NASA CR-166,338

NASA CONTRACTOR REPORT 166338

Purkinje Image Eyetracking: A Market Survey

NASA-CR-166338
19820017903

Lo. F. Christy
SRI International

CONTRACT NAS2-9846
March 1979

NASA

NASA CONTRACTOR REPORT 166338

Purkinje Image Eyetracking: A Market Survey

Lo. F. Christy

SRI International
333 Ravenswood Ave.
Menlo Park, California 94025

Prepared for
Ames Research Center
under Contract NAS2-9846

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

N82-25779 #

This Page Intentionally Left Blank

CONTENTS

LIST OF ILLUSTRATIONS v

LIST OF TABLES vii

LIST OF EXHIBITS vii

I INTRODUCTION 1

Overview 1
Theory of Eyetracking Operation 1

II BACKGROUND 5

Historic Overview of SRI Eyetracker Development 5
Description of the SRI Instrumentation 10
Dual Purkinje 12
Optometer 12
Three-Dimensional Eyetracker 13
Binocular System 13
Pupillometer 13
Planned Research 14

III APPLICATION POTENTIAL 15

Use in Research 15
Ongoing Efforts 15
Future Research 16
Clinical Use 17
Device Modifications 17
NEI Assessment of Clinical Applicability 19
Conclusions 24

IV MARKET ANALYSIS 27

Technoeconomic Assessment 27
Size and Scope of the Market 28
Factors Affecting the Eye Movement Monitoring Market 31
Funding 31
Technology 32
Regulations 32
Trade-Offs 32
Distribution and Promotion 33
Competitive Environment 33
The Ophthalmology Market 36
Overview 36
Emerging Trends 38
Commercialization Potential 40

REFERENCES 43

APPENDICES

A SRI PURKINJE IMAGE EYETRACKING LITERATURE 45

B AN INTERDISCIPLINARY DIRECTORY OF SCIENTISTS ENGAGED IN THE STUDY OF EYE MOVEMENTS 53

C COMPARISON OF EYE MOVEMENT MEASURING TECHNIQUES 87

D HONEYWELL OCULOMETER LITERATURE 91

E GULF AND WESTERN "EYE-TRAC" LITERATURE 107

F INSTRUMENTATION MARKETING CORPORATION LITERATURE . . . 131

ILLUSTRATIONS

1 Diagram of Purkinje Eyetracker Image Area 2

2 Program History 6

3 SRI Dual Purkinje Image Eyetracker
(a) Side View of Instrument 7
(b) Noninvasive Eyetracker Attachment 8
(c) Eyetracker Control Panel 9

4 Eyetracker Installations 11

5 Eyetracker History 12

6 Visual Field Map (White Dots) Indicating Locations of Mapping Stimuli Not Seen by the Subject, Superimposed on a Fundus Photograph of the Subject's Eye 25

This Page Intentionally Left Blank

TABLES

1 Number and Percentage of Office Visits to U.S. Ophthamologists by Principal Morbidity-Related Diagnoses, January-December 1976 20

2 Office Visits to Ophthamologists and All Specialists in the United States by Characteristics, January-December 1976 . . . 21

3 Applications of the SRI Dual Purkinje Image Eyetracker 26

4 Comparison of Eye Movement Monitoring Instrumentation and Proposed SRI 3-D Eyetracker 35

5 Number of Optometrists 39

6 Number of Ophthamologists 39

7 Number of U.S. Hospitals by Bed Size, 1978 40

EXHIBITS

1 Importance of 3-D Binocular Eyetracking in Clinical Neurological Diagnosis 18

I INTRODUCTION

Overview

The development of a fundamentally new system, the dual Purkinje image eyetracker, for measuring eye movement, by personnel of the Information Sciences and Engineering Division at SRI International (formerly Stanford Research Institute), Menlo Park, California, is an exciting engineering breakthrough. It is the first eye tracking instrument developed that can accurately and simultaneously monitor both lateral (translation) and rotary (accommodation) movement of the eye. With this capability, studies in relationships between eye movements and speech perception, the focusing ability of the eye, and visual sensitivity to spatiotemporal targets can be made. Examples of such studies and their applications are discussed in Section III.

The SRI eyetracking system is a synthesis of two separate instruments, the optometer that measures the refractive power of the eye and the dual Purkinje image eyetracker that measures the direction of the visual axis. These instruments, developed by SRI personnel under NASA sponsoring, were later combined to form the 3-D eyetracker, under funding by the National Institutes of Health (NIH). (See Appendix A for literature describing the SRI dual Perkinje image eyetracker device.)

The recent objectives of the SRI eyetracker program have been to develop an easy-to-use clinical version of the double Purkinje image eyetracker, to develop vision research instruments with added capabilities and flexibilities that eventually will have clinical usefulness as well, and to use these instruments in vision research for which they are uniquely suited.

SRI's current research activities in this area include:

- Improving eyetracker performance
- Completing a binocular facility
- Continuing active liaison with the users
- Continuing vision research effort.

Theory of Eyetracking Operation

As light strikes the eye, four reflections, called Purkinje images, are formed from the front and rear surfaces of the cornea and lens (see Figure 1). The first Purkinje image is formed at the surface of the cornea, the second occurs at the rear surface of the cornea, a third occurs at the front surface of the lens, and a fourth occurs at the rear surface of the lens. Because the second image is relatively dim and the third is formed in a plane far away from the others, they are not used for this method of measuring. The first image, which is the brightest, and the fourth, dimmer than the first but with only one-fourth the intensity, are therefore used to measure the relative displacement between the first and fourth images as they move. These two images move similarly under translation (lateral movement) and differentially (rotary movement)--i.e., they dance around.

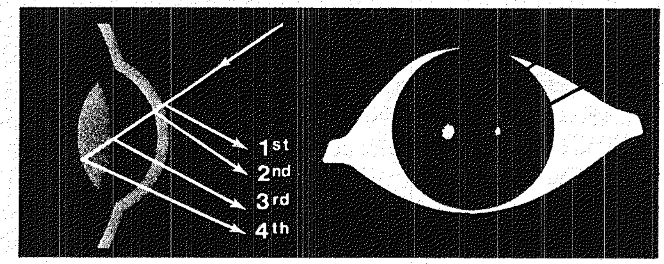


FIGURE 1 DIAGRAM OF THE PURKINJE EYETRACKER IMAGE AREA

For purposes of simplicity, the two surfaces in question--the front of the cornea and the rear of the lens--are assumed to resemble a clam shell arrangement (see Figure 1) where both surfaces have the same radius of curvature and have a separation equal to their radius of curvature. C_1 is the center of curvature for the cornea, and C_4 is the center of curvature of the rear of the lens. If these two surfaces are assumed to be spherical, the effect of collimated light is to produce the two images roughly in the center, equidistant between the two surfaces. The distance that each image moves as a result of eye rotation is related to the distance from the center of rotation CR to the center of curvature for the surface that forms it. The separation of the two images as a function of eye rotation Δ is approximately given by $S = 7 \sin \Delta$, where S is in millimeters.

Change in separation between these two images therefore is directly related to the angular rotation of the eye and is independent of head translation. The basic action of the eyetracker is to monitor or track continuously the separation of these two images. When collimated infrared light is directed toward the cornea, the direction of gaze can be accurately inferred from the relative position of the first and fourth image. The use of infrared light, incidentally, is common in nearly all tracking systems; it is nondamaging to the eye and does not interfere with normal vision.

In the SRI eyetracker, the first Purkinje image is brought to focus on a stationary photodetector by the receiving optics after reflection from a motor-driven mirror. The stationary photodetector senses any motion of this image and causes the mirror to rotate horizontally and vertically enough to keep the image centered on the stationary photodetector.

The fourth Purkinje image is focused onto a second photodetector after reflection from an additional motor-driven mirror. This second stationary photodetector senses any motion of the fourth image and causes the second mirror to rotate horizontally and vertically enough to keep the image centered on the photocell. After the first image is stabilized in space, the motion of the other image is exactly equal to the relative motion of the two images. From this relative motion, the direction of gaze can be accurately determined and studies, such as visual tracking tasks for pilots, can be made, and the investigation of human behavior in the correlation of language to the perceptual and cognitive process of the mind (Cooper, 1974).

This Page Intentionally Left Blank

II BACKGROUND

Historic Overview of SRI Eyetracker Development

The SRI eyetracker instruments evolved from a series of experiments in the mid 1960s on the mechanisms of human visual accommodation. An abbreviated history of SRI International's Visual Science Program is given in Figure 2. Specifically, Dr. Robert Randle (NASA-Ames) was interested in the need to measure visual accommodation for pilots. Early in these studies, it became apparent that it was necessary not only to measure the refractive power of the eye, but also to isolate small retinal areas; e.g., to map sensitivity to blur over different regions of the retina. This requires an accurate and continual measure of eye position so as to know what area of the retina is stimulated at every instant. The interaction between the eye movement and accommodation systems also was studied. Because no instruments were available to easily and accurately monitor both eye movements and accommodation, it was necessary to develop such instruments: one to measure the refractive power of the eye and one to measure the direction of the visual axis, both continuously. The first instrument is known as the optometer and the second as the dual Purkinje image eyetracker. These instruments were developed under NASA support during the years 1966-1971.

The first year's study in 1966 (NASA Contract NAS2-2760) was principally theoretical in nature. It resulted in the development of models for processing of the retinal image to determine the state of focus and the nature of the control system controlling the ciliary muscle. An optical range-finder technique which was based on a mode of vibration that seemed analogous to an observed vibration in the human lens system was developed to evaluate the potential role of this vibration in human focus control.

The second year's work in 1967 (NASA Contract NAS2-3517) was aimed primarily at the development of instrumentation to test a number of basic hypotheses generated in the first study. The two key items of instrumentation were a 2-D eyetracker and an optometer that measures the state of accommodation of the eye in real time.

During the third year in 1968 (NASA Contract NAS2-4322), the optometer and eyetracker were advanced to the point of operation. Experiments were begun on the human accommodation system.

During the fourth and fifth years from 1969 to 1971 (NASA Contract NAS2-5097), the optometer instrument was substantially improved and work was initiated on a new version of the Purkinje eyetracker. Experimental results have led to the tentative conclusion that aberrations of the optics of the eye play a critical role in the functioning of the accommodation system. Figure 3(a), (b), and (c) pictures the SRI eyetracking device.

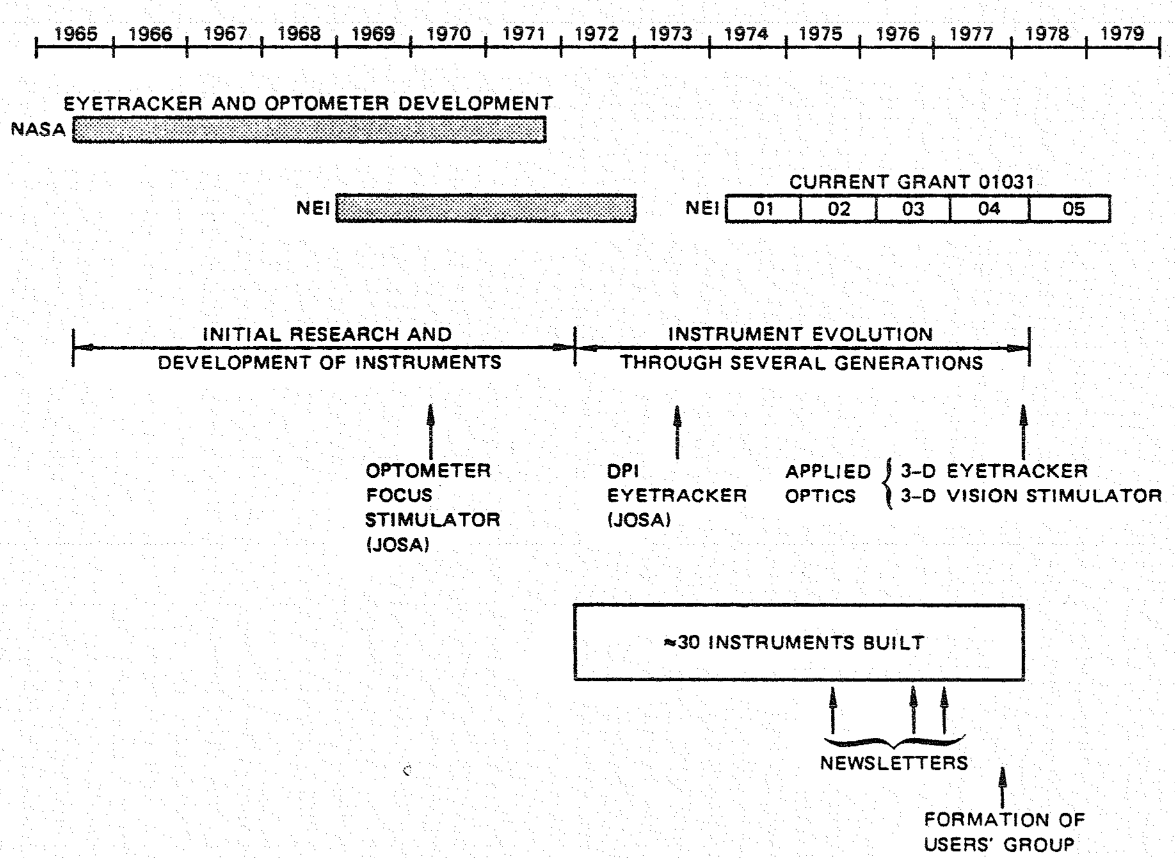
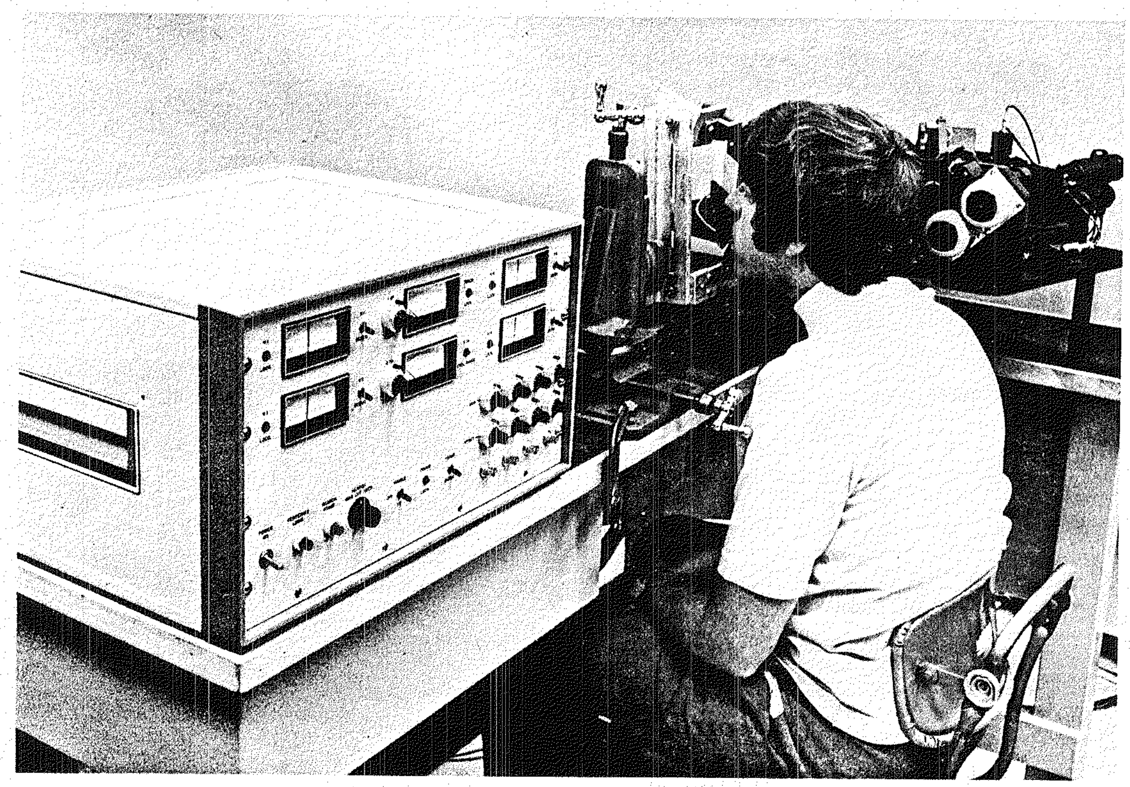
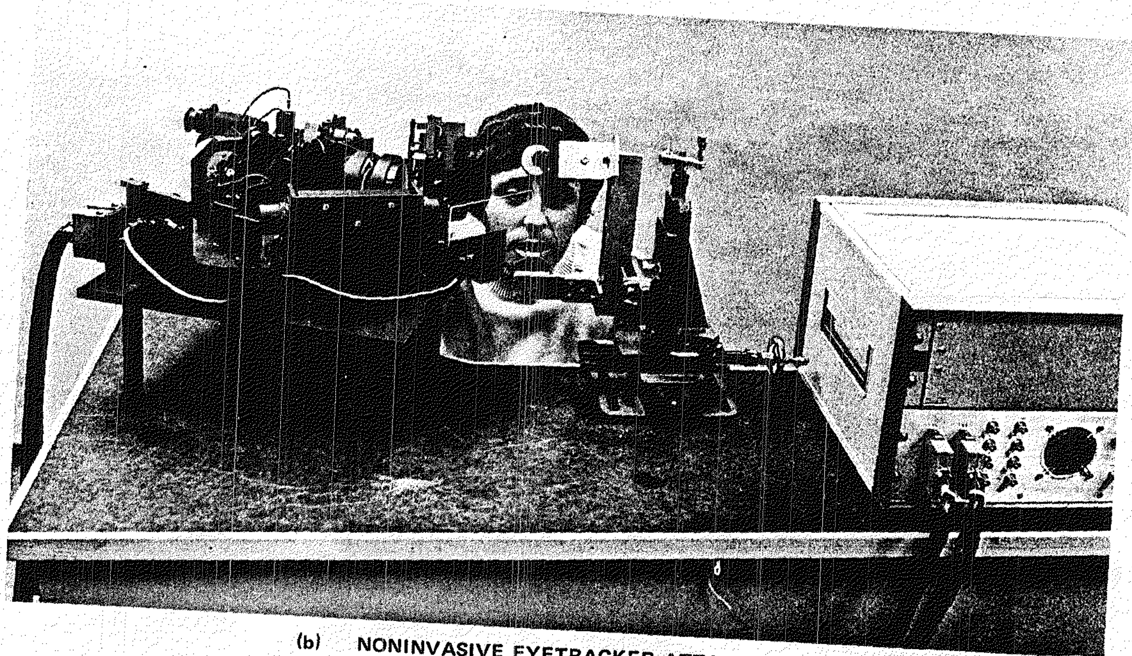


FIGURE 2 PROGRAM HISTORY



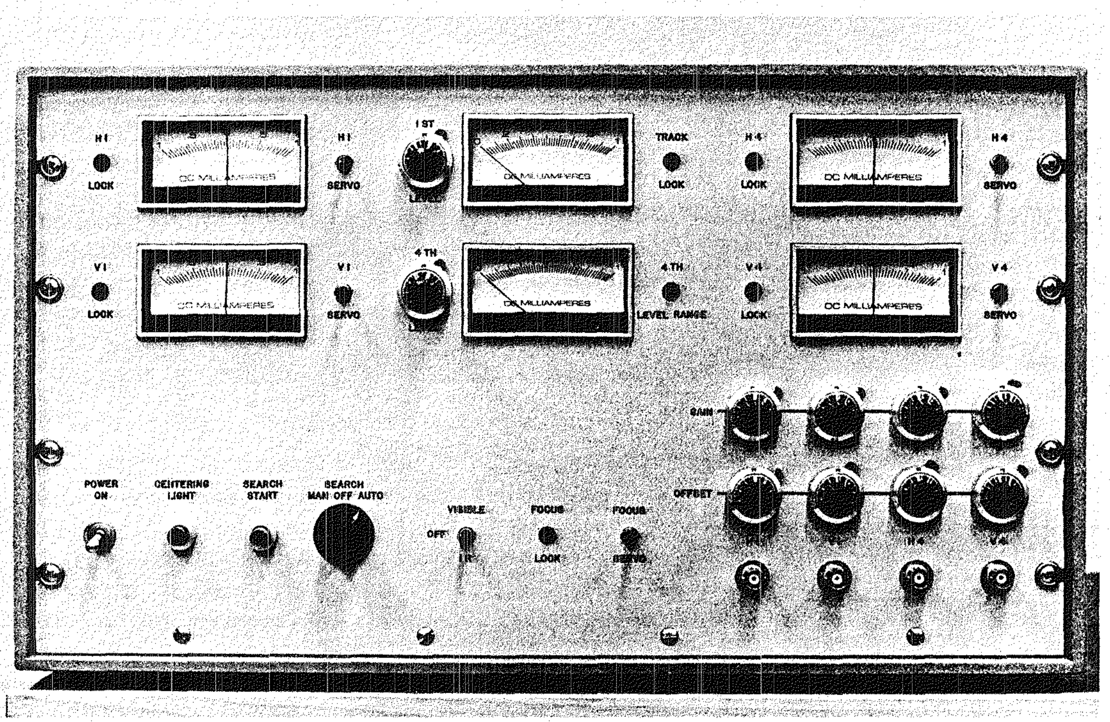
(a) SIDE VIEW OF INSTRUMENT

FIGURE 3 SRI DUAL PURKINJE IMAGE EYETRACKER



(b) NONINVASIVE EYETRACKER ATTACHMENT

FIGURE 3 SRI DUAL PURKINJE IMAGE EYETRACKER (Continued)



(c) **EYETRACKER CONTROL PANEL**

FIGURE 3 SRI DUAL PURKINJE IMAGE EYETRACKER (Concluded)

Partial support for this instrument development was provided by a multiple principal investigator grant from National Eye Institute (NEI) during the years 1969 to 1972. Papers on the optometer, focus stimulator, and dual Purkinje image eyetracker were published in the Journal of the Optical Society of America in 1970 and 1973. As a result of these publications and other forms of contact with the vision community, it was found that many others were interested in an accurate, noncontact method of eyetracking. Other laboratories expressed interest in acquiring the SRI dual Purkinje image eyetracker as early as 1972.

