be detected as shown in student MG71 who has a 7 mm OD pupil and a 6 mm OS pupil. A 2 mm difference in pupil size is significant and the color difference is easily detected. Student WH66 has a 5 mm OD pupil size and 7 mm OS pupil. Note, that only a small amount of light had penetrated to OD eye which shows almost no retinal reflex. Student RI138 has a 6 mm OD pupil and a 4 mm OS pupil.

B. Eye Alignment

Eye alignment, with respect to the student fixation on the LED, which is centered on the vertical axis of the lens and located above the lens, is critical. Any significant amount of left or right eye deviation from the LED will give a false esotropia indication as shown in the Figure 11 examples.

Student MO67 has a left gaze which indicated the OD eye as esotropic. However, notice the location of the corneal reflections. Also, the reflections in both eyes are located to the left of center near the left edge of each iris. The same analysis was applied to student TH6, the only difference being a right gaze. The two pictures of the student shown in the center of Figure 11 were taken about one minute apart. The picture on the left indicates artificial esotropia of the OD eye; the picture on the right shows that the retinal reflexes are uniform in color, the only problem being slightly myopic OU. True strabismus is shown in the lower two pictures of Figure 11: student BL30 indicates esotropia OD, and student CA167 indicates exotropia OD. Notice that in both cases the corneal reflection is relatively centered in each of the OS eyes.

C. Large Refractive Errors

In some cases where a large refractive error is involved in one eye, the eye having the large refractive error will appear brighter than the emmetropic eye. Plate 31 MATT from Reference 1 (Fig. 12) shows a patient with an emmetrope OD and -17.5 DS in the OS.

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RI 8 - 10MM OU



MG 71 - 7MM OD, 6MM OS



RI 138 6MM OD, 4MM OS



RI 180 - 4MM OU



WH53 - 8MM OD, 7MM OS



WH 66 - 5MM OD, 7MM OS

Figure 10. Effect of pupil size on retinal reflex color.

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TH6 - RIGHT GAZE



EYES FOCUSED ON LED



CA 167 - EXOTROPIA OD



MO 67 - LEFT GAZE



LEFT GAZE
(ARTIFICIAL ESOTROPIA)



BL30 - ESOTROPIA OD

Figure 11. Effect of eye alignment on retinal reflex color.

D. Summary

When a color difference is observed between the OD and OS, generally the following evaluation criteria should be applied.

1) Are the pupil sizes uniform? A 1- to 2-mm difference will show a color difference; the eye having the smaller pupil will be darker.

2) Determine the position of the corneal reflections in both eyes. If both corneal reflections are located off center either left or right, the indication would be false esotropia either OD or OS. If one corneal reflection is centered, the opposite eye would indicate a valid exotropia or esotropia condition.

3) If both eyes have similar pupil sizes and the corneal reflection is centered, then a large refractive error would be suspect in the lighter colored eye.

XI. PROBLEM AREAS

Several procedural and equipment problems were encountered in the Huntsville study. The procedural problem areas involved 178 students (or 10 percent of all data): (1) partial or obscured retinal reflexes caused by small pupils and partially or totally closed eyelids, and (2) positioning of students heads in the photorefractor. The equipment problems involved were (1) double corneal reflection which appeared in greater than 50 percent of all data and (2) poor performance of the LCD identification system.

A. Procedural Problems

The retinal reflex evaluation problems encountered in the Huntsville study did not seem to be as pronounced during the A.S.D. or Smith-Kettlewell studies. Approximately 10 percent, or 178 out of 1835 students photorefracted, were difficult to evaluate properly because of small-diameter pupils, eyelids partially closed obstructing the retinal reflexes, total eyelid closure, improper eye alignment, or improper head position. It was estimated that 80 percent of the 178, or about 140 students, had small, or extra small, retinal reflexes (see student CO29, Fig. 12). The majority of those students that were difficult to evaluate were black. The blacks had darker retinal reflexes than caucasians, and this condition, coupled with small pupil size, yielded very little reflected light to be recorded on the film.