During the years 1972 to 1977, 30 dual Purkinje image instruments were built at SRI at the request of vision research laboratories across the United States (see Figure 4). Over this period, there were several generations of instruments, as illustrated in Figure 5. The Generation I instrument demonstrated that the method was sound. However, its operating range was small, it was extremely difficult to use, and its performance was not consistent. Generation II, a fundamental redesign, resulted in greatly increased accuracy, reliability, and ease of use. The noise level (pointing accuracy) of this instrument was in the neighborhood of 10 to 20 minutes of arc. In Generation III, a number of significant improvements was made, including further improvements in noise level and frequency response. Historically, the four different groups of Generation III instruments as shown in Figure 4, each incorporated further improvements in performance. The present system has a noise level on the order of several minutes of arc peak-to-peak and a frequency response of 200 to 300 Hz.

Both the 3-D eyetracker and the 3-D visual stimulus deflector were described in a pair of papers published in the March 1, 1978 issue of Applied Optics. The first of these papers describes the Generation III eyetracking instrument. Because of the continual improvements in design, a newsletter was started in 1975 to serve as a medium of communication with the growing number of users. In September 1977, at the suggestion of the NEI, a conference of dual Purkinje image eyetracker users was convened at the Retina Foundation in Boston. A result of that meeting was the formation of the National Eyetracking Study Group. One of the first actions of the group was to meet with the NEI in Washington to discuss methods for standardizing all the NEI-sponsored dual Purkinje image instruments and for developing the necessary documentation for users to enable them to individually maintain and modify these instruments as much as possible. A supplement to SRI grant EY 01031 to cover the cost of this updating, standardization, and documentation program was approved by the National Eye Council at its January 1978 meeting. A second meeting of the users' group is scheduled for Spring 1979 at SRI International.

Description of the SRI Instrumentation

A description is given of the dual Purkinje image eyetracker, the optometer, and the combining of these two instruments to form the 3-D eyetracker. The binocular system and a pupillometer that were developed and incorporated into the 3-D eyetracker also are described.

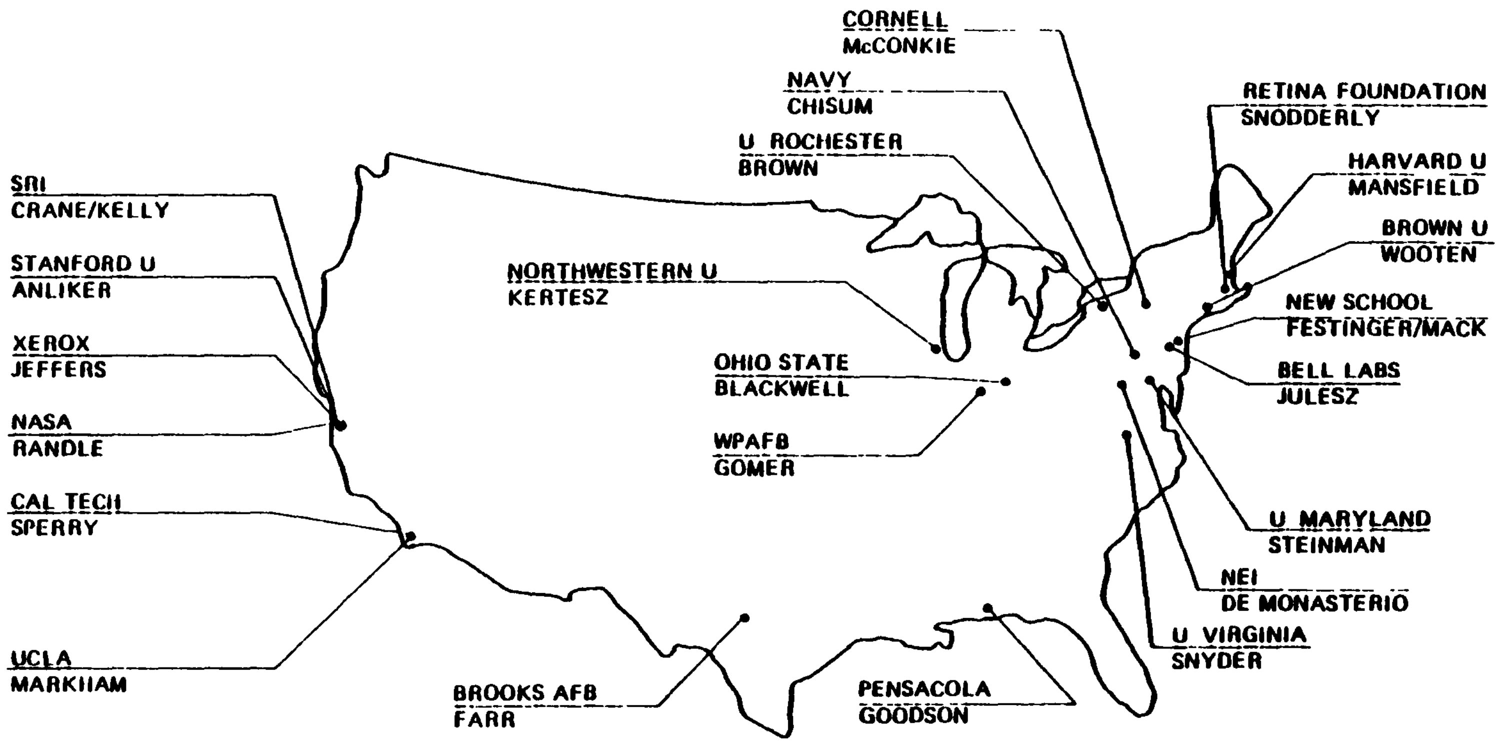


FIGURE 4 EYETRACKER INSTALLATIONS

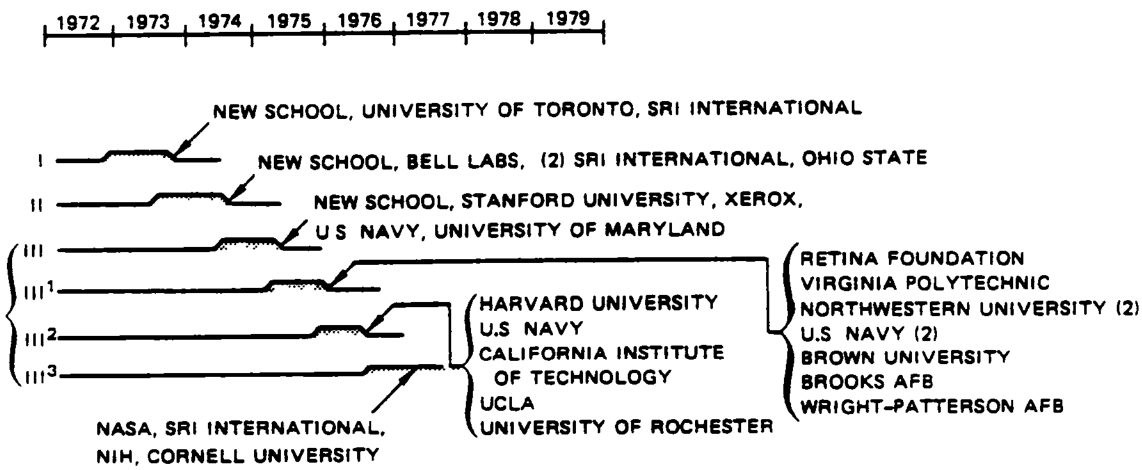


FIGURE 5 EYETRACKER HISTORY

Dual Purkinje

The Purkinje eyetracker currently has a noise level and absolute accuracy of the order of 1 minute of arc or 1° out of 360°. It is equally sensitive to both horizontal and vertical directions of eye motion. Contact-lens methods are accurate but inconvenient. Corneal, limbus, and Mackworth trackers are convenient, but their absolute accuracy is limited to 1° at best. The instrument that comes closest to the Purkinje eyetracker is the Honeywell oculometer (whose development was also supported by NASA); it has an accuracy of the order of 0.25° to 0.5°, is convenient to use, and is less obtrusive than the Purkinje (i.e., there is greater distance from the eye to the optics of the system). In addition to poorer accuracy and significantly higher cost, another disadvantage of the Honeywell oculometer is that it is based on a TV system wherein the processing time is approximately two TV-frame times, or approximately 30 ms as compared with a 1-2 ms delay with the Purkinje eyetracker.

When the Purkinje eyetracker is fitted with the optometer, a simultaneous 3-dimensional eyetracking system (described later) is created. The optometer is described below.

Optometer

The optometer has a range of approximately 20 diopters and a noise level on the order of 0.1 diopter. It operates by projecting an infrared image onto the retina of the subject and continuously monitoring the image so as to keep it focused on the retina under servo control. The design of this instrument had to eliminate the very bright reflection from the cornea.

An advantage of the combined 3-D instrument (see below) is that the optometer and eyetracker are merged after the first Purkinje image is stabilized by the eyetracker. This enables the optometer to operate on a stabilized image of the eye. This stabilization significantly reduces the problem of eliminating the corneal reflection and allows the optometer to operate even with considerable eye movements.

Three-Dimensional Eyetracker

The development of both the optometer and the Prukinje eyetracker was a difficult task. It appeared desirable to evolve them separately, but with the objective of eventually merging them, so that refractive power and direction of gaze could be measured simultaneously on the same eye. The two instruments were successfully combined during 1974 and 1975 (under NIH grant EY 01031 to Dr. H. Crane for the study of human accommodation). In effect, the combined instrument measures the point in 3-D space on which the eye is fixated. The instrument can thus be thought of as a 3-D eyetracker. Following is the abstract from an SRI manuscript in preparation that describes the 3-D eyetracker (Clark and Crane, 1979).

> A combined optometer and eyetracking instrument has been developed to measure the dynamic refractive power and the direction of gaze of the same eye. In effect, this instrument measures as a function of time the point in three-dimensional space on which the eye is fixated. Nothing is attached to the subject, who is easily aligned to the device. The measuring wavelength is in the near infrared and is invisible to the subject. The usable field of the instrument is greater than 20 degrees; the horizontal and vertical directions of gaze are measured with a noise level and repeatability of about 1 minute of arc. The range of the optometer is approximately 20 diopters; refractive power is measured to about 0.1 diopter. Three dimensional monocular and binocular eye movement records are shown.

Binocular System

In late 1975, SRI assembled a left-eye and right-eye set of 3-D instruments into a binocular configuration. To our knowledge, this is the only binocular 3-D eyetracking system available anywhere. There is no comparable instrument in terms of the variety of visual systems that are monitored simultaneously. For example, with the addition of a pupillometer (see below), the binocular system is uniquely suited for study of the triadic system (convergence, pupil, and accommodation).

Pupillometer

During 1975, it became evident that it was necessary to control the visual environment so as to be able to place a given stimulus anywhere in the visual field. Accordingly, a stimulator pupillometer was designed, as described in the following abstract (Clark and Crane, 1979).

A three-dimensional visual stimulus deflector has been designed so that a subject can view through it and the visual field (up to 25 degrees in diameter) can be moved over a range of 40 deg horizontally and 30 deg vertically. The optical focus of the object being viewed can be changed over a 15 diopter range, while the brightness and visual angle subtended by the object remain fixed. Further, the observer can view the object through a pupil of any desired size, shape, and transmittance. Horizontal and vertical movements are independent, with time delays of 1 msec and a response range from DC to 200 Hz. Focus change in independent of lateral motion with a time delay of 12 msec and a maximum slewing rate of approximately 40 diopters/sec. Two such devices can be aligned side by side in a binocular configuration for independent three-dimentional control of the fixation of each eye.

In early 1976, a binocular stimulator was integrated into the binocular 3-dimensional SRI eyetracker. The current facility is capable of monitoring all of the visual systems of version, vergence, accommodation (and eventually pupil) in both eyes and stimulating each of these mechanisms independently.

Planned Research

Future research areas for technological development of the eyetracker are being considered by the SRI group. Some of these areas are to:

- Design a pupillometer into the eyetracker.
- Develop means to lower the noise level further.
- Study lens overshoot phenomena and develop means to automatically scale the magnitude of the overshoot.
- Develop instrumentation for independent translation output.
- Study patient testing/examining considerations including increased eye relief and increased head freedom.

III APPLICATION POTENTIAL

Use in Research

Ongoing Efforts

The visual monitoring instrument developed at SRI currently is being used in various government and private research laboratories throughout the country. The first equipment delivered was the monocular 2-D eyetracker, but several recent systems include binocular or 3-D capability or both and a 3-D visual stimulating capability. These instruments have been used primarily in research applications where high precision and relative ease of use is essential; in many cases, these are the only instruments capable of accomplishing the research.

The areas of research application can crudely be divided into three broad categories: psychological studies, basic vision research, and applied research. Early psychological studies using these new instruments dealt with the perceptual system and how it is affected by fast, brief, jerky eye movements (Komoda et al., 1973) and slower tracking movements (Festinger, 1975). This effort attempted to explain the "outflow theory" of visual perception. Other research programs are looking at the interrelationship between visual, auditory, speech, and language processing mechanisms. Some endeavors soon will be directed toward understanding the effects of graphical displays on human perceptual mechanisms and how various scenes are analyzed both in terms of the eye movement patterns and the memory process (Cooper, 1979). Other investigations will be concerned with the correlation of musical text and the subsequent motor response (particularly during sight reading). A study of the influence of visual mechanisms on size and distance judgments also will be undertaken soon.

One of the first basic vision research studies conducted with the SRI eyetracker concerned the sensitivity of the visual sensory mechanisms to certain spatiotemporal patterns. This research examined the stabilization of the visual pattern on the retina so that visual thresholds could be monitored without eye movements displacing the visual pattern on the retina. This technique of visual stabilization with the SRI eyetracker--"or making the world stand still"--will soon be expanded to include studies of the sensitivity of peripheral regions of the retina, receptive field properties in monkeys, and the retinal sensitivity functions in certain subjects with hereditary color blindness. Other ongoing or soon-to-be-initiated basic research is concerned with studies of accommodation and its interaction with eye movement and vestibular mechanisms. An investigation of the properties of horizontal and vertical fusional eye movements currently is being initiated as is the recovery time in flash blindness experiments with monkeys.

The first applied research dealt with the monitoring of eye position to control the presentation of a video display, and in particular, to present high resolution only where the observer is looking and thereby reduce the amount of necessary video information that must be transmitted. More recent research has been planned to study pilot performance in visual tracking tasks on an aircraft instrument panel, the evaluation and improvement of visual image and other instrument displays, the assessment of the influence of windscreens on visual performance, and the subsequent processing and interpretation of this visual information.

Many of these studies are in the initial planning and checkout phases. Present and past users have, in general, found the eyetracker suitable for their needs. Most of them require a noncontacting visual monitor of great accuracy, and only the SRI device offers these joint capabilities. Several suggestions have been offered, however, on ways to improve the instrument. Psychologists have been most vocal in requesting that the eyetracker be capable of tracking the eye over a large range of eye movements, while allowing more freedom of movement of the head and greater separation between the subject's eye and the instrument. Basic vision researchers have expressed a desire for even greater accuracy and speed of response, and the applied researchers have mentioned a need for tracking the eye with brighter displays.

Future Research

Future applications of the eyetracker lie in the screening and feedback training of pilots for testing their ability to function optimally under stress conditions and also to study fatigue--attention span ratios of sonar operators, man-controlled ballistics missile operators, and commercial and military flight control operators. Feedback training could also be used to correct reading difficulties in children and adults. Other future applications of the eyetracker are in the analysis of visual patterns in the TV viewing of commercials, eye control of computer/video displays, video phone systems, and eye movement-linked manual-control mechanisms for paraplegics.

Many of SRI eyetracker users have expressed a feeling that these instruments will have a long-term impact on vision research. They can be used in reading research, in inducing forced visual scanning patterns with a stimulator, and in the study of certain visual field defects to better understand the effects of impaired vision. Other researchers have suggested that these devices would be helpful in the study of electronystagmography to assess vestibular function. Perhaps one of the most important applications of these visual monitoring systems is the mapping and measurement of specific anatomical locations of the retina to determine its characteristics. The anatomical localization of visual properties requires an extremely precise instrument that must be noncontacting for human subjects. The eyetracker, with its associated visual stimulator (used as a stabilizer), is the only eye movement monitor with capabilities necessary to carry out this research on a large number of patients.

Broader areas of research that could benefit from the unique features of the SRI eyetracker include neurology, pharmacology, psychiatry, and general binocular research. It has recently been shown that the dynamics of eye movements change with certain neurological disorders, such as brain lesions and tumors; moreover, the general eye movement patterns change with psychiatric impairments such as in schizophrenia and Parkinson's disease (see Exhibit 1). It has also been suggested that the effects of various drugs such as barbiturates on sensory-motor mechanisms could be assessed by measuring the effects of visual systems. These types of research have great clinical significance. Another type of investigation to which the binocular 3-D eyetracker is uniquely suited is the study of the interactions of various visual mechanisms, i.e., version, vergence, and accommodation. No other visual monitor can measure the state of accommodation in the presence of moderate to large eye movement; very few devices can measure binocular responses. Therefore, only with the SRI 3-D eyetracker can the interactions of these systems be assessed directly and instantaneously because they can be measured simultaneously.

Clinical Use

Device Modifications

Although most of these instruments have thus far been used for basic research in vision, interest has begun to develop in clinical applications as well. For clinical use, however, it will be necessary to make these instruments much easier to use and to redesign the basic instrument for greater freedom of head movement and eye relief (greater distance between the instrument and the patient's eye). Although critical for a clinical instrument, these improvements also would benefit a general research instrument.

Discussions were undertaken with NASA in early 1977 concerning the clinical applicability of the eyetracker. In May 1978, a NASA contract to SRI provided limited support for taking a first step in redesigning the instrument for clinical use. Eye relief and head freedom will be increased, and the electronics will be completely redesigned into a more compact and integrated form. The mechanical and optical portions will also be redesigned for simpler construction. The resulting instrument will be much simpler to align with a patient. This device, however, is only a "working breadboard prototype" which will require further development to bring it to the clinic.

As a result of growing interest in clinical applications, the NEI arranged a special administrative site visit to SRI in December 1977. The visitors included neurological and ophthalmological clinicians who gave an encouraging report to the NEI on the clinical potential of these instruments.

Exhibit 1

IMPORTANCE OF 3-D BINOCULAR EYETRACKING IN CLINICAL NEUROLOGICAL DIAGNOSIS

A systematic and quantitative analysis of oculomotor disorders is directly relevant to the diagnosis and treatment of a wide variety of neurologic disorders. Diseases affecting cerebral cortex, cerebellum, brainstem, all may lead to abnormal eye movements (Walsh and Hoyt, 1969). Accurate characterization of these movements may allow for precise anatomic localization of neurologic disorders, even when the exact nature of the disease process remains in doubt. The following brief list of examples is put forth to illustrate this point.

Anatomic Localization	Oculomotor Disorders
I. Central Nervous System	
A. Cerebral Cortex	contralateral, reversible conjugate gaze paresis, disorders of saccadic refixating and smooth pursuit.
B. Cerebellum	ocular dysmetria, flutter, opsoclonus, square-wave jerks.
C. Basal Ganglia	delayed initiation of saccades, hypometric saccades.
D. Brainstem	skew deviation, gase induced nystagmus, periodic alternating nystagmus, Horner's syndrome.
1. Midbrain	paralysis of upward gaze and convergence-retraction nystagmus, supranuclear accommodation paralysis, bilateral third nerve paresis, intranuclear ophthalmoplegia.
2. Pons	ipsilateral gaze paresis, ocular bobbing, internuclear ophthalmoplegia.
3. Medulla- high cervical cord	down-beating nystagmus.
4. Cervical cord lesions	alternating Horner syndrome cilio-spinal reflex.
II. Peripheral Nervous System	
A. Third Cranial Nerve	unilateral ptosis, paresis of superior rectus (upper division), paresis of pupillary reflexes, vergence, accommodation, inferior, medial rectus and inferior oblique (inferior division).
B. Fourth Cranial Nerve	paresis of the superior oblique muscle, superior oblique myokymia.
C. Sixth Cranial Nerve	paresis of the lateral rectus.
D. Eight Cranial Nerve Vestibular Branch	contralateral horizontal nystagmus, ipsilateral impaired caloric response.
E. Neuromuscular Junction	external ophthalmoplogia with prominent fatigue or facilitation with repetitive movement.
F. Muscle	external ophthalmoplegia with the fatigue response.

Source Excerpt from "Significance of the Proposal" section of a proposal from Dr. Langston and Dr. Hotson (associated with Stanford Medical Center) to NIH, defining the importance of 3-D binocular eyetracking and its potential in clinical neurological diagnosis.

In clinics, several diagnostic and therapeutic needs could be served by a device able to stabilize the image on the retina. Image stabilization could aid in biomicroscopic examination of the eye, which is currently limited by the presence of eye movement. If the viewing system were dynamically stabilized, higher magnification would become practical and clinical examination of the eye would be more precise. As can be seen in Table 1, about 4% of visits to ophthalmologists are for diseases of the retina and optic nerve. As the U.S. population grows in the absolute number and percentage who are elderly, retinal problems will increase. Even now, persons over 45 years of age account for more than 40% of the visits to ophthalmologists (see Table 2).

If wide clinical application of the eyetracker with image stabilization capability is planned, then the unique requirements of the elderly must be considered. For example, the degree of stability required now by the eyetracker would exclude certain elderly patients because of minor head tremors. In addition, diagnostic and therapeutic use of the eyetracker for strabismus (cross-eyed or weak muscles) would be limited because patients are generally in a young age group and therefore difficult to restrain (see Table 1).

The involuntary head and body movements of some neurological patients make head restraint and therefore recording eye movements impossible. For clinical application in these cases, the eyetracker would be required to have an extended range (±30 to ±40), which is far beyond its present capabilities. Other clinical applications may also be restricted in that the use of mydrietics would probably be required because of the dependence of the Purkinje eyetracker on pupil size.

NEI Assessment of Clinical Applicability

To identify the areas of clinical applicability of the SRI eyetracker and to assist in establishing priorities for future support considerations, the NEI initiated an administrative site visit. Prioritization was requested in relation to clinical/scientific yield, concentration of effort, and cost/benefit considerations. The site visit occurred December 6-7, 1977. The objectives of the meeting were:

- To provide the NEI with information on the feasibility of several possible clinical applications of the SRI eyetracker and to assign a relative priority to these clinical application opportunities.
- To provide direction, from the discussions and interactions at this meeting, to SRI International as regard their future research objectives, in particular the lines of the most realistic and feasible modifications of the SRI eyetracker for clinical application.

Table 1

NUMBER AND PERCENTAGE OF OFFICE VISITS
TO U.S. OPHTHALMOLOGISTS BY PRINCIPAL MORBIDITY-RELATED DIAGNOSES*
January-December 1976

Principal Diagnosis Most Commonly Rendered by the: Ophthalmologist	ICDA Codes	Number of Visits in Thousands	Percentage of Total Visits
Diseases of the nervous system and sense organs	320-389	22,121	75.5
Inflammatory diseases of the eye	360-369	3,396	11.6
Conjunctivitis and ophthalmia	360	1,504	5.1
Other diseases and conditions of the eye	370-379	18,361	62.7
Refractive errors	370	8,143	27.8
Myopia	370.0	2,604	8.9
Hyperopia	370.1	937	3.2
Presbyopia	370.2	1,307	4.5
Astigmatism	370.3	1,277	4.4
Strabismus	373	964	3.3
Cataract	374	2,220	7.6
Glaucoma	375	2,490	8.5
Other diseases of retina and optic nerve	377	1,207	4.1
Other diseases of eye	378	3,064	10.5
	378.7	1,268	4.3
Accidents, poisonings, and violence	800-899	1,079	3.7

*The term "morbidity-related" applies to a diagnosis that was associated with a pathological condition (ICDA codes 000-999), as opposed to a visit that was primarily associated with a routine examination or with a special condition such as surgical aftercare or prenatal care.

Source: "Blue Book of Optometrists," 1976.

Table 2

OFFICE VISITS TO OPHTHALMOLOGISTS AND ALL SPECIALISTS
IN THE UNITED STATES BY CHARACTERISTICS
January-December 1976

Patient Characteristic	Visits to Ophthalmologists: Number in Thousands	Visits to Ophthalmologists: Percent Distribution	Visits to All Specialists* (percent distribution)
Age			
Under 15 years	3,225	11.0	18.7
15-24 years	3,320	11.3	15.0
25-44 years	5,510	18.8	25.7
45-64 years	8,764	29.9	24.6
65 years and over	8,483	29.0	16.0
Sex			
Female	17,259	58.9	60.3
Male	12,043	41.1	39.7
Prior visit status			
New patient	8,099	27.6	14.2
Old patient, new problem	2,954	10.1	23.0
Old patient, old problem	18,250	62.3	62.8
Total visits	29,302	100.0	100.0

*Based on an estimated 588,300,170 visits made to all office-based physicians in 1976.

Source: "Blue Book of Optometrists," 1976.

To give the full results of their insights, we will quote from a report on their conclusions.

POTENTIAL CLINICAL APPLICATION OPPORTUNITIES

> The absence of reliable techniques of image stabilization in clinical procedures has probably collaborated to the scarcity of early diagnostic techniques. Such techniques involve psychophysical, electrophysiological, and high-magnification fundoscopy, whereas surgical treatments are based on highly localized retinal photocoagulation. Image stabilization and accompanying clinico-surgical procedures tend to be quite expensive, time-consuming, and complex. For these reasons these techniques should probably be developed initially and applied in selected clinical centers and with selected patient populations.

At an earlier September 1977 meeting, both SRI and the Eyetracking Study Group, identified areas of possible clinical application for the Purkinje eyetracker. Some of the areas identified include the following:

- Detection of blood pulse in eye movements.
- The ability to detect overshoots that result from lateral motion of the lens in the globe during a saccade (may be useful in the study of certain visual problems associated with the lens such as Marfan's syndrome).
- Understanding the translational motions of the globe, the accompanying rotational motions of the eye (may be useful in defining more precisely how the extra-ocular muscles attach to the globe and how they exert their force).
- Retinal tracking of scotomas, blood vessels, and eyetracker-guided photocoagulation.
- Neuroophthalmologic diagnosis via recording and analysis of fine structure of eye movements in congenital nystagmus, degenerative brain disorders, etc.
- Perceptual eye studies in binocular fusion mechanisms especially related to strabismus surgery and the role of accommodation in binocularity.
- Detection of small eye movements in those patients with unstable fixation and to correlate these with visual acuity.
- Use of image stabilization to and in biomicroscopic examination of the eye.

The visitors recognized that, if the procedures are successful, the obtained data will provide more accurate and early diagnosis of many retinal disorders. With the application of the eyetracker to the clinical environment, additional studies on the following abnormalities could be pursued: macular diseases, retinochoroidal vascular diseases, humor vitreous pathologies, color vision defects, psychogenic disorders and also for differential diagnostic procedures in conditions such as central scotomota, optic nerve abnormalities, etc.

The following are further excerpts from the NEI report of significance in the considerations of clinical application of the Purkinje image eyetracker.

PROBLEMS/OBSTACLES

Engineering

1. System requires separation of the tracker as far away as possible from the eye. This may increase the noise level of the tracker.
2. At present time a contact lens may be necessary at least for focal ERG and laser photocoagulation. Use of the contact lens may produce difficulty in finding the first Purkinje-image.
3. System may not be directly applicable in patients lying down without additional modification (photocoagulation).
4. The tracker is not perfectly linear, so that eye movements may not be perfectly compensated for.

Financial: System is costly.

PRIORITY AREAS FOR APPLICATION

While applications of the PIET to retinal mapping, eye-movement characterization, binocularity and accommodation research all appear promising, retinal function studies with psychophysical and electrophysiological procedures seem the most fruitful areas for clinical work at present and should be urgently pursued. Time, effort, and expenditure to build the instrument and testing in selected clinical center environments appear justified. The system for laser photocoagulation available today may undergo some future modification. Although an eyetracker appears essential in accurate aiming of the laser beam on the fundus pathology, such a system may require adjustment and alteration as the new laser system develops.

SUMMARY OF RECOMMENDATIONS

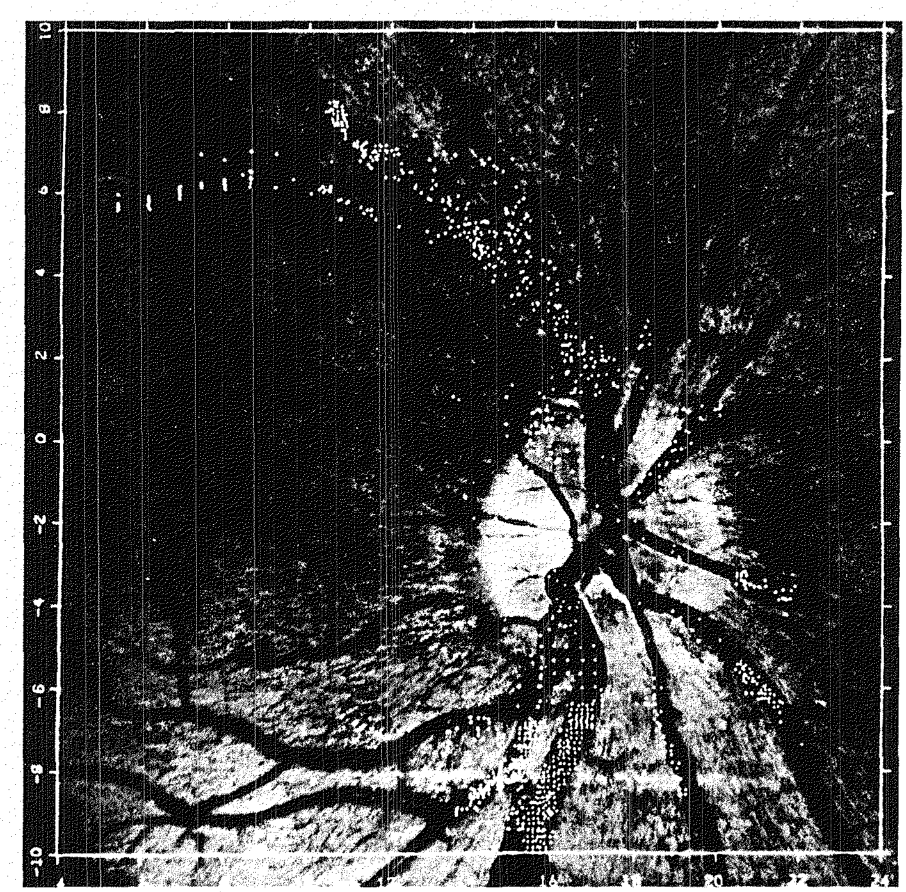
The immediate clinical potential of the Purkinje image eyetracker lies in its application to fixation and stabilization of the eye. Such fixation is of the highest importance in retinal laser photocoagulation, in the psychophysical mapping of local scotomata (see Figure 6), in studies of branch vein occlusion, and in local ERG measurements. An opportunity also exists in exploiting the capabilities of the instrument to reveal abnormalities of fine fixation.

Clinical applications of the three-dimensional and binocular version of the PIET are less immediate. This lesser present applicability should not discourage further research studies on accommodation or binocularity, nor does the above recommendation oppose full exploitation of all the capabilities of the instrument in laboratory investigations.

Conclusions

Table 3 lists applications of the SRI dual Purkinje image eyetracker. The various uses are categorized by previous applications and potential applications of the eyetracker.

Clinical use of the SRI eyetracking device will be hampered until enough research is completed to validate clinical application. With the application of the eyetracker to the clinical environment, additional studies on the following abnormalities could be pursued: macular diseases, retinochoroidal vascular diseases, humor vitreous pathologies, color vision defects, and psychogenic disorders, as well as differential diagnostic procedures in conditions such as central scotomata, optic nerve abnormalities, etc. The importance of small eye movements to diagnosis of these and other neurological problems (tumors, lesions) is not completely known yet. One of the advantages of the SRI option is its ability to measure such movements noninvasively. The initial assessment of the importance of small eye movements is promising, particularly in the early diagnosis of diseases. Nevertheless, the unknowns are still great and further research is in order.



Snodderly, D. M. et al., 1978

FIGURE 6 VISUAL FIELD MAP (WHITE DOTS) INDICATING LOCATIONS OF MAPPING STIMULI NOT SEEN BY THE SUBJECT, SUPERIMPOSED ON A FUNDUS PHOTOGRAPH OF THE SUBJECT'S EYE

The map was produced by controlling the stimulus position in the visual field with eye-position signals measured by the dual-Purkinje-image eyetracker.

Table 3

APPLICATIONS OF THE SRI DUAL PURKINJE IMAGE EYETRACKER

Previous applications

- Latencies of eye movement responses
- Eye movements and perception
- Reading eye movements
- Retinal stabilization
- Visual control of video displays
- Fixation eye movements

Possible applications

- Spatio temporal sensitivity
- Miniature eye movements and accommodation
- Psychiatric correlates of eye movements
- Amblyopia
- Physiological defects and eye movements
- Semantic control of eye fixation
- Eye movements tracking patterns and learning
- Color vision and genetic defects
- Eye movements and manual control (paraplegics, robots)
- Eye control of computers
- Eye movements of infants
- Vision and pilot performance

IV MARKET ANALYSIS

Technoeconomic Assessment*

The present SRI 3-D eyetracker has offered unique capabilities to the research community because of its accuracy, resolution, and simultaneous accommodation measurement. This has been accomplished through the technique of monitoring two images reflected from the eye. The first Purkinje image is reflected at the front surface of the cornea, while the fourth Purkinje image is simultaneously reflected from the rear surface of the eye lens. Each image is monitored by discrete tracking mechanisms. The monitoring of focus or depth of field accommodation (by using an infrared optometer) provides an indication, when coupled with the two Purkinje image trackers, of the location of the point in space at which the eyes are fixating. The complexity of the optics and the electronics used to monitor the fourth Purkinje image contribute substantially to the cost of the 3-D eyetracker, priced in the range of $40,000. Though the accuracy and flexibility of the SRI eyetracker are attractive and serve a need in research, the cost is often difficult to justify. (Present purchases are at the rate of approximately one per month.) Consequently, the market for a fully equipped 3-D eyetracker has remained small.

Therefore, in view of the high cost and narrow market for the fully equipped 3-D eyetracker, it has been proposed to build another instrument reduced in cost to the $15,000-$20,000 range. This would be achieved by eliminating the fourth Purkinje image monitoring mechanism. This eyetracker, with an optometer and (optional) pupillometer also attached, would be based on monitoring the corneal or first Purkinje image. This form of instrument would be less expensive and much easier to use than a 3-D instrument built on the double Purkinje method of eyetracking. Hence, the trade-offs are cost versus accuracy. The reduction of the double Purkinje image device to one that relies on the single corneal-reflected image reduces the accuracy to a level obtainable by a few other competitive instruments. The combination of competitive technical specifications (plus the added feature of accommodation measurement) and a competitive price would provide a basis for significant market acceptance both in present research-oriented programs and in possible future clinical applications. The added accommodation measurement is a differentiating product feature that can uniquely address the needs of segments of the research community at the present time and the clinical community in the future. The simpler, less expensive instrument would be targeted for neurological and ophthalmological research. If research validates its use in the clinic, the largest market would be for clinical applications.

---

*Parts of the analysis are based on a previous market survey done by ILT Research Institute, "Market Survey: 3-D Eyetracker."

Size and Scope of the Market

Eye monitoring devices have been an important tool in various research, clinical, and commercial applications. Because the human brain is not open to simple exploration, the eyes are useful in providing clues to complex psychophysiological processes. Research applications include studies of vision, perception, television viewing, reading image scanning, simulator training, linguistics, work load, and fatigue. Many diseases, such as schizophrenia, apparently affect scanning patterns, eye movements as well as pupillometry, and these patterns are increasingly being examined as part of the study of this and other neurological disorders. Commercial applications include human factors design and study of the effectiveness of advertisements and design. The field is growing as various disciplines interface with the study of eye movements. The entire research market for eyetracking instruments has not as yet been fully penetrated, particularly as result is spin off from current research. This is attributed primarily to the high cost of the instrumentation. Moreover, the continuing growth in the field of eye movement research also increases the demand for advancements in pertinent research tools.

The interest in eye movement research is based on the perception by specialists in various fields that the study of the eyes, and in particular eye movements, will permit the understanding, diagnosis, and treatment of several human functions and dysfunctions that have heretofore been either undefinable or unquantifiable. Based on the specific projections in certain areas of the medical field such as neurology, psychology, or ophthalmology, there are indications that certain disorders and anomalies may be diagnosed by observation of eye movements. As data accumulate to substantiate these projections, the clinical use of eye movement instrumentation will become a more quantifiable entity. At the present time it can only be suggested that the potential exists for a significant future clinical use of this type of instrumentation in the specialized areas mentioned above.

The area of basic eye movement research encompasses studies of the following representative conditions:

- Pursuit and saccadic eye movements
- Nystagmus
- Vergence and muscular imbalance
- Amblyopia
- Size and form perception
- Peripheral vision
- Fixation and gaze avoidance
- Control of eye movements
- Strabismus
- Eye-head coordination
- Dominance.

Major medical centers and universities specializing in ophthalmology or optometry are typical users of eye monitoring instrumentation for this purpose. Researchers in various other disciplines in these areas also conduct eye movement studies.

Related to these efforts in a more applied sense are studies of human performance as determined by environment:

- Stress versus workload
- Night vision
- Man-machine interface
- Industrial inspection
- Fatigue
- Anxiety
- Radiographic techniques.

The nature of these particular activities has drawn researchers from a broad range of disciplines. These would include psychologists, physiologists, human performance experts, industrial engineers, aerospace engineers, neurologists, and ophthalmologists. University, government, and commercial programs also are directed to these kinds of studies. Each may lead to advancements in the way we develop technology toward improving human performance and productivity. A simplified 3-D eyetracker would aid in accelerating progress in these areas.

The area of medical diagnosis also is related to eye movement research. Diagnostic research in neurology, physiology, ophthalmology, and psychology is interested, however, in studying eye movements as indicators of other bodily disorders. An example from the field of neurology is presented in Exhibit 1 where specific disorders are indicated as being linked to and diagnosable by movements of the eyes. There are also active programs aimed at diagnosing the effects of alcohol and drugs by means of eye movement measurements. Again, as in the case of general eye research, the medical centers and universities are primary users of eyetracking instruments for this purpose. The potential for the simplified eyetracker is linked to practicing neurologists and possibly ophthalmologists in either medical center referral locations or in individual private practice.

The various areas discussed above related to medical and diagnostic research in eye movement constitute the primary market segment for a simplified 3-D eyetracker. An indication of this market potential is that more than 350 individuals are conducting research in eye movements from the perspective described in preceding paragraphs. Many of these individuals are interested in the advantages of a simplified 3-D eyetracker and would be potential purchasers; still others not involved may be attracted by the cost-performance aspect of the eyetracker. In the long run, practicing neurologists and ophthalmologists in medical centers serving as referral locations can be considered potential users of eyetracking instrumentation. This potential can be estimated at about 163 based on the number of residency programs in ophthalmology and at 112 based on the number of residency programs in neurology. Beyond this, some penetration of individual practitioners can occur, but the major demand in this area would not be realized until graduates begin purchasing instruments. At the present time, approximately 10,000 ophthalmologists and 2,000 neurologists are practicing in the United States. The market demand in this latter area would not be significant for 5-10 years, or until substantial data and clinical procedures have been established.

Reading research is another area that can effectively use the features of an eyetracker with accurate horizontal as well as vertical measurement and quick response time and at a reduced cost over the present SRI unit. Those performing this type of research are generally psychologists, at universities or in some cases at corporations, who have an interest in reading ability. Potential users of eyetracking equipment are researchers in education where accuracy and cost are important. Approximately 60 individuals are engaged in eye movement research related to reading; however, it is difficult to project the potential of eyetracking instruments in this field as it relates to education and reading improvement programs.

The field of aviation encompasses several studies that relate to measurement of eye movements: aircraft display design, simulator design, training and evaluation of aircraft pilots, training and evaluation of air traffic controllers. Other eye monitoring instruments allow great flexibility in head movement and are thus ideally suited, indeed specifically designed for, this type of research. (See the following section on Competitive Environment.) The nature of the 3-D eyetracker precludes gross movements of the head, but its accuracy and capability to measure accommodation create interest among researchers in this field for possible use in static testing programs. Those conducting the research operate out of universities with government support or at military research installations. The size of this segment of the market would not be substantial. Those now doing work in this area number about 20 at locations across the United States.

Driver and highway safety research forms yet another potential market segment somewhat analogous to that in aviation. The type of head movement freedom required has led to use of competitive instruments, however, the potential exists for static testing programs (which require greater accuracy) to create a demand for the SRI 3-D eyetracker. Again the potential size is low, on the order of 10 locations, engaged in some form of research in this area. Typical users could include Department of Transportation, state drivers programs, and automobile manufacturers. Comments from researchers in the area of transportation indicate that the present methods and auditable devices (excluding the Purkinje Image) are generally satisfactory for the types of research currently undertaken.

The evaluation of the market size for a simplified SRI Purkinje image eyetracker demonstrates a potential research market of 270 users. This market universe is composed of institutions and individuals in the fields of ophthalmology, optometry, physiology, psychology, and neurology. These users would be influenced by the priorities of research-granting organizations. If the current level of research monies is available, then approximately eight units would be sold each year for the first 5 years after introduction. At the projected price of $20,000-$25,000 per unit, the sales per year would amount to $160,000 to $250,000. This estimate is based on the market demand now in effect and would change as more research results became known. If the device were licensed after a 3-year research and development phase, the market demand would be stronger, drawing from the clinic and application community.