Another small percentage of the students had poor head position, the head not being properly positioned in the hood, which resulted in out-of-focus images. For example, the head of student CA184 (Fig. 12) was cocked to the left, and student CA4 (Fig. 12) had partially closed eyelids. Apparently, the head position was not always carefully checked before the students were photorefracted.

B. Equipment Problems

Two minor equipment problems were noted during the study, the first of which was the double corneal reflection. This can be readily observed in the retinal reflexes shown in student CH5 of Figure 12. The main corneal reflection is located near the center of the retinal reflex, and the secondary corneal reflection is smaller

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CO 29 - SMALL DIA. PUPILS



CA 184 - HEAD POSITION



CO 7 - NORMAL HOOD POSITION



PLATE 31 MATT



CA 4 - EYE LID OBSTRUCTION



CH 5 SECONDARY CORNEAL REFLECTION
CONCAVE HOOD POSITION

Figure 12. Problem areas.

and located just above the main reflection. The secondary corneal reflection is absent from the reflexes of student CO7. Analysis of the data indicates that this was caused by the head positioning hood. The hood is flexible, and when some of the students positioned their head in the hood, the upper part would flex down as shown in CH5. Since the flash was located below the camera lens, the light would reflect off the smooth inner surface of the hood and cause a secondary corneal reflection. When the upper part of the hood was level or concaved upward, no secondary reflection was produced (CO7).

The LCD problem concerned the light outline of the student identification number that appeared in the LCD. The purpose of the numbers was to identify each student that was photorefracted during the study. The numbers on the slides were too faint to be legible on the 4 in. x 5 in. internegatives that were made to produce the 4 in. x 5 in. color prints. To obtain 4 in. x 5 in. prints with legible identification data, it was necessary to manually enter the identification data on the internegative with a fine tip black felt pen.

XII. INACCURACIES OF GRRIS

The GRRIS photorefractor does not detect all refractive error discrepancies. During the Huntsville study, of the 1835 students screened, 111 failed the Snellen visual acuity measure test, and of these 111 students, 72 were detected by GRRIS and 39 were missed (Table 2). Some of the 39 that were missed are shown in Figure 13. The 39 that were missed by the evaluators were classified as emmetropes, although most were scheduled to be re-photorefracted because of their small retinal reflex (ECM37).

A. Pupil Size

Student RI272 passed the visual acuity test 20/30 OU, although there was a lighter color streak across the retinal reflexes of both eyes, especially the OD. Student WHM54 failed the visual acuity test, 20/50 OS, and there is a light-colored area in the OS eye. Student DHM23 also failed the test, 20/70 OS, and had 8 mm diameter pupils; and the OS eye appears emmetropic (possible uncontrolled accommodation). Students WIM49 and ECM37 both failed the test, 20/50 OU. Both students had 6 mm diameter pupils, and were evaluated as emmetropic, although student ECM37 had very dark retinal reflexes. Retinoscopic examination data, which was not available on any of these students, would have provided the evaluators with information about the type of ametropic defect (myopia or hyperopia) and the diopter of refractive error. GRRIS cannot detect, with any consistency, hyperopes with less than 2 diopters of refractive error if the pupil size is 6 mm or less. GRRIS does better on myopes, and the detection threshold sensitivity seems to be around +1 to +1.5 diopter with 6 mm pupils.

B. Uncontrolled Accommodation

GRRIS has difficulty in detecting latent hyperopes [2], where the person is able to accommodate and overcome some or all of their refractive error. "A clinician relies on the results of many visual tests to make this diagnosis, and the use of cycloplegic agents often confirms any suspicion of high hyperopia. The effects of