The largest market would be the yet untapped market in clinical practice of ophthalmological residency programs, eye clinics, optometric schools, and larger metropolitan hospitals. Based on specific research results, penetration into these areas could lead to a volume of 30 per year within the 5-10 years after introduction. The potential users would number about 700, if referral center environments at hospitals and clinics, as well as the foreign market, were taken into consideration. Penetration of this market would only be sizable if the Purkinje image eyetracker became an established means of diagnosis and treatment. If this occurred, then the estimates in the 5-10 year period would be conservative, and an even greater demand would be expected.

Factors Affecting the Eye Movement Monitoring Market

The primary users of eye movement monitoring equipment currently reside within universities and research organizations. This growing field is still new enough that very few of the devices are used in clinics or for practical application. With research being the focus of eye movement devices, the market is heavily dependent on outside forces such as governmental priorities and other funding agencies, such as university research boards and grant-giving foundations. A brief discussion of each of these forces follows.

Funding

The needs for an eyetracker with the desirable options and the required accuracy must be worked out in conjunction with the projects budget. Governmental grants (NEI and NIH) and independent projects with outside funding sources are tied to the magnitude of the grant and the general research allocations environment. Consequently, cost considerations vary widely from one project to another depending on the resources of the research groups as well as the sponsoring institutions. The integral relationship between grants and purchased equipment has implications for the rate of advancement of the study of eye movement. For example, the NIH plays an important role in the use and demand for the SRI Purkinje image eyetracker. Approximately one-half of the newer SRI eyetrackers are in the hands of NIH-supported researchers.

Funding of eye movement research currently comes from a wide variety of sources, depending on the specific nature and application potential of the research. The majority of these sources or sponsors are from various government agencies whose charter encompasses the financial support and encouragement of eye movement studies. The following list is representative of the majority of funding sources:

- National Institutes of Health (DHEW)
- National Institute of Mental Health
- National Institute for Occupational Safety and Health
- National Institute for Drug Abuse and Alcoholism
- U.S. Air Force (Air Force Office of Scientific Research)
- U.S. Army
- U.S. Navy
- NASA.

Technology

Aside from cost, selection of a particular device is determined on the basis of the technique used to determine movement, the accuracy desired, the required mobility of the instrument and/or the patient, and the form of output obtainable. Refer to Appendix B, Table 1, for a comparative presentation of the various eye movement measuring instruments.

Regulations

Regulations governing instrumentation related to eye movement measurement are of significance where intimate contact is required with the eye or the head. Contact lens techniques or electrooculographic (EOG) methods using electrodes would require satisfactory compliance with federal safety regulations. The remaining eye movement instruments would not require similar contact other than to provide means for supporting the head during testing (e.g., a headrest or bite board). The SRI 3-D eyetracker would fall in the latter category. Nevertheless, medical device regulations as established by FDA would be a concern to any manufacturer of such instrumentation, whether of a contacting or noncontacting type.

Trade-Offs

The nature of the research market is such that among those involved in the work, there is tolerance for:

- The considerable length of time devoted to setup and calibration.
- The large amount of subject influence.
- The large amount of operator expertise required.
- The form of output that may require additional time and effort to evaluate.

Nonetheless, researchers would welcome any versions of instruments that would permit both a greater number of tests to be administered during their work and a more easily managed form of output. The primary tradeoff that usually must be made is whether efficiency and ease of use justify a degradation in accuracy. Some studies may permit such a tradeoff whereas others may not. What is certain is that any attempt to use the same procedures and instruments (having characteristics listed above) under greater constraints of time, less controlled environments, with less knowledgeable patients and operators, as occurs in a clinical situation, would not be successful. If these constraints can be satisfied and provision made for options (e.g., an accommodation and possibly pupil diameter measurement) at a total price competitive with other units, then an effective tool can be marketed to meet research needs today and clinical needs in the future.

Distribution and Promotion

Distribution and promotion occur through the channels established for medical research equipment. The promotional activities could be further expanded to include the clinical medical community and all associated publications and professional seminars and conferences, particularly in the area of neurology, ophthalmology, and psychology. This is a normal process as data are accumulated and specific findings are reported. It is also important to maintain contact with the colleges and universities to keep future specialists aware at an early stage as to the practical utility of the eyetracking instrumentation.

Competitive Environment

Several methods are available for the measurement of eye movements. Each method concentrates on the different characteristics of the eye that serve as indicators of motion. Each method presented in Exhibit 1 of Appendix C has warranted development and commercial introduction by various organizations. The product characteristics representing each method serve the needs of particular segments or groups of segments in the marketplace. At the present time, the SRI 3-D eyetracker represents the only instrument that uses the double Purkinje images of the eye for measurement of eye movement and also provides for measurement of accommodation.

The proposed simplified version of the SRI eyetracker unit could compete more effectively with other instruments already on the market, including other SRI versions. This new version may offer price advantages as well as added measurement capability. The advantages would be attractive to users who are currently doing research in areas both similar to and different from research with the present 3-D eyetracker.

The potential for effectively positioning the simplified 3-D eyetracker in the marketplace is illustrated in Table 4. The various eye monitoring techniques devices are compared with the proposed 3D eyetracker in terms of accuracy, frequency response, range, freedom of head movement, and price. The conclusions are that the proposed instrument can provide:

- Reasonable accuracy
- High-frequency response
- Good range
- Sufficient head movement in stationary testing
- Competitive price.

In June 1978, a survey asked more than 270 scientists engaged in the study of eye movements to indicate which eye monitoring devices were currently available to them. The survey covered the total eye movement community and thus included scientists from a variety of disciplines, including optometry, physiology, military research, psychology, ophthalmology, and neurology. (A full listing of these scientists is provided in Appendix B, Exhibit B.) The survey indicated that EOG, the most widely accepted and used method of eyetracking, is preferred almost two to one over any other method or device. EOG was well represented in all of the disciplines. Schools of optometry and ophthalmology also extensively used this method. The only area that EOG did not penetrate fully is in military and aviation applications; the Honeywell oculometers are most widely used in these areas.

The Honeywell oculometer has certain benefits over the EOG and other methods of observation. On the other hand, the Honeywell system is so extremely expensive that only large laboratories could afford it. Because the remote oculometer does not interfere with the normal activities of the subject, it is particularly useful for human factors research--for example, the flight research that NASA is performing at its Langley Research Center (LRC). Though this device can effectively track the eye, it lacks capability to stabilize the image on the retina and thus is useful in only certain applications.

The eyetracking and eye movement community is diverse not only in its cross-disciplinary emphasis, but also in its specifications for the devices now in use and those for future purchase. Thus, there is no one market for eyetrackers, and the variety of devices now available represents the acceptance of differing trade-offs. For example, Corneal and limbus eyetrackers can record very small eye movements, but their accuracy is poor. This inaccuracy arises from the translation eye movements

Table 4

COMPARISON OF EYE MOVEMENT MONITORING INSTRUMENTATION
AND PROPOSED SRI 3-D EYETRACKER

Attribute Method (Instrument)	Accuracy	Frequency Response	Range	Free Head Movement	Price
Corneal reflex (Polymetric)	Comparable	Lower	Smaller	Greater	Higher or comparable
Contact Lens	Greater	Comparable	Smaller	Comparable	N/A
Electrooculography	Lower	Lower	Greater	Greater	Lower
Limbus boundary (Gulf & Western)	Lower	Comparable	Smaller	Comparable	Lower ($3,000)
Pupil-center-corneal reflection distance (Honeywell, and Gulf & Western)	Greater	Lower	Comparable	Greater	Higher* ($20,000-$50,000)
Double Purkinje image (SRI-present version)	Greater	Comparable	Comparable	Comparable	Higher ($30,000-$40,000)

*A price at the upper end of this range would reflect substantial purchase of optional recording instrumentation.

that are indistinguishable from eye rotation movements. On the other hand, the double Purkinje method of eyetracking eliminates the translation discrepancy from the eye-rotation measurement, and thus eye rotation can be measured accurately without being confused in translation. Another criterion for judgment is the discomfort of the method of testing. EOG and tight-fitting contact lenses can cause discomfort in some patients and are unsuitable for general clinical application. This is particularly true with the trend in medicine toward noninvasive means of testing and evaluation. Cost is a major factor, particularly in research where most devices are purchased only after research grants have been approved.

The question then arises, "What unique niche does the SRI Purkinje image eyetracker address and what would be its competitive advantage?" This question is a legitimate one, but is complicated because the SRI eyetracker is still under development and undergoing evolutionary change in each new generation. The absolute limits of the Purkinje image method of eyetracking have not been fully explored because experimental data are lacking, and the use of the actual devices has limited full exploration of the method's potential. In addition, little attention has been devoted to comparing the relative advantages of the EOG, IR, Purkinje, and magnetic coil techniques for recording eye movements. With the eye movement field still in its infancy, basic research still needs to be done before its wider applicability and thus larger market can be assessed.

Product literature from the major manufacturers of eye monitoring instrumentation is included in Appendixes D and E. The manufacturers include Honeywell Radiation Center and Gulf and Western Applied Sciences Laboratories.

The Ophthalmology Market

Overview

The ophthalmology market appears to consist of at least four segments: supplies and medication, including lens blanks; devices; office and surgical furniture; and instruments and systems. The device segment is composed of hand-held instruments, such as surgical instruments, ophthalmoscopes, lights and wands, and contact lenses. The instrument and systems segment of the market which ranges from simple slit-light systems to computer-controlled refractors, laser photocoagulators, and ultrasonic diagnostic and therapeutic devices; the eyetracker would be included in this segment. Most available systems appear to have their origins in the classical optical systems. Modifications and improvement to these devices have been made primarily from an application point and appear to use few new technologies. Exceptions are the automatic refractor, the photocoagulators, and the ultrasonic devices that are making use of modern electrical and mechanical technologies. The transfer of techniques, technologies, and sophistication of optics and electronics developed for space and military applications into the ophthalmological instrumentation market is slowly making headway. New products and new techniques will remain the catalysts needed to keep the industry moving through the 1980s.

The ophthalmology market is difficult to summarize. It is fragmented over a fairly large product sphere. The ophthalmology market is composed of many small companies among several large companies. To remain viable and capture an adequate share of the market, a majority of companies are looking for products, product lines, and other companies. Apparently, companies have decided to grow by acquisition rather than by internal development.

The question then arises, "How do new procedures and technologies get introduced into the marketplace?" It appears, for example, that the ultrasonic fragmentation and laser photocoagulator instruments were developed with the cooperation and/or support of leading physicians in the field. Further, it appears that the leading companies have their supporting cadre of physicians who defend and promote their products. A significant number of papers at the technical meetings in ophthalmology are devoted to explaining, evaluating, or reporting the results of the various instruments and techniques. It would be difficult for a new company to enter this rather closed marketing world without the support of a leading medical expert and the published validation of research results. In summary, the introduction of new technologies into clinical practice is dependent on a growing body of research and the advocacy of these procedures by respected medical personnel. Any commercialization strategy of the eyetracker should understand the established procedures for the introduction of innovative ideas into the ophthalmological marketplace.

One of the largest possible applications of the simplified 3-D eyetracker would be in ophthalmological research and later in clinical application. With the current emphasis on expanding the definition of "optometry," optometrists also could be a potential market. If the Purkinje eyetracker becomes important as a diagnostic tool, it could become an essential component in these applications.

Before we describe the nature of these markets it would be best to differentiate the respective roles of ophthalmologists, optometrists, and opticians. Although ophthalmologists are the bonafide medical specialists for the eye, diagnosing and treating eye diseases and performing eye surgery, optometrists provide a wide variety of important eye care services, including vision screening and eye examination, contact lens fitting, glaucoma screening, prescribing eye glasses, orthoptics (eye exercises), and visual field testing. Opticians, on the other hand, prepare and dispense lenses and optical appliances on prescription from either optometrists or ophthalmologists. The eyetracker capabilities of diagnosis and treatment would then be of interest primarily to ophthalmologists and to a smaller extent to optometrists.

In many states at the present time, jurisdictional conflict and interprofessional rivalry exist between optometrists and ophthalmologists. (See Who Should Use Drugs in Your Eyes?) The problem arises from both professions sharing many of the same functions: vision testing, eye examination, and prescribing eyeglasses. Ophthalmologists take the position that optometry should be limited to refraction, prescribing and adjusting glasses, and providing optical devices; while optometrists feel that their role is considerably broader, including offering primary eye care services and ocular pathology screening, as well as detecting eye abnormalities that include ocular manifestations of systemic disease. (See "The Role of the Optometrist in Health Care Delivery.")

Emerging Trends

Out of this controversy, a market trend is emerging that may effect the sales of an eyetracker. Traditionally, optometry has been isolated from other components of the health care system. Solo practice is the predominant mode of employment although a trend seems to be developing toward partnership practice and employment in multidisciplinary group practices or other organizational entities, particularly among younger optometrists.

There is a trend among hospitals of sufficient size (400 beds and up) to incorporate the optometrist within their organizational framework. Thus, some consideration is being given to the establishment of eye clinics that use both optometric and ophthalmological services. It is the development of these clinics that would give the marketplace entities of sufficient "mass" to efficiently use and thus buy an expensive Purkinje eyetracker. As indicated in Tables 5 and 6, optometrists and ophthalmologists in solo practice would justify the expense of such an item. If the trend is to work in teams and not in solo practice, however, the eyetracker market will expand from the obvious market with teaching hospitals and eye clinics (see Tables 5 and 6). About 900 hospitals currently are of sufficient size to economically justify the use of expensive clincial devices in eye care (see Table 7). This trend toward hospital-based teams would have a long-term effect on the market for eye movement monitoring equipment. This trend would probably have little impact during the first 5 years, after introduction, but could become a market source of growing proportions in the subsequent years.

The traditional eye clinics--usually part of an eye, ear, and throat clinic--number 22 in the United States. If the Purkinje eyetracker were proved feasible in the clinical setting, complete penetration of the clinic market could be expected within 5-10 years after introduction.

Given their tasks of qualifying their students to detect and diagnose disease conditions of the eye and ocular trauma, the 12 optometric schools would provide a good market for the SRI eyetracker. In addition, professors of optometry often have their own research programs that necessitate the use of eye movement monitoring equipment. Each of these schools probably would use this equipment in teaching as well as research.

Table 5

NUMBER OF OPTOMETRISTS

	Number	Annual Average Change (percent)	Optometrist per 100,000 People
1950	20,792	--	13.7
1960	21,824	+0.5	12.1
1964	20,818	-1.2	10.9
1966	20,610	-0.5	10.5
1967	20,565	-0.2	10.3
1968	20,301	-1.3	10.1
1969	20,611	+1.5	10.1
1971	20,736	+0.6	10.0
1973	21,697	+	10.1

Note: These figures include active and inactive optometrists.

Source: Blue Book of Optometrists

Table 6

NUMBER OF OPHTHALMOLOGISTS

			Hospital-Based		
	Total Active	Office-Based	Training	Full-Time Physician	Other Professional Activity*
1967	9,083	7,048	1,247	540	248
1970	9,927	7,662	1,334	517	414
1971	10,252	7,903	1,402	545	402

*Includes medical teaching, administration, research, and other.

Source: AMA Center for Health Services Research & Development

Table 7

NUMBER OF U.S. HOSPITALS BY BED SIZE
1978

Number of Beds	Number of Hospitals
6-24	377
25-49	1,305
50-99	1,677
100-199	1,551
200-299	819
300-399	440
400-499	305
500 or more	608
Total	7,082

Commercialization Potential

The commercialization of a simplified 3-D eyetracker is critically dependent on the advancements and commensurate needs of the eye movement research community, whether in the public, private, or not-for-profit sectors, or on a contract basis or in independent studies. As interest and activity increases in this field, the need for efficient, accurate, reasonably priced instrumentation will increase. In many areas of research, the ability to measure accommodation in conjunction with vertical and horizontal eye position will be a serious purchase consideration. The SRI unit would offer researchers a significant opportunity to purchase an accurate, flexible instrument at a price comparable to that for other available instruments. Thus, the simplified 3-D eyetracker would be an important complementary product to the more complex double Purkinje image 3-D eyetracker now being used.

The transition to clinical diagnostic applications requires the firm establishment of a reliable data base that will establish the utility of the 3-D eyetracker to practitioners. The general consensus is that initial clinical usage would be found at referral centers at major hospitals and clinics or major medical centers affiliated with universities. Only after the instrument has established its worth in a diagnostic environment can individual practitioners be expected to express interest to the point of willingness to purchase. It must initially be established that an eyetracking instrument can aid the diagnostic process in various fields. Further, to be of practical value in a professional medical practice environment, the instrument must have demonstrated efficiency, easy of operation, and the capability for interaction in other applications. Cost is measured not only in terms of dollars, but also in terms of time, operator training, patient involvement, instrument calibration, and maintenance. The objective of any commercial venture in this field should be to minimize all of the above.

At each stage of the introduction process, promotional considerations would be oriented toward literature and pertinent conference vehicles. This would generate interest and constructive criticism and help to educate practitioners and increase their awareness of the utility of monitoring eye movements through instrumentation such as the 3-D eyetracker. Education and information programs should also be conducted and encouraged in the various neurology and ophthalmology residency programs, as well as in the major psychology and physiology education centers. Because this is the source of future researchers and practitioners, such programs thus form an important means of creating familiarity with the practical aspects of monitoring eye movements.

The commercialization process described here is confirmed by ophthalmic goods manufacturers. There is concern, however, about the limited potential market sizes in the research area coupled with the uncertainty of clinical diagnostic acceptance without a substantial data base. Nevertheless, there is recognition that the capabilities of the SRI 3-D eyetracker warrant serious consideration as a new product prospect. Reduction of costs through use of advanced electronics (e.g., microprocessors) and production design evaluation would do much to increase the commercial viability of the 3-D eyetracker.

The following people have expressed interest as potential manufacturers of the 3-D eyetracker:

Dr. John Merchant
Honeywell Radiation Center
2 Forbes Road
Lexington, Massachusetts
617/862-6222

Mr. Albert Harabedian
Vice President
Human Factors Research, Inc.
6780 Cortona Drive
Goleta, California 93017

Mr. Michael Reynolds
Manager, New Products Planning
Telesensory Systems, Inc.
1889 Page Mill Road
Palo Alto, California 94304
415/493-2626

Mr. George S. Leonard
Products Manager
Gulf and Western
Applied Science Laboratories
335 Bear Hill Road
Waltham, Massachusetts 02154
617/890-5100

REFERENCES

Blue Book of Optometrists, 1976.

Clark, M. R., and H. D. Crane, "A Three-Dimensional Visual Stimulus Reflector," Applied Optics, 706-714, March 1, 1978.

Cooper, Roger, Applied Optics, 1974.

Festinger, 1975 (source unknown).

Komoda et al., Japanese Journal of Ophthamology, 2057-62, 1976.

"Market Survey: 3-D Eyetracker," Contract NASW-2837, IIT Research Institute (May 20, 1977).

Site Visit Report, National Eye Institute, Washington, D.C. (1977).

"The Role of the Optometrist in Health Care Delivery," Canadian Journal of Public Health, 66:131-136, 1975.

Snodderly, D. M., et al., "Mapping Small Retinal Features in a Freely Moving Eye with Precise Control of Retinal Stimulus Position," S. J. Cool and E. L. Smith, eds, Frontiers of Science (Springer, New York, New York, 1978).

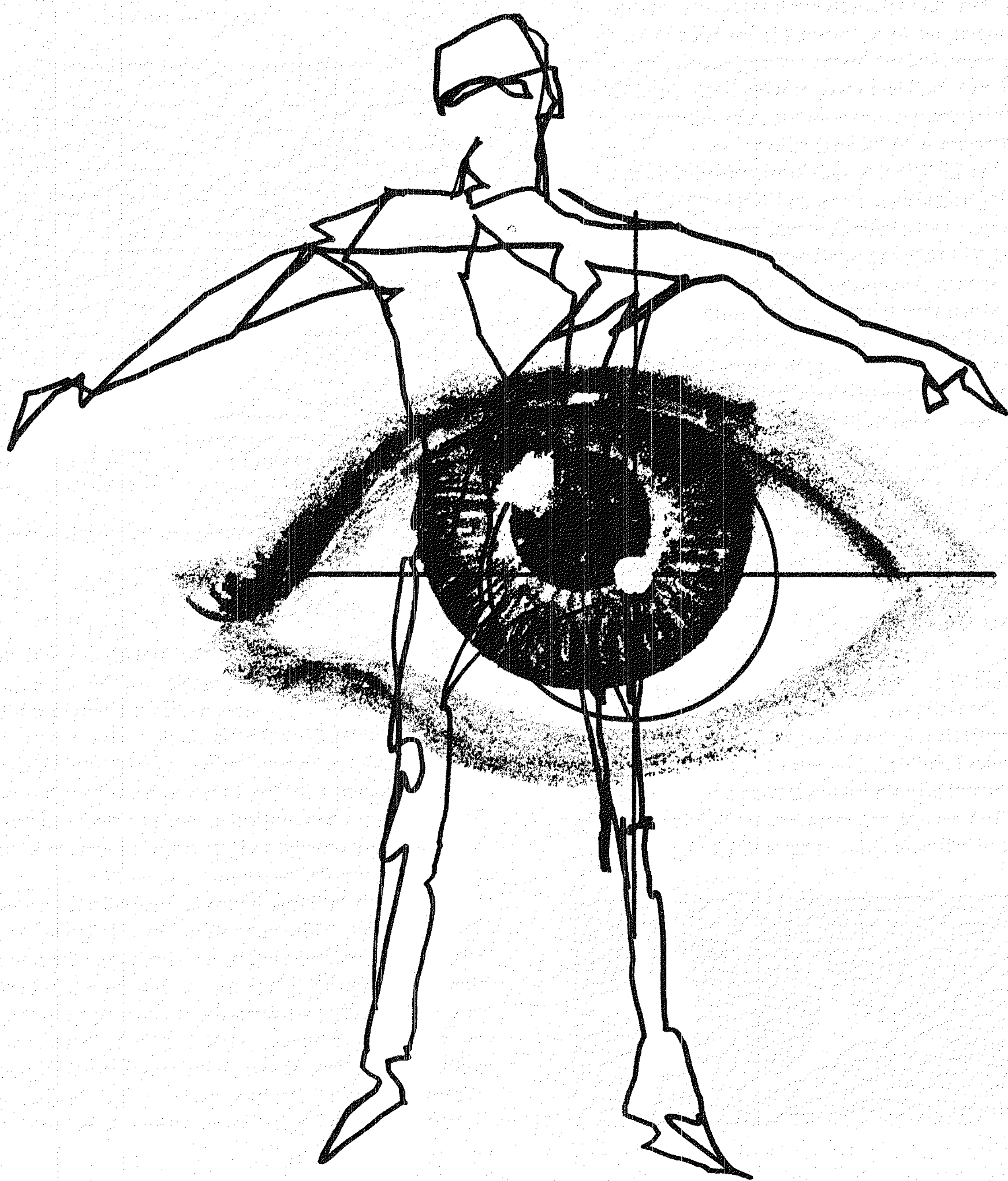
"Who Should Use Drugs in Your Eyes?", New York State Ophthamological Association, 7147 Madison Avenue, Albany, New York 12208.