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WE 45



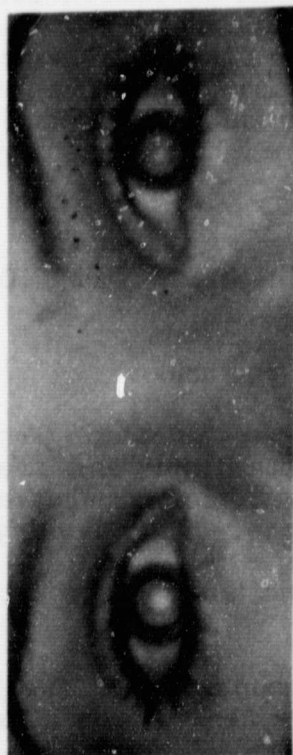
WH-M-5A - 7MM PUPILS - 20/50 OS



EC-M-37 - 6 MM PUPILS - 20/50 OU



DH-M-23, 8MM PUPILS, 20/70 OS



RI 272 EMMETROPE



WI-M-49 - 6MM PUPILS - 20/50 OU

Figure 13. Inaccuracies of GRRIS photorefractor.

accommodation on GRRIS imagery are shown clearly in Figure 14 (plate 3). The subject in these photographs is an adult with a small-angle strabismus who was instructed to keep his eyes straight (Plate 3a) and to try for best focus (Plate 3b). The subject was able to do this task and to report which state he was maintaining. With his eyes straight (Plate 3a), both eyes show approximately equal amounts of hyperopia. (This photograph was also used for his ranking with respect to retinoscopy; it fell near the 1:1 line). However, when the subject accommodates with his nondeviating eye (Plate 3b), the hyperopic fringe is absent. (In one of the demonstration photographs supplied with the GRRIS (Plate 4), a child with +5.37 DS refractive error in the left eye presents that eye as emmetropic. The child would, however, have been referred on the basis of the 10 deg of exotropia)" [2].

C. Detection of Astigmatism

The capability of the GRRIS to detect astigmatism is limited, as pointed out by Norcia and Zadnik [2]. "Since the GRRIS photorefractor measures refractive error for the vertical meridian of the eye only, the axis of astigmatism is not determinable, especially for oblique and vertical axes. With-the-rule astigmatism (axis 180 deg) is measured as total power in the vertical meridian, while against-the-rule astigmatism (axis 90 deg) seems to be measured roughly as the equivalent sphere (half the power of the astigmatic correction in addition to the spherical component of the refractive error). Astigmatism of oblique orientation also shows up as the spherical equivalent, but orientation is not evident. This could lead to an underestimate of moderate astigmatic errors with no accompanying spherical refractive error. For example, 2.00 D of astigmatism is clinically significant. It may, however, show up as only 1.00 D and perhaps be dismissed as not significant." Only 35, or 7 percent of the students photorefracted were classified as having significant astigmatism (see students W31 and LA39 on Fig. 4). It is obvious that either the myope or hyperope crescent is not centered with respect to the vertical meridian of each eye. Here again, retinoscopic examination data was not available for verification of the refractive error. It appears that some correlation could be established between the off-axis location of the crescent and 1-2 D of astigmatism, based upon the relatively large data base of the Huntsville study. Possibly, any person with pupils 8 mm or larger, and classified as a minimal hyperope or myope with any indication of significant astigmatism, should be referred for retinoscopic examination.

XIII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The GRRIS photorefractor is capable of detecting anisometropic, ametropic, and some non-ametropic eye anomalies. Anisometropic and ametropic anomalies are hyperopia, myopia, and astigmatism. Non-ametropic anomalies are strabismus, retinal pigmentation/pattern and lens obstructions. The advantages of GRRIS are as follows:

- 1) The system is non-invasive and not hazardous to the person being photorefracted.
- 2) The system requires minimal cooperation of the person being photorefracted. The person is required only to focus his/her eyes on a flashing LED and open wide his/her eyelids.

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Plate 3a. Eyes straight,
accommodation relaxed.
Hyperopia apparent in both
eyes.

Plate 3b. Accommodation
for best focus, non-accom-
modating eye deviates.
Hyperopic fringe is absent
from accommodating eye.

Plate 4. GRRIS photograph
supplied with instrument.
+5.37 D refractive error is
not visible in left eye.

<u>SLIDE NO.</u>	<u>AGE</u>	<u>SEX</u>	<u>RACE</u>
341	6	F	W
<u>REFRACTIVE ERROR</u>		<u>OCULAR ALIGNMENT</u>	
-6.25 - 1.25 X 25		10 LET	
+6.00 - 1.25 X 165			

Figure 14. Refractive error accommodation.