Appendix A

SRI PURKINJE IMAGE EYETRACKING LITERATURE

EYETRACKING

. . . Extreme accuracy using Purkinje images and optics

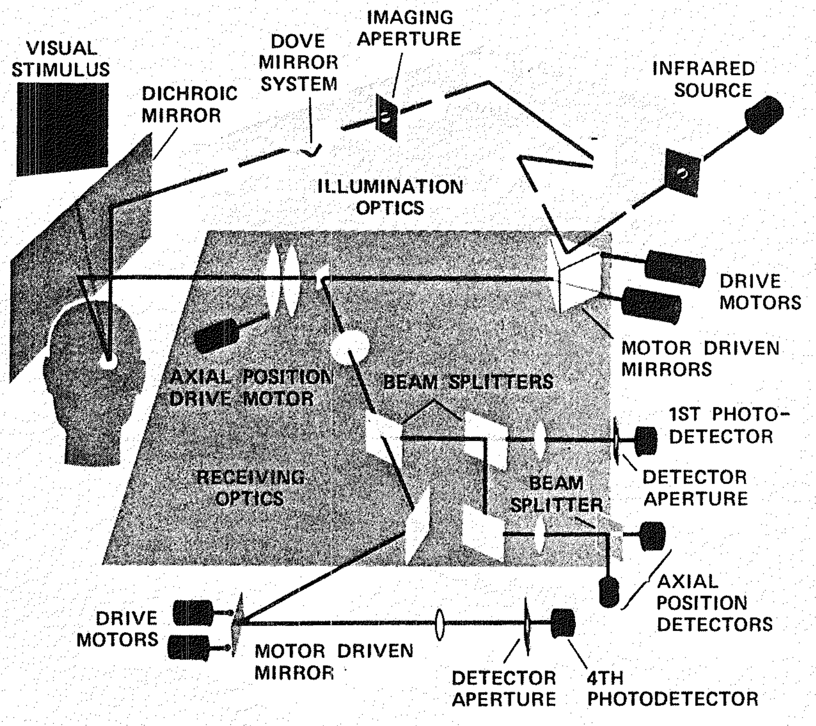


EYETRACKING

The development of the Dual Purkinje Image (DPI) Eyetracker at SRI is an exciting engineering breakthrough* which promises to extend the horizons of VISION research. Based on the unique optical properties of the eye, the DPI eyetracker can determine the direction of gaze over a large two-dimensional visual field with great accuracy and without attachments to the eye. Troublesome artifacts due to translational and axial movements of the head and eye ranging up to a centimeter are automatically eliminated. The inconvenient bitebar is not necessary, and simple chin and forehead rests provide head stabilization. The SRI Eyetracker operates with infrared light and does not interfere with normal vision.

Personnel in the Electronics and Bioengineering Laboratory of the Information Science and Engineering Division developed the DPI eyetracker and are now utilizing its capability to study the relationships between eye movements and speech perception, the focusing ability of the eye, and visual sensitivity to spatio-temporal targets. Commercial and government projects within and outside SRI have made use of the SRI eyetracker to do research in pilot eyetracking of an aircraft instrument panel as well as basic research in vision and perception.

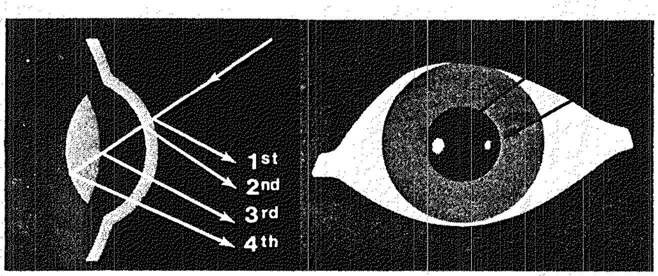
*Cornsweet, T. N., and Crane, H. D., *J. Opt. Soc. Am.* 63(8): 921-928 (1973).



Schematic Drawing of Eyetracker Illustrating Operation

PURKINJE IMAGES

Light rays striking the eye produce four reflections, called Purkinje images, from the front and rear surfaces of the cornea and lens. The first (virtual) and fourth (real) Purkinje images are almost coincident and lie in the same focusing plane. These two images move similarly under translation and differentially under rotation. The change in separation is used to determine eye rotation free of artifacts induced by translation.

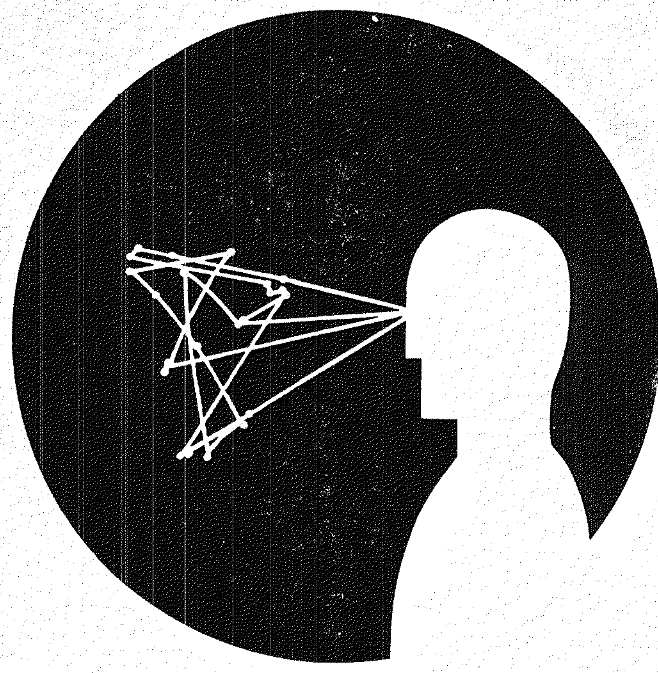


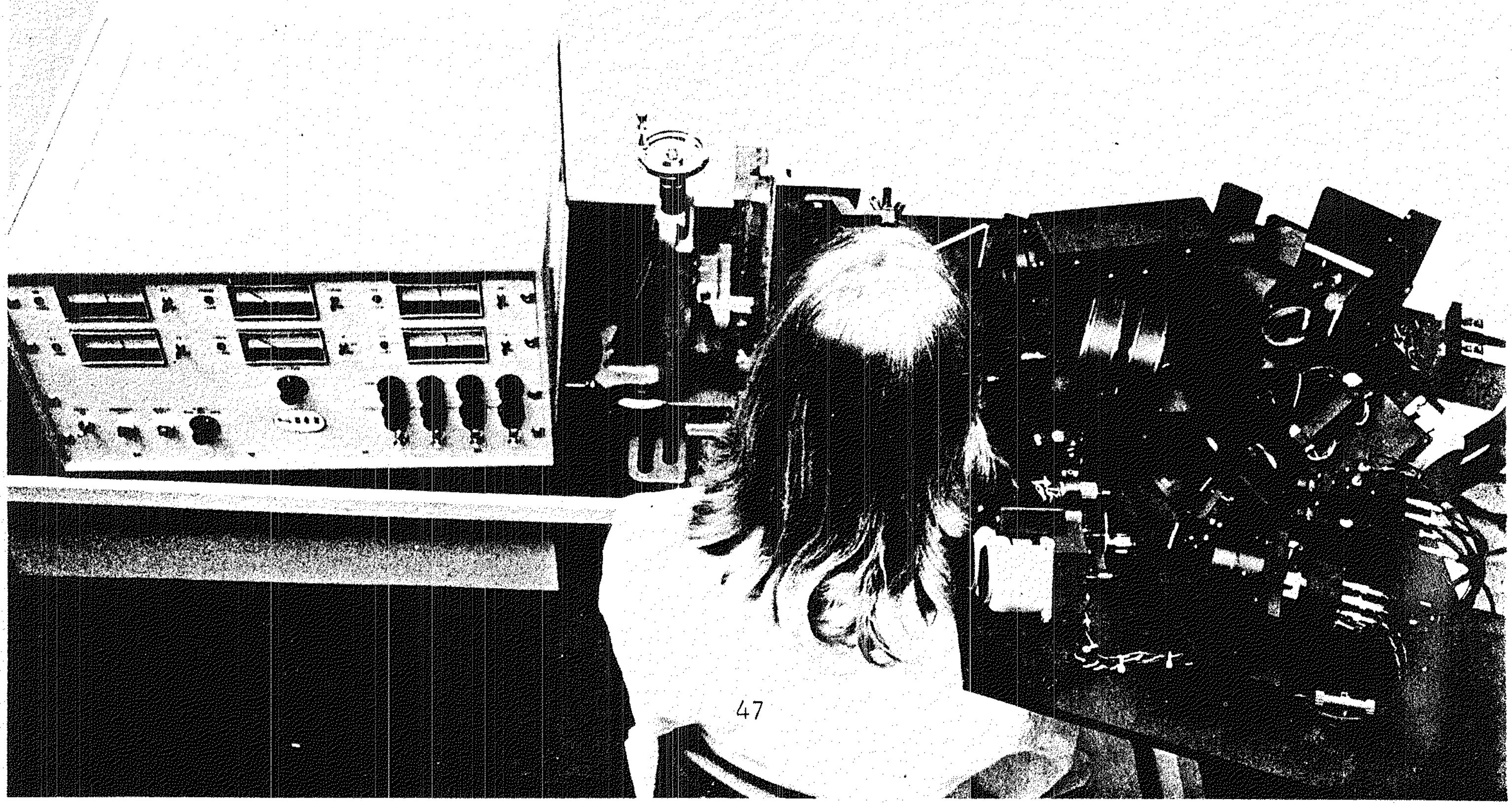
THEORY OF OPERATION

In SRI's DPI Eyetracker a collimated infrared light source illuminates the eye at an angle to the direction of gaze, forming two Purkinje images within the pupil (as illustrated by diagram at left). The first Purkinje image is brought to focus on a stationary photodetector by the receiving optics after reflection from a motor-driven mirror. The stationary photodetector senses any motion of this image and causes the mirror to rotate horizontally and vertically enough to keep the image centered on the stationary photodetector.

The fourth Purkinje image is focused onto a second photodetector after reflection from an additional motor-driven mirror. This second stationary photodetector senses any motion of the fourth image and causes the second mirror to rotate horizontally and vertically enough to keep the image centered on the photocell. Since the first image is stabilized in space, the motion of the other image is exactly equal to the relative motion of the two images. From this relative motion, the direction of gaze can be accurately determined.

The convenience and accuracy possible with DPI Eyetracking make it attractive for control applications, for designing and testing complex displays, for computer-aided education and for such clinical uses as drug evaluation and diagnosis of neurologic disorders.





This Page Intentionally Left Blank

APPLICATIONS

Eyetracking, with its convenience and accuracy, can be applied to

- IMAGE STABILIZATION
- SPEED READING
- ANALYSIS OF VISUAL PERCEPTION
- PILOT TRAINING
- THERAPY FOR STRABISMUS
- AIRCRAFT INSTRUMENT EVALUATION
- NEUROLOGIC DIAGNOSIS
- MAN-MACHINE INTERACTION
- ADVERTISING READERSHIP ANALYSIS

ADVANTAGES AND COMPARISON WITH OTHER SYSTEMS

- Accurate to 1 minute of arc
  - as accurate as contact lens methods
  - 30-60 times more accurate then photoelectric methods
- No eye attachments or bitebar
  - safer and more convenient than contact lens
  - photoelectric methods require bitebar for accuracy
- Allows translation and axial movements of up to 1 cm
  - axial movements not allowed in contact lens techniques
  - neither movement allowed with photoelectric techniques
- Large two-dimensional field (>25°)
  - larger than that allowed with contact lens due to slippage
  - comparable with photoelectric methods
- Operates in infrared
  - does not interfere with normal vision

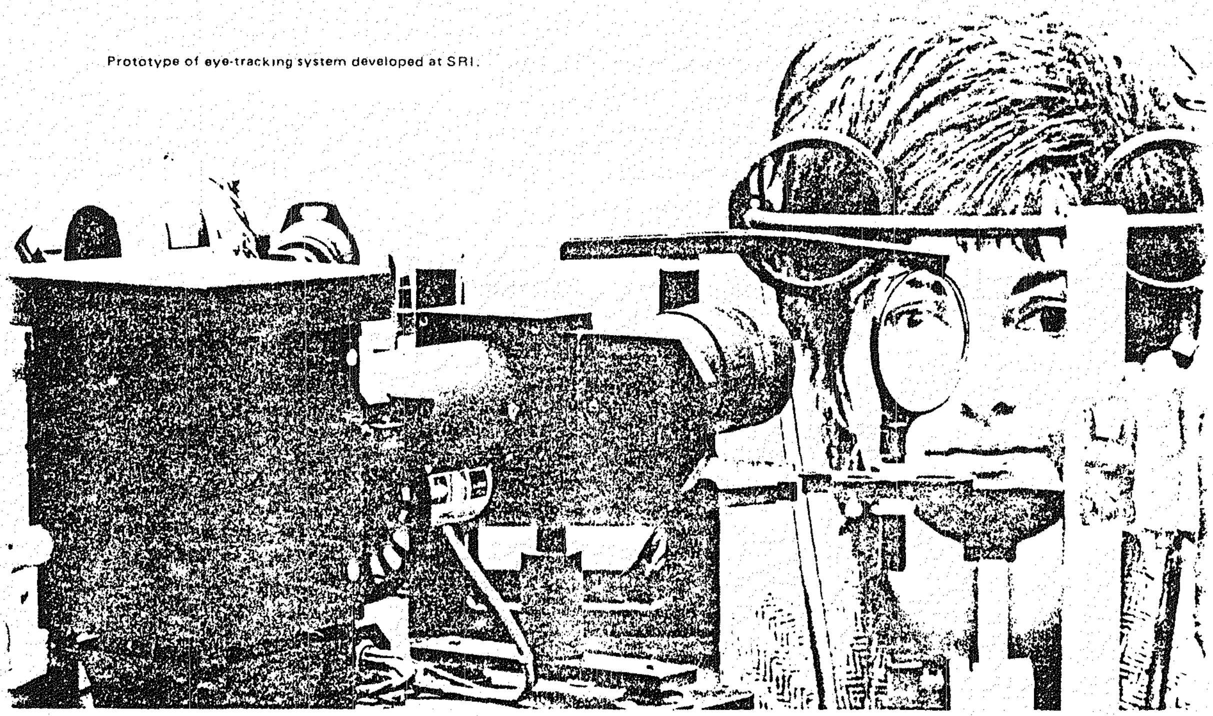
MORE INFORMATION

For more information, contact Information Science and Engineering Division, Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California 94025 Telephone (415) 326-6200

Move robots with your eyes!

New Eye-tracking System Has Promis

Prototype of eye-tracking system developed at SRI.



Imagine what it would be like to control the movements of a robot just by looking in the direction you wanted it to go. From a safe distance, you could cause it to manipulate objects in a hostile environment.

You might, for example, make the robot's hand follow your gaze deep into the seething interior of a steel-making furnace, grasp a red hot metal ingot and pull it back out again. No knobs for you to turn or buttons to press. No need to formulate verbal instructions.

An eye-tracking system recently developed at SRI makes it feasible to perform this and other complex applications based on eye movements. Although eye-tracking systems have been available for some time, these systems are either too limited in accuracy or too inconvenient for such uses.

Systems that are convenient to use cannot distinguish between two types of movement that the eye commonly makes. The important movement for an eye tracker to measure is the rotation of the eye as it looks from one object to another. But the eye is also in constant lateral motion in its socket.

These wobbling movements have no effect on the direction of the gaze at any particular moment. However, they interfere with the measurement of eye rotation and seriously limit the accuracy of the eye-tracking systems.

Previously, the only way around the problem was to mount a suitable device directly to a very tightly fitted contact lens that was inconvenient to put on and sometimes dangerous to wear.

The SRI system gets around the problem without touching the eye. Instead, it tracks light reflections (known as Purkinje reflections) from two surfaces of the eye (in particular, the front surface of the cornea and the rear surface of the lens), just as a star tracker tracks the light from a distant star. These reflections move in characteristic ways that are independent of the translational motions of the eye, but can be related directly to its rotational motions.

The system has an accuracy comparable to that of contact lens systems – about 1 minute of arc. This means that in the robot example above, if your gaze were fixed on a spot 15 feet away, the robot's fingers would be maintained to within about

in Industrial and Medical Applications

a millimeter of that spot This is 30 to 60 times as accurate as other non contact systems

Its convenience and accuracy make the instrument attractive not only for control applications but also for clinical uses such as drug evaluation detection of brain tumors (which constrain eye movements within certain patterns) and the design of complex displays For example by knowing where the viewer is looking at a particular display and what his physiological reactions are at that moment the designer would be better able to decide how to alter the design of the display

Because of its potential for instantaneous feedback the instrument is also attractive for training applications For example it might be used to train cross eyed children to use their eyes correctly A system could be developed using two eye trackers one for each eye Each eye tracker would project onto a screen a different colored spot that would indicate where that eye was looking

If the two eyes were looking in the same place the two spots would be superimposed If not the spots would be separated and the child would be instructed to bring them back together

The high accuracy of the SRI system would be critical for this application because unless the spots reflected the eye movements precisely and immediately the child would soon become frustrated

Another possible training application would be speed reading One objective in speedreading is to train the student to use his full visual span for information gathering If he moves his gaze to the beginning of a new line some of his visual span will extend into the margin and be wasted The eye tracker could be used to show him where to start reading the line for maximum efficiency It could do this by lighting up an area equal to his visual span and moving this lighted area along with his gaze

SRI researchers developed the instrument together with an optometer that measures the plane of focus (see box) to help them in their studies of vision Their next step is to merge these two instruments into a single system that measures both focus and eye movements simultaneously

In the meantime says Hewitt D Crane staff scientist in vision research at SRI the present instrument could be developed for commercial use

Three copies of the latest version of the instrument currently exist Two were built by SRI for use in other research laboratories and the third is in use at SRI Single copies of the instrument can be made for between $15 000 and $20 000 But the price would of course be much smaller in large scale production

Apart from building a composite instrument incorporating the optometer as well as the eye tracker the SRI researchers are also interested in developing advanced versions that do not require even the chin and head rests currently used to keep the subject s head properly aligned

SRI has filed patent applications on this instrument as well as on more advanced designs and would be interested in licensing these patents for the purpose of further private development ■

NEW INSTRUMENT FITS GLASSES AUTOMATICALLY

The eye tracker is only one of the instruments developed at SRI for monitoring the behavior of the eye Another called the optometer measures the instantaneous plane of focus of the eye and can track even the most rapid changes in focus

This instrument has a potentially large market for automatic fitting of eyeglasses Instead of the current practice of having the patient look through one lens after another in search of one that best corrects his focus the ophthalmologist would use the instrument to monitor the eye focus as the patient focused on a target that moved closer and further away from him The instrument would then read out the points at which the eye ceased to focus correctly

The instrument would also be useful in clinical research for drug evaluation for example as well as in other types of vision research In addition it could be used as a training device In a recent application subjects were trained to focus their eyes to infinity i e to far distances against a dull background lacking in contrast

Under these conditions most of us tend to focus at a distance of about 3 feet away This phenomenon known as empty field myopia can be dangerous to jet pilots and others who must operate at high speed

Whistle while you look

Dr Hewitt D Crane staff scientist at SRI and coinventor of the optometer and the eye tracker described in this article says that the instrument was modified in the laboratory to serve as a training aid by causing it to produce an audible tone that increased or decreased in frequency as the eye focused on a near or far object

The subject was instructed to listen to this tone in one ear and to a command tone in the other ear and to make the two match After a few hours practice he was able to play a tune with his eye focus without even being able to explain exactly how he did it

The optometer consists of a system that projects invisible light into the eye and a second system that receives the light reflected back out of the eye from the retina If the input light pattern is in focus on the retina the reflected image is stationary otherwise it is in motion

A servo control system moves the incoming infrared light patterns in such a way that no matter how the eye focus changes the input light pattern remains focused on the retina and the reflected image is therefore stationary The instrument reads out continuously how far the incoming light beam must be moved to cause the light to remain in focus on the retina

SRI is currently negotiating with several firms that are interested in further development and marketing of the optometer ■

This Page Intentionally Left Blank

Appendix B

AN INTERDISCIPLINARY DIRECTORY OF SCIENTISTS ENGAGED IN THE STUDY OF EYE MOVEMENTS

This Page Intentionally Left Blank

AN INTERDISCIPLINARY DIRECTORY OF SCIENTISTS ENGAGED IN THE STUDY OF EYE MOVEMENTS

Fifth Edition

Richard A. Monty

and

B. Diane Barnette

June 1978

APPROVED: [signature]
JOHN D. WEISZ
Director
U. S. Army Human Engineering Laboratory

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland 21005

Abstract

The purpose of this directory is to foster communication between members of the various disciplines engaged in the study of eye movements This edition lists the names, addresses, phones numbers, educational background and interests of approximately 270 scientists interested in this field of endeavor. Entries were made on a voluntary basis and a form is enclosed for those who wish to be included in subsequent editions Entrants will automatically be informed of future conferences on this topic to be sponsored by the Human Engineering Laboratory.