- 3) The system is portable.
- 4) The cost of the slide for each person is about 30 cents, or less if bulk film is used.
- 5) The system can be operated by semi-professionals.
- 6) Semi-professionals can perform the retinal reflex image analysis with some training, and with the aid of sample images.
- 7) A permanent record is established for the person's eyes.
- 8) Accuracy of the system is probably at least 90 percent with respect to detecting anisometropia, ametropia, and strabismus.
- 9) The system has other applications, such as the screening of infants and the determination of contact lens power [1].
- 10) The system can determine deficiencies of the lens power of glasses. For example, student WE45 (Fig. 13) was photorefracted with his glasses (note minimal myope OU).

B. Recommendations

Although the current 4-m system performs satisfactorily, it needs optimization in several areas: (1) improvement of image quality and portability, (2) determination of threshold sensitivity of anisometropes and ametropes, and (3) establishment of a comparative analysis retinal reflex matrix for semi-professional evaluators.

1) Image Quality - The current Celestron 500 mm lens has a depth of field, at a sharp focus point, of less than 13 to 14 mm which resulted in many out-of-focus pictures. In addition, the lens does not seem to have the ability to resolve good detail. It is recommended that an improved lens be obtained having a greater resolution capability and an increased depth of field at 4 m of at least 20 to 25 mm.

2) Portability - The 4 m GRRIS photorefractor system is portable but not ideal. The system's mass is approximately 46 kg, and consists of three relatively large subassemblies: (1) head positioning station, (2) camera station, and (3) inter-connect beam. One person cannot easily carry the system, and it requires 20 to 25 min to assemble and disassemble. It is recommended that the GRRIS be redesigned so that one person could easily carry the system and reduce the setup time to less than 10 min. Consider the possibility of reducing the total system length to less than 4 m.

3) Threshold Sensitivity - Threshold sensitivity should be determined for anisometropes/ametropes at two different pupil sizes: 5 mm and 10 mm. Of particular interest is to determine the refractive error through retinoscopic examinations of a sample of students who are classified as minimal hyperopes and myopes with 5 mm and 10 mm size pupils. For the 5 mm pupils, this would provide a threshold sensitivity value in diopters that could be used as a baseline reference guide (possible 3D for hyperopes and 2D for myopes). The minimal indication in 10 mm size pupils may be 0.75D for hyperopes and 0.5D for myopes. This type of data would aid in developing the comparative analysis retinal reflex matrix for evaluators.

4) Analysis Matrix - Presently, there are only a half dozen people in the Huntsville area who are skilled at reading and interpreting retinal reflex images. Commercialization of the GRRIS photorefractor cannot be accomplished unless semi-professionals can perform the image analysis without any extensive special training. This training can be accomplished by the use of video tapes and photographic samples of anisometropic, ametropic and non-ametropic anomalies. This approach may require retinoscopic examinations of 50 to 100 students to establish a good baseline of data. This method should also include the development of a simple and rapid technique for measuring pupil sizes.

5) Improved LCD - The present LCD does not have adequate performance. Problems were encountered in entering numbers on the display, resulting in poor contrast of the numbers on the slides which were barely legible to the raters. The LCD subsystem should be improved by adding at least a two-alpha designation (AA through ZZ) to provide a group identification capability. The contrast of the letters and numerals that appear on the 35 mm slides should also be improved.

6) LED Display - This display is a single blinking LED located above the camera lens. It is provided as an eye fixation aid for persons being photorefracted. The LED could be increased in size to provide a larger fixation target. It was noticed during the ASD study that one or two students with severe myopia were unable to see the LED.

7) Head Positioning Hood - The head positioning hood is much too flexible, and is the cause of the secondary corneal reflection. The hood should be reduced in length, front to rear, and fabricated from a less flexible material.

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APPROVAL

OCULAR SCREENING TESTS OF ELEMENTARY SCHOOL CHILDREN

By John Richardson

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.



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Director, Technology Utilization Office