If you are interested in being listed in subsequent editions of the directory or if information in the present directory needs updating please complete the following:

Privacy Act Statement: Eye Movement Directory Form. Authority: 10 USC 3012. Purpose: Collection of data for entry into an International Directory of Scientists Engaged in the Study of Eye Movements. Routine Uses: (1) To facilitate verbal and written communication, (2) To identify personnel with specialized interests; (3) Serves as a mailing list. The directory is available for public release. Completion of form is voluntary; an incomplete form will result in an incomplete listing or no listing.

Check one: ( ) NEW ENTRY ( ) CORRECTION

NAME ______________________________

MAILING ADDRESS ______________________________

____

____

PHONE ______________________________

DEGREES	SCHOOL	DATE	FIELD
________	________________	________	____________
________	________________	________	____________
________	________________	________	____________
________	________________	________	____________
________	________________	________	____________

List up to three principal areas of interest in eye movements (i.e., reading, search, etc.) and after each indicate if you are actively involved in research in the area with an (A) or currently inactive with an (I).

1.________________ 2.________________ 3.________________

Indicate eye monitoring devices which are currently available to you.

a.________________ b.________________ c.________________

RETURN TO: Richard A. Monty
Behavioral Research Directorate
Human Engineering Laboratory
Aberdeen Proving Ground, MD 21005

If you are interested in being listed in subsequent editions of the directory or if information in the present directory needs updating please complete the following

Privacy Act Statement· Eye Movement Directory Form. Authority· 10 USC 3012. Purpose Collection of data for entry into an International Directory of Scientists Engaged in the Study of Eye Movements. Routine Uses (1) To facilitate verbal and written communication, (2) To identify personnel with specialized interests; (3) Serves as a mailing list The directory is available for public release. Completion of form is voluntary, an incomplete form will result in an incomplete listing or no listing.

Check one ( ) NEW ENTRY ( ) CORRECTION

NAME ______________________________

MAILING ADDRESS ______________________________

____

____

PHONE ______________________________

DEGREES	SCHOOL	DATE	FIELD
________	________________	________	____________
________	________________	________	____________
________	________________	________	____________
________	________________	________	____________
________	________________	________	____________

List up to three principal areas of interest in eye movements (i.e , reading, search, etc.) and after each indicate if you are actively involved in research in the area witn an (A) or currently inactive with an (I).

1 ________________ 2. ________________ 3. ________________

indicate eye monitoring devices which are currently available to you.

a. ________________ b. ________________ c. ________________

RETURN TO· Richard A. Monty
Behavioral Research Directorate
Human Engineering Laboratory
Aberdeen Proving Ground, MD 21005

Description of Directory Entry Format

The directory entry format contains the information items described below:

1. Name

2. Preferred mailing address

3. Telephone number

4. Degrees, schools and fields of specialization

5. Areas of interest (numbered) followed by either an (A) indicating that the listee is actively involved in research or an (I) indicating that he or she is inactive in that area.

6. Eye movement devices that are currently available to the listee (lettered).

Adams, Anthony J., University of California, School of Optometry, Berkeley, California, 94720, 415-642-5904, B App. Sc., Melbourne University, 1962, Applied Science, L.O. Sc., Victorian College, 1962, Optometry, Ph.D., Indiana University, 1970, Physiological Optics. 1. Tracking, (I) 2 Search (I) a Electro-optical (Limbal sensing) b. EOG

Adams, B D., Department of Physiology, University of Toronto, Room 3317, Medical Science Building, Toronto, Ontario, M5S 1A8 Canada, 416-978-6072, B.Sc., University of Toronto, 1977, Physiology, 1. Saccades (A) 2. Night vision (1) 3 Aviation applications (A) a. Infra-red Diode Device (Hallett, P.E.)

Alder-Grinberg, Deborah, College of Optometry, University of Houston, Houston, TX, 77004, 713-749-4103, B.S., University of California, 1969, O.D., University of California, 1971, Optometry, Ph.D., University of California, 1976, Physiological Optics 1 Search, reading (1) 2. Dynamic EMs (saccadic pursuit in children and clinically) (A) 3 OKN (adult, children, clinically) a. IR-photo cell system b. EOG c. Magnetic field system (under construction)

Aiken, E. G., Code 306, Navy Personnel Research and Development Center, San Diego, California, 92152, 225-6617, Ph.D., University of Illinois, 1954, Psychology 1. Reading (A) 2 Attention (A) 3. Effort (I). a Whitiker.

Allen, R. Wade, 13766 Hawthorne Blvd , Hawthorne, California, 90266, 213-679-2281, B.S., UCLA, 1962, Engineering, M.S , UCLA, 1965, Engr./Biotechnology 1 Driving (A) 2. Piloting (A) 3. Display Scanning (A) a. STIEPR Mk. II

Anliker, James E., 1272 Mills Street, Menlo Park, California, 94025, 415-325-9749, S.M., University of Chicago, 1952, Biological Sciences, Ph.D., Harvard University, 1955, Experimental Psychology. 1. Picture perception (A) 2 Scanpath analysis (A) 3 Eye-controlled displays (A) a. SRI Purkinje Tracker with computerized scanpath analysis b Electrooculography.

Antes, James R., Department of Psychology, University of North Dakota, Grand Forks, North Dakota, 58201; 701-777-3451, B.A., Drake University, 1968, Physics, MS., Iowa State University, 1970, Psychology, Ph.D., Iowa State University, 1973, Psychology, 1 Picture Perception (A) 2. Visual Attention (A). a Biometrics.

Arend, Jr., Lawrence E., Department of Psychology, Brandeis University, Waltham, Massachusetts, 02154, 617-647-2954, A.B., Stanford University, 1965, Psychology, Ph.D., Duke University, 1970, Psychology. 1. Maintenance of vision (A) 2. Target detection, search, & scanning (A). a. Search coil in suction contact lens (A. Skavenski)

Arima, James K., Code 54Aa, Naval Postgraduate School, Monterey, California, 93940, 408-646-2686, Ph.D., Northwestern University, 1962, Psychology 1. Search (I) 2. Displays (I).

Arlin, Marshall, Department of Educational Psychology, University of British Columbia, Vancouver, B.C. V6T 1W5, Canada; Ph.D., University of Chicago, 1973, Education. 1. Reading (A) 2. Memory (A). a. Biometrics.

Bach'y-Rita, Paul, Smith-Kettlewell Institute of Visual Sciences, 2232 Webster Street, San Francisco, California, 94115; 415-563-4321, ext. 2481; M.D., National University of Mexico, 1959, Medicine. 1. Neurophysiology (A) 2. Morphology of Eye Muscles (A).

Baker, Mary Anne, Indiana University Southeast, New Albany, Indiana, 47150; 812-945-2731, ext. 293; B.A., University of Louisville, 1964, Art History, M.A., University of Louisville, 1969, Psychology; Ph.D., University of Louisville, 1971, Psychology. 1. Form Perception (A) 2. Stimulus Variables Affecting (A) 3. Mathematical Predictions (A). a. Mackworth Eye Camera.

Bermudez, John M., Qtrs. 6402E, USAF Academy, Colorado, 80840, 303-472-3860, B.S., Florida State University, 1965, Psychology; M.Ed., Our Lady of the Lake College, 1970, Psychology; Ph.D., Arizona State University, 1975, Educ. Psychology. 1. Peripheral Processing (A) 2. Search (A) 3. Effects of Stress (A). a. Infra-red tracker b. Head position sensor c. Pupilometer.

Bertera, James H., 607 N.E. 15th Street, Oklahoma City, Oklahoma, 73108, 405-272-9876; B.A., Fairfield University, 1970, Psychology, M.A., Hollins College, 1972, Psychology. 1. Search (A) 2. Tracking Self-Moved Targets (A) 3. Hand-Eye Coordination (A). a. EOG b. Corneal Reflection (home-built) c. Video Tape.

Bevan, Thomas, Science Applications, Inc., 1911 N. Fort Myer Drive, Suite 1200, Arlington, Virginia, 22209; 703-527-7571; A.B., Dartmouth College, 1969, Psychology, Ph.D., Princeton University, 1973, Physiological Psychology. 1. Reading (A) 2. Human Factors (A) 3. EEG (A). a. Whittaker 19945 b. EOG (Grass).

Bischof, Norbert, Psychological Institute of the University of Zurich, Dept. of Experimental-Mathematical Psychology, Seilergraben 53/55, CH-8001, Zurich, Switzerland; 32 62 41, int. 2138 (ext.) Ph.D., University of Munich, 1966, Psychology. 1. Space constancy (A). a. IR-recording.

Bizzi, Emilio, Department of Psychology, E10-235, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139, 617-253-5769, M.D., University of Rome, 1958. 1. Central control of eye movements (A) 2. Eye-head coordination (A) 3. Vestibular system (A). a. Silver-silver chloride electrodes b. Methods of Bond & Ho.

Black, F. Owen, Department of Otolaryngology, Room 925, Eye and Ear Hospital, 230 Lothrop St., Pittsburgh, PA, 15213, 412-683-3500 ext. 368, B.A., Southeast Missouri State, 1959, Chemistry; M.D., University of Missouri, 1963. 1. Vestibulo-ocular reflexes (A) 2. Ocular motor reflexes (A). a. EOG b. PEOG c. ODD.

Bowen, Richard W., Department of Psychology, Columbia University, New York, New York, 10027, 212-280-4325; B.A., Case Western Reserve, 1968, English/Psychology, M.A., Columbia University, 1970, Psychology, Ph.D., Columbia University, 1974, Psychology. 1. Eye Movements and Space Perception (A) 2. Oculomotor Control (A) 3. Oculomotor Physiology (I). a. Scleral contact lens - optical lever system.

Bradshaw, J. J., Department of Psychology, Monash University, Clayton, Vic. 3168, Australia; 541-3958, M.A., Oxford University, 1963, Experimental Psychology, Ph.D., Sheffield University, 1967, Experimental Psychology. 1. Reading (A) 2. Information Processing (A) 3. Pattern Perception (A). a. Closed circuit TV.

Bronson, Gordon W., Department of Psychology, Mills College, Oakland, California, 94613, 415-632-2700 Ext 287, B.S., University of California, 1947, Electrical Engineering, Ph.D., University of California, 1957, Psychology 1. Development in infancy (A) 2 CNS Mechanisms (I).

Brooks, Barbara A., Department of Physiology, University of Texas, Health Science Center, 7703 Floyd Curl Dr San Antonio, Texas, 78284, 696-6581; B.A., University of Florida, 1959, Experimental Psychology, Ph.D , Florida State University, 1964, Experimental Psychology 1. Psychophysics (A) 2. Lateral geniculate (A) 3 Saccades (A) a. EOG b Infrared reflectance

Brown, Brian, Smith-Kettlewell Institute of Visual Sciences, 2232 Webster Street, # 204, San Francisco, California, 94115, 415-567-2865, B A.S., Melbourne University, 1965, Optometry, M.A.S., Melbourne University, 1969, Optometry; B.S., Melbourne University 1969, Psychology & Physiology, Ph.D , Melbourne University, 1971, Optometry 1. Saccadic Control (A) 2 Smooth Pursuit Control (A) 3. Search (I). a Limbal sensing b EOG

Brown, Donald R., Stewart Center 109, Purdue University, West Lafayette, Indiana, 47907, 317-749-2221, B.S., Purdue University, 1957, Psychology, 1961, Psychology, 1. Reading (A) 2. Stabilized Images (A) 3 Search (I). a Eye Camera b Stabilized Image "System".

Buchsbaum, Monte, Chief, Unit on Perceptual and Cognitive Studies, Room 2N-212, Bldg 10, National Institue of Mental Health, Bethesda, Maryland, 20014, 301-496-4749, M.D , University of California, 1965, Medicine 1 Eye Tracking 2 Individual differences in search patterns. a. Corneal reflection monitored with computer-TV camera. b Biometric infrared.

Bullinger, Andre, Universite de Geneve, Dept de Psychologie, 24 G. Dufour, 7211 Geneve 4-CH, 20-93-33 # 2628, M.A , Universite de Geneve, 1968, Psychologie, Ph.D., Universite de Geneve, 1970, Psychologie experimentale. 1. eye movements and posture in infancy (A) 2 eye movements and cognition with children (A) a. One-line retinal reflection b. Corneal reflection.

Burns, David, Department Psychology, McMaster University, Hamilton, Ontario, Canada L8S4K1, 406-525-9140, B.S., University of Maryland, 1970, Mathematics, M.S., University of Maryland, 1973, Psychology, Ph.D., University of Maryland, 1974, Psychology. 1 Psychophysics (A) 2 Attention (A) 3 Pupilometry (A). a. Pupilometer.

Carmody, Dennis P., Department of Radiology, Radiology Research Laboratory, Temple University School of Medicine, Philadelphia, Pennsylvania, 19140, 215-221-4011, B.S., Newark College of Engineering, 1970, Mechanical Engineering, M.A., Montclair State College, 1974, Psychology. 1. Visual search (A) 2 Picture perception (A). a. Narco Eye-Trac interfaced with PDP-11 b. Mackworth wide-angle camera.

Carpenter, Patricia A., Psychology Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15213, 412-621-2699, ext. 483, B.S., University of Iowa, 1968, Psychology, Ph.D., Stanford University, 1972, Psychology. 1. Reading and processes in sentence-picture comparison (A) 2. Visual Search (A). a. Corneal-reflectance, eye marker with computerized stimulus display and scoring.

Chenoweth, Maynard B., Bio-Medical Research, Dow Chemical Company, 607 Bldg., Midland, MI, 48640; 517-636-3325; A.B., Columbia College, 1938, M.D., Cornell University, 1942. 1. Chemical effects (A) 2. Drug effects (I). a. Whittaker Eye View Monitor b. Hewlett Packard CRT. .

Christensen, Julien M., Department of Industrial Engineering and Operations Research, College of Engineering, Wayne State University, Detroit, Michigan, 48202, 313-577-3821, B.S., University of Illinois, 1940, Accounting and Econmics, M.A., Ohio State University, 1952, Psychology, Ph.D., Ohio State University, 1959, Experimental Psychology and Statistics. 1. Peripheral Vision Form Field Studies (I) 2. Search (I) 3. Reading (I). a. Eye-Movement Camera b. Eye-View Monitor.

Ciuffreda, K.J., Medical Center/School of Optometry, University of Alabama, Birmingham, AL, 35294, B.A., Seton Hall University, 1969, Biology, O.D., Massachusetts College of Optometry, 1973, Optometry; Ph.D , University of California, 1977, Physiology optics. 1. Amblyopia (A) 2. Neurological disease (A) 3. Reading (A). a. Photoelectric b. EOG.

Clark, Michael R., SRI, 333 Ravenswood, Menlo Park, California, 94025, 415-326-6200 Ext. 2542, B.S.E.E , University of California, 1966, Electrical Engineering, Ph.D , University of California, 1973, Bioengineering. 1. Binocular eye movements (A) 2. Accommodation (A) 3 Triad (A). a. SRI Eyetracker

Clement, Warren F , Systems Technology Inc., 2672 Bayshore-Frontage Rd. Suite 505, Mountain View, CA 94043, 415-961-4674, B.S., Massachusetts Institute of Technology, 1950, Aerospace Engineering; M S., Massachusetts Institute of Technology, 1951, Aerospce Engineering 1 Manual Control Displays (A) 2. Image Scanning and Perception (A) 3. Reading (A). a. STI Mark I and Mark II Eye Point of Regard Systems.

Cohen, Bernard, Atran 726, Mount Sinai School of Medicine, 1 E. 100th St., New York, New York, 10029, 212-650-7068, A.B., Middlebury College, 1950, Chemistry-Biology, M D., New York University, 1954, Medicine. 1. Reticular control of eye movements (A) 2. Visual-vestibular interactions (A) 3. Eye movements of patients with Parkinson Disease (A). a. E O.G. b Photoelectric eye movement monitor.

Cohen, Karen M., 2040 South York, Developmental Psychology, University of Denver, Denver, Colorado, 80210; 303-753-3625; B.A., Washington University, St. Louis, 1970, Psychology, Ed.M., Harvard University, 1972, Developmental Psychology and Education. 1. Peripheral Vision (A) 2. Reading (A) 3. Visual Scanning (A). a. On-line retinal reflection b. Off-line corneal reflection.

Cohen, Malcolm M., Crew Systems Department, Naval Air Development Center, Warminster, Pennsylvania, 18974; 215-672-9000, ext. 2537, B.A., Brandeis University, 1959, Psychology, M.A , University of Pennsylvania, 1961, Psychology, Ph.D., University of Pennsylvania, 1965, Psychology. 1. Space perception (A) 2. Vestibular function (A) 3. Search (I). a. Corneal reflection camera b. EOG.

Coles, Peter R., Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3PS, England, G.A., Manchester University, 1971, Psychology, M.A., Manchester University, 1975, Psychology. 1. Picture perception (A) 2. Eye movements and cognitive development in infancy (A) 3. Perceptual disorders. a. Infra-red T.V. on-line analysis b. Diffuse scleral reflectivity c. EOG.

Collins, Carter, C., Smith-Kettlewell Institute of Visual Sciences, 2232 Webster Street, San Francisco, California, 94115, 415-563-4321, ext 2464, B.S., University of California at Berkeley, 1949, Engineering Physics, M.S., University of California at Berkeley, 1953, Electrical Engineering, Ph.D., University of California at Berkeley, 1966, Biophysics 1. Oculomotor biophysics (A) 2. Nonlinear clinical models of eye movement (A) 3. Innervational/mechanical mechanisms of strabismus (A). a. Biometrics b EOG c. Photelectric

Collins, William E., CAMI-FAA, AAC-118,P.O. Box 25082, Oklahoma City, Oklahoma, 73125, 405-686-4846, B.S., St Peter's College, 1954, Sociology & Philosophy, M.A., Fordham University, 1956, Psychology, Ph.D., Fordham University, 1959, Experimental Psychology 1 Visual control of vestibular eye movements (A) 2. Influence of alcohol and drugs on vestibular nystagmus (A) 3 Role of visual fixation in habituation of vestibular nystagmus (A). a. ENG recorders

Cooper, Roger M., Stanford Research Institute, Menlo Park, California, 94025, 415-326-6200, ext 3973, B.S., University of Illinois, 1961, Physics, M.S., Illinois Institute of Technology, 1963, Mathematics, Ph.D., Illinois Institute of Technology, 1969, Mathematics, Ph.D., University of Colorado, 1972, Experimental Psychology. 1. Speech understanding (A) 2. Semantic control (A) 3 Language processing (A). a SRI eyetracker.

Cornsweet, Tom N., Department of Psychology, University of California, Irvine, Irvine, California, 92664, A.B , Cornell University, 1951, Experimental Psychology, M.S., Brown University, 1953, Experimental Psychology, Ph.D , Brown University, 1955, Experimental Psychology 1. Control of small movements (I) 2 Effects of small movements on vision (I)

Crane, Hewitt D., Stanford Research Institute, Menlo Park, California, 94025, 415-326-6200, ext 2939, B.S., Columbia University, 1947, Electronics Engineering, Ph.D., Stanford University, 1959, Electronics Engineering. 1. Visual Accommodation (A) 2 Interaction of Accommodation and Eye Movements. a. SRI Purkinje Tracker.

Creyghton, Ton, University of Leiden, Unit of Psychologische Funktieleer, Stationsplein 10 II, Leiden, The Netherlands, post-graduate student, Psychologished Funktieleer.

Cumming, Geoff D., Department of Psychology, La Trobe University, Bundoora, Australia 3083, 478-3122 (Melbourne), B.S., Monash University, 1967, Maths Statistics, Ph.D., Oxford University, 1971, Experimental Psychology (Visual Masking). 1. Saccadic Movement (A). a. Infra-red Reflectance (under development)

Curthoys, Ian S., Department of Psychology, University of Sydney, Sydney NSW, Australia, 660-9570, B.A., Sydney University, 1965, Psychology - Vision, Ph.D., Monash University, 1968, Psychology - Hearing. 1. Vestibulo-ocular reflex (A) 2. Effects on perception (A) a EOG.

Daley, Michael L., Department of Psychiatry, University of Oregon Health Science Center, Portland, Oregon, 97201, 503-225-8462, B.S.E.E , University of Massachusetts, 1968, Electrical Engineering, M.S.E.E., University of Rochester, 1970, Control Systems and Electrical Engineering; Ph.D., University of Rochester, 1973, Visual Psychophysic Control System. 1. Psychotropic drugs and visual neurophysiology (A) 2. Smooth pursuit control (I) 3. Perception of discrete targets (A). a. Infrared reflection b. EOG c. Visual Observation.

Davis -King, W. Michael, Department of Physiology & Biophysics, University of Washington, Seattle, Washington, 98195; 206-543-5350; A.B., Harvard University, 1966, Physics, M.S., Northeastern University, 1969, Electrical Engineering. 1. Brainstem (A) 2. Superior colliculus (I) 3. Cerebellum (I). a. EOG b. Search coil.

Day, Merle E., Mental Health Clinic, Downey Veterans Administration Hospital, Downey, Illinois, 60064, 312-689-1900, ext. 463; B.S., Long Island University, 1951, Psychology, M.A., Long Island University, 1953, Psychology; Ph.D., New York University, 1957, Psychology 1. Left-movers vs. Right-movers (A) 2. Attentional Processes (A) 3. Psychotherapy (A).

Deutsch, Stanley, Director, Bioengineering HQ, NASA, Washingon, D.C., 20546, 202-755-3300; Certificate, Rhode Island State College, 1944, Basic Engineering B.A., Brooklyn College, 1948, Psychology, M.S., Purdue University, 1951, Industrial Psychology, Ph.D., Purdue University 1957, Industrial Psychology. 1. Signal detection (I) 2. Display reading (A) 3. Visual attention.

Dixon, Peter, Department of Psychology, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15213, A.B , Stanford University, 1975, Psychology, M.S., Carnegie- Mellon University, 1976, Psychology

Dobson, Michael W., Geography Department, State University of New York at Albany, 1400 Washington Ave., Albany, NY, 12222, 518-457-7619; B.A., California State, Los Angeles, 1968, Geography, M.A., University of Kansas, 1972, Geography-Cartography, Ph.D., University of Kansas, 1977, Geography-Cartography. 1. Visual search (A) 2. Map Perception (A) 3. Performance (A). a. Mackworth wide angle.

Eaton, Prescott, 4401 Lee Highway, 67, Arlington, Virginia, 22207, 703-524-8058, B.A., University of Washington, 1953, Anthropology, M.S., University of Washington, 1967, Psychology 1. Human Vigilance Research (I) 2. Reading (I).

Edwards, David C., Department of Psychology, Iowa State University, Ames, Iowa, 50010, 515-294-1742, B.S., University of Wisconsin at Milwaukee, 1959, Psychology, M.A., Iowa State University, 1961. Psychology, Ph.D., Iowa State University, 1962, Psychology. 1. Attention (A) 2. Peripheral Detection (A) 3. Visual Search (A). a. Corneal Reflection b. EOG.

Ehrlichman, Howard, CUNY Graduate Center, 33 West 42nd Street, New York, New York, 10036, 212-790-4695, B.A., Queens College, 1966, Psychology; Ph.D., New School for Social Research, 1972, Psychology 1. Eye movements during thinking (A) 2. Lateral eye movements (A) 3. Interpersonal gaze (A). a. EOG.

Ellison, Richard, McDonnell Douglas, # 1 Fox Meadow Lane, Cahokia, Illinois, 62206, 314-232-6640; B.A., So. Illinois University, 1969, Physiology, M.S., So. Illinois University, 1971, Physiology. 1. Scanning (I) 2. Point of Fixation (I). a. Biometrics eye-movement monitor.

Enoch, Jay M., Department Ophthalmology, University of Florida College of Medicine, Box J284 JHMHC, Gainesville, Florida, 32610, 904-392-4098, B.S., Columbia University, 1950, Optics and Optometry, Ph.D., Ohio State University, 1956, Physiological Optics. 1. OKN, other indicators of infant activity (A) 2. Visual search (A) 3. Studies of accommodation, eye position, visual space and related topics.

Farley, Arthur, Computer Science Department, University of Oregon, Eugene, Oregon, 97403, 503-686-4428, B.S., Rensselaer Polytechnic Institute, 1968, Mathematics, Ph.D., Carnegie-Mellon University, 1974, Computer Science 1. Picture Perception (A).

Festinger, Leon, 65 Fifth Avenue, New York, New York, 10003, 212-243-2777, B S., City College of New York, 1939, Psychology, M.A., State University of Iowa, 1940, Psychology, Ph.D., State University of Iowa, 1942, Psychology. 1. Control System (A) 2 Effect on perception (A). a. SRI Eyetracker b EOG.

Findlay, John, Department of Psychology, University of Durham, Durham, DH1 3LE, England, B.A., Cantabury University, 1963, Physics, Ph.D., Cantabury University, 1967, Physics 1 Visual parameters of the fixation reflex (A) 2 Performance effects on microsaccades (A) 3. Direction perception and microsaccades (I). a. Bifurcated fibre Optics limbus tracking b. Infrared corneal reflex devide.

Fisher, Dennis F., Behavioral Research Directorate, U.S Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, 21005, 301-278-3273, B.A., San Jose State, 1965, Psychology, M.A., University of Delaware, 1970, Experimental Psychology, Ph.D., University of Rochester, 1973, Experimental Psychology (Vision). 1. Reading (A) 2 Visual Search (A) a Lambert oculomotor b. Biometrics

Fishman, Rachelle Batushansky, 3871 Sedgwick Avenue, 2J, Bronx, New York, 10463, 212-884-7952, B.A , Brooklyn College, 1969, Chemistry and Biology, M.A., The City College, 1970, Biology, Animal Behavior, Ph.D., City University of New York, 1975 (Anticipated) 1 Development (A) 2. Attention, visual centering (A) 3 Reading (I) a Videotape and microscope.

Flagg, Barbara N., 413 Larsen Hall, Appian Way, Harvard University, Cambridge, Massachusetts, 02138, 617-495-3541, A.B., Mount Holyoke College, Psychology, Ed.D., Harvard University, 1977, Human Development. 1. Motion picture perception (A) 2 Selective attention (A) 3 Reading (A) a Whittaker Eye View Monitor.

Flom, Merton C., School of Optometry, University of California, Berkeley, California, 94619, 415-642-6547; B.S., University of California, 1950, Optometry, M. Optom., University of California, 1951, Optometry, Ph.D., University of California, 1957, Physiological Optics 1 Drug effects (A) 2 Illusions (A) 3. Normal Tracking (A) a Eye-trac b EOG c. Limbal sensing.

Frecker, Richard C., Institute of Biomedical Engineering, University of Toronto, 4 Taddle Creek Road, Toronto, Ontario, Canada M5S1A4, 416-928-4801, B.S., Memorial University, 1961, Biology; M.D., Dalhousie University, 1966, Medicine, Ph.D., University of Toronto, 1973, Pharmacology & Bioengineering. 1. Psychotropic drug effects of Saccadic Movements 2. Diurnal Variations in Saccadic Movements 3. Saccades as predictors of CNS disease. a Own developed corneal reflection technique (high resolution) b. Mackworth/Llewellyn-Thomas head camera.

Friedman, Alinda, National Jewish Hospital, Psychophysiology Laboratory, 3800 East Colfax Ave., Denver, Colorado, 80206, 303-322-1881, B.A., SUNY at Stony Brook, 1971, Psychology; M.A., University of Colorado, 1973, Experimental Psychology, Ph.D., University of Colorado, 1977, Experimental Psychology 1. Identification of objects in pictures (A) 2. Exploration of pictures (A) 3. Reading (I). a. Whittaker Eye Monitor.

Friedman, Mark B., Department of Psychology, Carnegie-Mellon University, Pittsburgh, PA, 15213; 412-421-2600 ext. 278, B.S., MIT, 1966, Life Science; Ph.D., Rutgers-IAB, 1972, Psychobiology. 1. Visual control of posture and locomotion (A) 2. Selective use of specialized retinal region (A) 3. Avian vision (A). a. IR TV (retinal and corneal reflection) computerized output b. EOG.

Frost, Douglas, Institut d'Anatomie, Universite de Lausanne, 9 rue du Bugnon, Lausanne, Switzerland, (021) 238219, S.B., MIT, 1971, Electrical Engineering; S.M., MIT, 1971, Electrical Engineering; Ph.D., MIT, 1974, Psychology & Brain Science. 1. Central control of eye movements (A) 2. Eye movements in human with brain damage (A). a. EOG recording system.

Fry, Glenn A., Ohio State University, College of Optometry, 338 West Tenth Avenue, Columbus, Ohio, 43210, 614-422-6603, A.B., Davidson College, 1929, Psychology, M.A., Duke University, 1931, Psychology, Ph.D., Duke University, 1932, Psychology. 1. Convergence in relation to accomodation and convergence 2. Fixational and fusional movements 3. Search. a. Biometrics Eye Movement Monitor b. Ophthalmograph c. Oculography.

Fuchs, Albert F., Department of Physiology & Biophysics and Primate Center, University of Washington, Seattle, Washington, 98195, 206-543-1430; B.S., Drexel Institute of Technology, 1960, Electrical Engineering, M.S., Drexel Institute of Technology, 1961, Medical Instrumentation, Ph.D., Johns Hopkins University, 1966, Bioengineering. 1. Neurophysiology of Eye Movements (A) 2. Characteristics of normal eye movements 3. Vision during saccades. a. Eye coil (magnetic field coils) b. EOG.

Gaarder, Kenneth, UTHSCSA, Department of Psychiatry, San Antonio, Texas, 78284, 512-696-6215, B.S., University of Minnesota, 1951, Science; M.D., University of Minnesota, 1954, Medicine. 1. Vision (I) 2. Arousal (I) 3. Control (I) and Biofeedback (A). a. EOG.

Gainer, P A , Langley Research Center (M.S. 152D), Langley Station, Hampton, Virginia, 23665, 827-3871, B.S , West Virginia University, 1952, Aerospace Engineering. 1. Flight management systems (A). a. Honeywell.

Ganz, Leo, Department of Psychology, Stanford University, Stanford, California, 94305, 415-497-3748, B.A., CCNY, 1952, Psychology, Ph.D., University of Chicago, 1959, Psychology. 1 Reading (I) 2. Saccadic suppression (A) 3. Visual search (A).

Gatchell, Susanne M., 2260 G.G. Brown Lab, Industrial & Operations Engineering, University of Michigan, Ann Arbor, MI, 48109, 313-763-2189; B.S.E., Oakland University, 1969, Engineering, M S., University of Michigan, 1972, Industrial Engineering, Ph.D., University of Michigan, 1976, Industrial Engineering. 1. Transportation (A) 2. Search (A) 3. Learning (I). a. Corneal reflection.

Geiselman, Ralph E., Department of Psychology, University of California, Los Angeles, CA, 90024, 213-825-9029, B.S., Purdue University, 1971, Psychology; M.S., Ohio University, 1973, Experimental Psychology; Ph.D., Ohio University, 1976, Experimental Psychology. 1. List learning (I) 2. Reading (I) a. Biometrics Reading Eye II.

Gerhardt, Lester A., Professor and Chairman, Electrical and Systems Engineering Department, Rensselaer Polytechnic Institute, Troy, New York, 12181, 518-270-6313; B.E.E., CCNY, 1961, Electrical Engineering; M.S.E.E , SUNYAB, 1964, Electrical Engineering, Ph.D., SUNYAB, 1969, Information Processing 1. System development for monitoring eye movement (A) 2. Target recognition/identification using eye tracks (A) 3. Reading and control studies (A)

Gibbon, Jr., Samuel Y., 421 Larsen Hall, Appian Way, Cambridge, Massachusetts, 02146, 617-495-3541, A.B., Princeton University, 1953, English Literature. 1. Television (A) 2 Reading (A) 3. Search (I).

Girgus, Joan S., Department of Psychology, City College of CUNY, 138th St. and Convent Ave., New York, New York, 10031, 212-690-8155/8156, B.A., Sarah Lawrence College, 1963, Psychology, M.A., New School for Social Research, 1965, Psychology, Ph.D., New School for Social Research, 1969, Psychology 1 Shape perception (A) 2. Reading (I) a. EOG.

Goldberg, Michael E., Armed Forces Radiobiology Research Institute, Bethesda, Maryland, 20014, 301-295-1334, A.B., Harvard University, 1963, Biochemistry, M.D., Harvard University, 1968, Biochemistry. 1. Visual-Oculomotor Neurophysiology (A) 2 Computer methods (A) 3. Clinical Oculomotor deficits (I). a. EOG.

Goodson, James E., Head, Aerospace Psychology Department, Naval Aerospace Medical Research Laboratory, Naval Aerospace Medical Institute, Naval Aerospace and Regional Medical Center, Pensacola, Florida, 32512, 904-452-3281; B.A., Baylor University, 1955, Psychology, M.A., Baylor University, 1956, Psychology, Ph.D., George Washington University, 1969, Psychology/Biophysics 1 Visual Acquisition (A) 2. DVA (A) 3. Optokinetic Response (A). a. Biometrics b EOG c SRI

Goolkasian, Paula, Department of Psychology, University of North Carolina at Charlotte, Charlotte, North Carolina, 28223, 567-2116, B.A., Emmanuel College, 1970, Economics/Psychology, M.S., Iowa State University, 1972, Psychology, Ph.D., Iowa State University, 1974, Psychology. 1. Visual attention (A) 2. Training effect on peripheral detection (I). a. EOG.

Gould, John, IBM Research Center, Box 218, Yorktown Heights, New York, 10541, 914-945-2237, Ph.D., University of Wisconsin, 1963, Psychology. 1. Search (I) 2. Pictures (A) 3. Memory (A). a. TV - corneal reflectance.

Griffin, Donald C., 4105 Pacific Avenue #7, Marina Del Rey, California, 90291, B.A., Oberlin College, 1960, Psychology; M.A., University of California at Los Angeles, 1966, Education, M.A., University of California at Los Angeles, 1968, Psychology; Ph.D., University of California at Los Angeles, 1968, Education. 1. Reading (A).

Guedry, F. E., Chief, Perceptual & Behavioral Sciences Division, Naval Aerospace Medical Research Laboratory, Naval Air Station, Pensacola, Florida 32508, M.S., Tulane University, 1948, Psychology, Ph.D., Tulane University, 1953, Psychology. 1. Oculovestibular responses (A) 2. Visual tracking and visual search (A). a. Corneo-Retinal Potential Amplification b. Reflected light into photocells.

Guitton, Daniel, Aviation Medical Research Unit, Department of Physiology, McGill University, Montreal, Canada; 514-392-4219, Ph.D., McGill University, 1970, Engineering, Ph.D., McGill University, 1974, Neurophysiology. 1. Neurophysiology of visual and oculomotor systems (A). a. Eye coil in magnetic field (Robinson). b. EOG.

Gutman, J. C., 130 Whittemore Hall, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 24061, 703-951-5358; B.S., Franklin and Marshall College, 1973, Psychology. 1. Search (A) 2. Target Acquisition (I). a. SRI Double Purkinje Eyetracker.

Haber, Ralph Norman, Department of Psychology, University of Rochester, Rochester, New York, 14627, 716-275-2066, B.A., Michigan University, 1953, Philosophy, M.A., Wesleyan University, 1954, Psychology, Ph.D., Stanford University, 1957, Psychology. 1 Reading (A) 2. Search (A) 3. Picture Reading (A). a. home-made.

Haddad, G. M., Wilmer Institute, Woods 355, Johns Hopkins Hospital, 601 N. Broadway, Baltimore, Maryland, 21218; 301-955-3587, B.A., Trinity College, 1968, Psychology, Ph.D., University of Maryland, 1972, Experimental Psychology. 1. Vestibular-ocular reflex (A) 2. Slow control (A) 3. Voluntary control (I). a. Optical lever b. Search coil c. Purkinje tracker.

Haegerstrom-Portnoy, Gunilla, Smith-Kettlewell Institute of Visual Sciences, 2232 Webster Street, Room 204, San Francisco, California, 94115, 415-567-2865, B.S , University of California, 1972, Optometry 1. Saccadic Control (A) 2. Smooth Pursuit Control (A) 3. Search (I). a. Limbal Sensing b EOG.

Hainline, Louise Donnee, Department of Psychology, Brooklyn College, Brooklyn, New York, 11210, 212-780-5033, A.B., Brown University, 1969, Psychology, A.M , Harvard University, 1972, Psychology (developmental), Ph.D., Harvard University, 1973, Psychology (developmental). 1. Form Perception (A) 2 Reading (A) 3. Visual Search (A). a. Off-line corneal reflection b. On-line retinal reflection.

Haith, Marshall M., 2040 South York St., Denver, Colorado, 80210, 303-753-2041, B.A., University of Missouri, 1959, Psychology, M.A., University of California at Los Angeles, 1962, Child Psychology; Ph.D , University of California at Los Angeles, 1964, Developmental Psychology. 1 Form Perception (A) 2. Reading (A) 3. Visual Search (A). a. Off-line corneal reflection b. On-line retinal reflection.

Hall, Lesley C., Psychology Department, Monash University, Clayton, Melbourne, Victoria, Australia 3168, 544-0811, ext. 3962, B.A., Australian National University, 1969, Psycholinguistics, Ph.D., Edinburgh University, 1975, Developmental - Eye Movement Control. 1. Directive role of inaguage (A) 2. Developmental aspects (A) 3. Reading (I). a. Corneal Reflection.

Hall, Robert J., Department of Psychology, University of Nevada, Las Vegas, Nevada, 89154, 702-739-3254, B.A., University of Wyoming, 1952, Psychology; M.A., University of Wyoming, 1955, Psychology, Fulbright, University of London, England, 1956, Psychology, Ph.D., Claremont Graduate School, 1966, Psychology. 1. Stress 2. Centrifugal control 3. Evoked potential

Hallett, P E., Department of Physiology, University of Toronto, Ontario, M5S 1A8, Canada, 416-978-6072, B.A , Oxon, 1958, Animal Physiology, B.S., Oxon, 1960, Night Vision, B M., Oxon, 1962, Medicine, Midwifery, Surgery; M.A., Oxon, 1962, Medicine, Midwifery, Surgery. 1. Saccades and Smooth Pursuit movements with fixed head 2. Night vision 3. Visual neuroanatomy (mouse) (A) a. Self built infrared diode device.

Hansell, Roger Ian C., Department of Zoology, University of Toronto, Ontario, Canada, 416-978-6563, B.Sc., University of Toronto, 1963, Biology; Ph.D., University of California, Riverside, 1970, Biological Control. 1. Classification (A) 2. Character (feature) importance (A) 3. Decision Process (A). a. Eye tracker (Kolers') b. Eye tracker (Berlyne).

Harms, Dieter, German Air Force Institute of Aviation Medicine, Postfach 172 KFL D-808, Fuerstenfeldbruck, Germany, 08141/9621 ext. 6556, M.D., University of Munich, 1973, Medicine. 1. Saccadic and pursuit eye movements (A) 2. Visual information processing (A) 3. Interference between sensory channels (A) a. EOB b. NAC Eye Mark Recorder.

Harnad, Stevan R., Department of Psychiatry, Rutgers Medical School, Box 101, Piscataway, New Jersey, 08854, 201-564-4293, B A., McGill University, 1967, Psychology, M.A., McGill University, 1969, Psychology, M A., Princeton University, 1971, Psychology, Ph.D., Princeton University, 1976, Psychology. 1. Perception (A) 2. Laterality (A). a. EOG b. TV c. EEG.

Hein, Alan, Psychology Department, E10-20C, MIT, Cambridge, Massachusetts, 02139, 716-253-5759; Ph.D., Brandeis University, 1960, Psychology. l. Guidance of Behavior 2. Ontogenesis.

Herman, Edward M., 3400 N Broad St., Temple University, School of Medicine, Radiology Research Lab , Philadelphia, Pennsylvania, 19140, 215-221-4011, B.A , University of Michigan, 1966, Psychology, M.A., New School for Social Research, 1969, Psychology, Ph.D , New School for Social Research, 1975, Psychology 1 Motion and space perception (A) 2. Picture search (A) 3 Characteristics of eye movement control systems (A) a. Biometrics Eye Tracker b. Mackworth Wide Angle

Heywood, Simon P , Department of Psychology, University of Warwick, Coventry CV4 7AL, England, B.A., Oxford University, 1966, Psychology & Philosophy, A.M., Harvard University, 1969, Psychology, D. Phil , Oxford University, 1973, Psychology. 1. Pursuit eye movements (A) 2. Oculomotor feedback (A) 3. Neurological aspects of eye movements (I). a. Computerized I R. Photoelectric b. Computerized on-line video oculometer c. EOG.

Hochberg, Julian, 314 Schermerhorn Hall, Columbia University, New York, New York, 10027, 212-280-4585, B.S., City College of New York, 1945, Physics, M.A., University of California at Berkeley, 1947, Psychology, Ph D., University of California at Berkeley, 1949, Psychology. 1. Reading (A) 2. Attention (A) 3. Effects of motion picture-cutting (A) a. Corneal reflection b Whittaker Eye View Monitor c. Direct telescopic motion picture photography.

Hofstetter, H. W , School of Optometry, Indiana University, Bloomington, Indiana, 47401, 812-337-7777, B.S., The Ohio State University, 1939, Optometry, M S , The Ohio State University, 1940, Physiological Optics, Ph D , The Ohio State University, 1942, Physiological Optics 1. Accomodation and convergence (I) 2. Fixations in darkness (I) 3 Fusional movements (I). a. Haxloscope b EOG c. Eye movement camera.

Holden, R. W , Department of Psychology, University of Melbourne, Parkville, Victoria, Australia 3052, B.A., Manitoba University, 1974, Psychology, M.A., Manitoba University, 1976, Psychology. 1. Relation of eye movements to problem solving (A) 2. Search (I) 3. Reading (I).

Holly, Frank, USAARL, Box 577, Ft. Rucker, Alabama, 36362, 205-255-6415, M.A., Michigan State University, 1971, Experimental Psychology, Ph.D., Michigan State University, 1974, Experimental Psychology 1 Visual Stability (A) 2. Saccadic Suppression (I). a. Navco-Biosystem Model S200

Hornseth, John P , 180 Estelle Avenue, Enon, OH, 45323, 864-1055, Ph.D., University of Wisconsin, 1952, Psychology 1. Plant (vehicle) control (A) 2. Search strategy (A) 3. Target identification (A) a. Honeywell Oculometer b. NAC Eye Mark Recorder.

Igarashi, Makoto, Department of Otorbinolaryngology and Communicative Sciences, Baylor College of Medicine, Houston, TX, 77030; 713-790-4666, M.D., Keio University School of Medicine, 1952, Medicine, D.M.Sc., Keio University School of Medicine, 1958, Otolaryngology 1. Vestibular (A) 2. Cervical (A) 3. CNS (A) a. ENG Beckman Polygraph.

Iwawaki, Saburo, Department of Psychology, Chukyo University, Showaku, Nagoya, 466 Japan; Ph.D., Tohoku University, 1972, Psychology. 1. Visual search (A) 2. Visual attention (A) 3. Cognitive Psychology (A).

Jex, Henry R., Systems Technology, Inc., 13766 South Hawthorne Boulevard, Hawthorne, California, 90250; 213-679-2281; B.S., Massachusetts Institute of Technology, 1951, Aerospace Engineering, M.S., California Institute of Technology, 1953, Aerospace Engineering. 1. Manual Control Displays 2. Image Scanning and Perception 3. Reading. a. STI Mark I and Mark II Eye Point of Regard Systems.

Johnson, Frank, Medical Physics, University Hospital, Nottingham, NG7 2UH, England, 0608-700111, B.Sc., University of Salford, 1968, Electronics, M.A.Sc., University of Toronto, 1970, Bioengineering, Ph.D , University of Toronto, 1973, Neural Control Systems. 1. Radiographic search and perception (A) 2. Temporal correlates of spatial search (A) 3 Training and search efficiency (A). a. N.A.C. Eye Mark recorder.

Jones, Daniel B., P O. Box 281, Ft. Monroe, VA 23651, 804-727-3759, B.A.E., University of Florida, 1943, Engineering, M.S., Tulane University, 1950, Psychology, Ph.D., University of Missouri, 1965, Psychology. 1. Search leading to Target Acquisition (A).

Jones, G. Melvill, DRB Aviation Medical Research Unit, Department of Physiology, McGill University, 3655 Drummond Street, Montreal, Quebec, Canada H3C 3G1, 514-392-4217, M.A., 1944, Nat. Sci., M.B Beh., Cambridge University, 1949 Medicine. 1 Neurophysiology 2 Aerospace Medicine. a. EOG b. Electromagnetic c. Photographic.

Jones, Margaret H., UCLA Pediatrics, 742 Via de la Paz, Pacific Palisades, California, 90272, 825-6295, M D., Cornell University, 1933, Pediatrics, M.Ph., Harvard University, 1940, Public Health 1. Eye movements in infants (A). a. EOG.

Jones, Ronald, The Ohio State University, College of Optometry, 338 West 10th Ave., Columbus, Ohio, 43210, 614-422-1665, O.D., Ontario College of Optometry, M.S., Ohio State University, 1970, Physiological Optics, Ph.D., Ohio State University, 1972, Physiological Optics. 1. Fusional vergence (A) 2. Recording methodology (I) 3. Visual attention (I). a. Matrix Photoelectric b Biometrics c. EOG.

Jonides, John, Department of Psychology, University of Michigan, 330 Packard Rd., Ann Arbor, MI, 48104, 313-764-0192, B.A., Johns Hopkins University, 1969, Psychology, M. Ed., Johns Hopkins University, 1971, Education, M.A., University of Pennsylvania, 1971, Psychology, Ph.D., University of Pennsylvania, 1975, Psychology. 1. Search (I) 2. Reading (I)

Judge, Stuart J , National Institute for Mental Health, Room 1D-02, Bldg. 36, Bethesda, MD, 20014, 301-496-4864, B.A., University of Keele, 1969, Physics & Math, Ph.D., University of Keele, 1976, Communications. 1. Saccadic suppression (A) 2. Visually guided eye movement mechanisms (A) a. EOG b. Magnetic search coil.

Just, Marcel Adam, Psychology Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15213, 412-621-2600, ext. 323, B. Sc., McGill University 1968, Psychology, Ph.D., Stanford University, 1972, Psychology 1. Comprehension (A) 2. Problem-Solving (A) 3. Scene Perception (A) a. Corneal reflection b. Digitizer c. Gase-contingent video display.

Kahn, Arthur, 2 Cove of Cork Lane, Annapolis, Maryland, 21401, 301-765-3014, B A., University of Pennysivania, 1938, Chemistry, M.A., University of Pennsylvania, 1941, Psychology, Ph.D., Indiana University, 1952, Psychology. 1 Search (I) 2. Tracking (I) 3 Eye-Hand Coordination (I).

Kappauf, William E., 713 Psychology Building, University of Illinois, Champaign, Illinois, 61820, 217-333-3636, A.B., Columbia University, 1934,Mathematics, M.A., Brown University, 1935, Psychology, Psychology; Ph.D , University of Rochester, 1937, Psychology 1 Scale Reading (A). a. Biometrics.

Kennedy, Alan R., Psychology Department, University of Dundee, Dundee, Scotland, U-V, 0382-23181, Ph.D , Birmingham University, 1963, Psychology 1 Reading (A) 2 Associative priming and reading (A) a. Infrared reflection with on-line analysis by PDP-12 computer

Kennedy, Robert Samuel, U.S. Naval Missile Center, Code 5342, Point Mugu, California, 93042, 805-982-8981, B A., Iona College, 1957, English, M.A., Fordham University, 1959, Experimental Psychology, Ph.D., University of Rochester, 1972, Sensation & Perception, Vestibular Functions. 1 Visually coupled systems (A) 2 Visual target acquisition & dial reading (A) 3. Eye movement as independent measures of arousal (A) a. Biometrics - IR Eyeglass System b. EOG c. Mackworth camera d. NAK- Head-mounted Electro-Optic Sensor

Ketcham, Mary A., Human Factors Engineering Branch, N342, Naval Missile Center, Point Mugu, California, 93042, 805-982-8981, B.S. Washington University, 1970, Electronic Engineering 1. Eye Movements and Behavior. a. Biometrics SVG/2 b. EOG.

Kinchla, Ronald A., Department of Psychology, Princeton University, Princeton, New Jersey, 08540, 609-452-4471, Ph.D., UCLA, 1960, Experimental Psychology. 1. Movement Perception (A) 2. Involuntary eye movements (I) 3. Micro-saccadic (I)

Klare, George R., Department of Psychology, Ohio University, Athens, Ohio, 45701, 594-3821, B.A., University of Minnesota, 1946, Psychology and Educational Psychology, M A , University of Minnesota, 1947, Psychology and Educational Psychology, Ph.D , University of Minnesota, 1950, Psychology and Educational Psychology 1 Reading (I) 2. Learning from text (I). a. Reading Eye I.

Kochhar, Dev S., Department of Systems Design, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1, 519-885-2354, B. Tech , Indiana Institute of Technology, 1970, Mechanical Engineering, M A.Sc., University of Waterloo, 1972, Man-Machine Systems, Ph.D., University of Waterloo, 1974, Man-Machine Systems. 1. Visual search (A) 2. Visual inspection/display evaluation (I) 3. Information processing/driving (A). a. EOG.

Kolers, Paul A., Department of Psychology, University of Toronto, Toronto, Canada M5S 1A1, 416-978-7305, Ph.D , New York University, 1957, Psychology 1. Reading (A) 2. Looking (A) 3. Search (A). a. Purkinje Eye Tracker

Komoda, Melvin K., 65 Fifth Avenue, New York, New York, 10003, 212-675-2700; B.A., University of Hawaii, 1965, Psychology, M.A. University of Hawaii, 1968, Psychology; Ph.D., York University, 1971, Experimental Psychology. 1. Characteristics of Eye Movement Control Systems (A) 2. Space and Movement Perception (A) 3. Reading (I). a. Cornsweet and Crane Eyetracker b. Electro-oculography.

Kowler, Eileen, Department of Psychology, University of Maryland, College Park, Maryland, 20742; 301-454-5351, B.A., Queens College, 1972, Psychology. 1. Pursuit & saccadic subsystems (A) 2. Eye movements and cognitive processes (A) 3. Development (I). a. Contact lens optical lever b. Purkinje image tracker.
I = gone to NY Univ, no longer uses SRI = DPI

Krebs, Marjorie J., R2340, 2600 Ridgeway Parkway, Systems and Research Center, Honeywell, Inc., Minneapolis, Minnesota, 55413, B.S., Pennsylvania State University, 1962, Psychology, M.A., University of Virginia, 1968, Experimental Psychology; Ph.D., University of Virginia, 1971, Experimental Psychology. 1. Search (target acquisition) (A) 2. Pilot Scanning Patterns (A) 3. Reading (A). a. Honeywell Mark III A Cubic Foot Oculometer b. Honeywell Viewing Hood Oculometer.

Krueger, Gerald P., P.O. Box 577, U.S. Army Aeromedical Research Laboratory, Ft. Rucker, Alabama, 36362, 205-255-6504, B.A., University of Dayton, 1966, Psychology, M.A., Johns Hopkins University, 1975, Engineering Psychology; Ph.D., Johns Hopkins University, 1976, Experimental and Engineering Psychology. 1. Pilot visual search (A) 2. Visual task performance (I) 3. Illusions (I). a. EYE NAC Mark Recorder.

Kundel, Harold L., Department of Radiology, Temple University School of Medicine, Philadelphia, Pennsylvania, 19140; 215-221-4011; M.D., Columbia University, 1959, Medicine; M.S., Temple University, 1963, Radiology, A.B., Columbia University, 1958, Liberal Arts. 1. X-ray film reading (A) 2. Peripheral vision (A) a. Mackworth Stand Camera. b. Narco Eye Trace interfaced to PDP-11 computer.

Kurbjun, Max C., Langley Research Center (M.S. 152D), Langley Station, Hampton, Virginia, 23665, 804-827-2282, B.S., Virginia Polytechnic Institute, 1944, Aerospace Engineering. 1. Cockpit Instrumentation (A). 2. Pilot Training (A) 3. Cockpit Design Certification (A). a. Honeywell b. Modified Honeywell c. SRI.

Kwatny, Eugene, Krusen Center for Research & Engineering, 12th St. and Tabor Rd., Philadelphia, Pennsylvania, 19141, 215-329-9580, B.S., Drexel University, 1966, Electrical Engineering; M.S., Drexel University, 1968, Biomedical Engineering, Ph.D., Drexel University, 1971, Biomedical Engineering. 1. Eye movements in brain damaged humans (A) 2. Eye-head coordination (A) 3. Eye movements and perception (A). a. EOG b. Limbus tracking.

Lai, David C., Department of Electrical Engineering, University of Vermont, Burlington, Vermont, 05401, 802-656-3330, Ph.D. Johns Hopkins University, 1960, Electrical Engineering. 1 Measurement and recording (A) 2. Search and scanning behavior (A) 3. Eye Movements and Higher Mental Processes (A). a. Biometrics Eye Tracker.

Lambert, Robert H., Behavioral Research Directorate, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, 21005, 301-278-5175, 2519 Emerald Avenue, Las Vegas, Nevada, 89120, B.S., University of Michigan, 1959, Aeronautical Engineering. 1. Instrumentation (A). a. EG&G/HEL Oculometer.

Lefton, Lester A., University of South Carolina, Department of Psychology, Columbia, South Carolina, 29208, 803-777-2539, B A., Northeastern University, 1969, Psychology; Ph.D , University of Rochester, 1972, Psychology. 1. Reading (A) 2. Search (A). a. Biometric Eye-Trac.

Leisman, Gerald, Department of Health Sciences, Brooklyn College, CUNY, Brooklyn, New York, 11210, 212-780-5692/5026, B.A., Queens College, CUNY, 1957, Psychology/Biology; M.S., University of Manchester, 1969, Physiology, Ph.D., University of Manchester, 1971, Neurosciences; M.B., University of Manchester, 1972, Medicine. 1. Visual perception (A) 2. Saccadic control/servo systems (A) 3. Reading (A). a. EOG b. Infrared scanning c. Stabilized image procedures.

LeMaster, W. Dean, Air Force Human Resources Laboratory, Williams AFB, Arizona, 85224, 602-988-2611, ext. 6945, M.A., New Mexico State University, 1971, Psychology 1. Visual Cue Utilization During Flight (A) 2. Flight Simulator Visual Systems (A) 3. Peripheral Vision (I). a. NAC Eye Mark Recorder.

Lentz, J Michael, Code L 44 - Bldg. 1811, Naval Aeromedical Research Laboratory, Naval Air Station, Pensacola, FL, 32508, 904-452-2541; B.S., Eastern Illinois University, 1970, Psychology, M.A., Bradley University, 1971, Psychology, Ph.D , University of Oklahoma, 1975, Biological Psychology. 1.Vestibular (A) a. Electronystagmography.

Leonard, George S., Gulf and Western, Applied Science Laboratories, 335 Bear Hill Rd., Waltham, Massachusetts, 02154, 617-890-5100. Eye Movement instrumentation specialist.

Levy, Deborah L., Box 829, Topeka, KS, 66601, 913-234-9566, B.A., University of Chicago, 1972, Political Science, Ph.D., University of Chicago, 1976, Psychology 1. Smooth pursuit eye movements in psychiatric patients (A) 2. Vestibular function in psychiatric patients (A). a. Beckman dynographs (ENG) b. Hewlett-Packard 3960 FM tape recorder. c. Sony FM tape recorder.

Levy-Schoen, Ariane, Laboratoire de Psychologie Experimentale et Comparee, 28 rue Serpente, F5006 Paris, France, 329 12-13 P.33.88, THESE, University of Paris, 1962, Psychology 1 Cognitive and sensory-motor control of visual scanning (A). 2. Peripheral vision (A). a. Computerized IR Photoelectric b. EOG.

Lewis, Alan Laird, State University of New York College of Optometry, 122 East 25th St., New York, New York, 10010, 212-477-7994, B.S., Massachusetts College of Optometry, 1965, Optometry; O.D , Massachusetts College of Optometry, 1970, Optometry, M.Sc., Ohio State University, 1971, Physiological Optics, Ph.D., Ohio State University, 1971, Physiological Optics 1 Covergence and accommodation (A) 2. Strabismus (I). a. Biometrics b. EOG.

Lisberger, Stephen G., Department of Physiology and Biophysics and Regional Primate Research Center, University of Washington, Seattle, Washington, 98195, 206-543-5350, B.A., Cornell University, 1971, Mathematics. 1. Vestibulo-ocular reflex (A) 2. Brainstem neural mechanisms (A) 3 Cerebellar influences on eye movements (A). a. Search coil b. EOG

Llewellyn-Thomes, E., Institute of Biomedical Engineering, University of Toronto, Toronto, Ontario, Canada, 416-9283-3114, B.S., London, 1951, Electrical Engineering; M.D., McGill University, 1955, Medicine. 1. Search (I) 2. Drugs on eye movements (A) a. Eye monitor head camera.

Loeb, Michel, Psychology Department, University of Louisville, Louisville, Kentucky, 40280, 502-636-6107; B.S., University of Alabama, 1948, Chemistry; M.S., Columbia University 1949, Psychology; Ph.D., Vanderbilt University, 1953, Psychology. 1. Visual Tracking (A) 2. Form Identification (I) 3. Observing Responses during monitoring (I). a. Space science IR recorder b. Polymetric wide angle"Mackworth" device.

Loftus, Geoffrey R., Psychology Department, University of Washington, Seattle, Washington, 98195, 206-543-8874; B.A., Brown University, 1967, Psychology, Ph.D., Stanford University, 1971, Psychology. 1. Picture Memory. a. Home-built scleral reflection.

Luria, S. S., Naval Medical Research Laboratory, Sub Base, Groton, Connecticut, 06340, 203-449-3867; Ph.D., University of Pennsylvania, 1955, Experimental Psychology. 1. Search 2. Cognition. a. Biometrics Eye Movement Monitor.

Lyman, John, 4173 Engineering I, University of California at Los Angeles, Los Angeles, California, 90024, 825-2811, B A., University of California at Los Angeles, 1943, Mathematics and Psychology, M.A., University of California at Los Angeles, 1950, Mathematics and Psychology; Ph.D., University of California at Los Angeles, 1951, Experimental Psychology. 1 Skilled Hand Movement (A) 2. Restricted Visual Fields (A) 3 Eye-Motor Coordinated Movement. a. Mackworth Camera b. EOG.

Macdonald-Ross, Michael, Text Research Group, IET, The Open University, Milton Keynes, England, 090863372; B. Sc., University College of London, 1960, Zoology. 1. Reading complex texts (A) a. corneal reflection b. page- and book-level recorder (Whalley).

MacKay, D. M., Dept. of Communication, University of Keele, Keele, Staffordshire ST5 5BG, England, Phone 0782-71-371; B.S., St. Andrews, 1943, Physics; Ph.D., London, 1951, Physics. 1. Visual Stability 2. Saccadic Suppression. a. EOG b. Contact lens.

Mackworth, Norman H., 16232 Camellia Terrace, Los Gatos, California, 95030, 408-356-9643, M.B Ch. B., Aberdeen University, 1939, Medicine, Ph.D , Cambridge University, 1947, Psychology, 1. Reading 2. Learning Disability 3 Cognitive Psychology a. Mackworth line of sight eye camera b Mackworth Stand Eye Camera.

Matheny, W G., Life Sciences, Inc., 227 Loop 820 NE, Hurst, Texas, 76053, 817-284-3438, A.B. Ft. Hays Kansas State, 1946, Psychology, Ph.D , University of Maryland, 1949, Industrial Psychology 1. Pilot Information Display Content (A) 2. Search (A) a. NAC Eye Mark Recorder

Matin, Ethel, C.W Post Center of Long Island University, Greenvale, New York, 11548, 516-299-2377, B.A , Hunter College, 1952, Psychology & Physiology, Ph.D., Columbia University, 1962, Experimental Psychology 1. Saccades and constancy of visual direction (A) 2. Saccadic suppression (A) 3. Temporal characteristics of saccades (I). a. Contact lens technique.

Matin, Leonard, Department of Psychology, Columbia University, New York, New York, 10027, 212-280-4538, B.S., Brooklyn College, 1950, Psychology, M A , University of North Carolina, 1952, Psychology, Ph.D., Columbia University, 1959, Psychology 1. Visual Direction of Spatial Localization (A) 2. Control and Generation (A) a. Optical Leyer Contact Lens.

McConkie, George W., Department of Education, Stone Hall, Cornell University, Ithaca, New York, 14850, 607-256-2063, B.S., Brigham Young University, 1960, Psychology, M.S , Brigham Young University, 1961, Psychology, Ph.D., Stanford University, 1966, Experimental Psychology. 1. Reading (A) a. Biometrics Type SG.

McDermott, LeRoy D., Western Civilization, 2106 Wescoe Hall, University of Kansas, Lawrence, Kansas, 66045, 864-3011, B.A., Oklahoma State University, 1965, History, M.A., University of Kansas, 1973, History of Art 1 Gaze laterality and stimulus content (A) 2. Artistic styles and picture perception (A) 3. Cognitive psychology (A). a. Mackworth Camera b. Video Recordings.

McDowell, Edward D., Industrial and General Engineering, Oregon State University, Corvallis, Oregon, 97331, 503-754-2460, B.S., Ohio State University, 1965, Engineering Physics, M.S., Ohio University, 1970, Industrial and Systems Engineering, Ph.D., Ohio State University, 1975, Industrial and Systems Engineering. 1 Highway traffic safety (A) 2. Flying training (A).

Mezrich, Joseph J , RCA Laboratories, Princeton, New Jersey, 08540, 609-452-2700, S.M., Massachusetts Institute of Technology, 1969, Electrical Engineering, E.E., Massachusetts Institute of Technology, 1970, Electrical Engineering, A.M , University of Michigan, 1974, Statistics, Ph.D., University of Michigan, 1975, Psychology. 1. Pattern perception (I) 2. Cognitive psychology (I).

Miller, James M., Department of Industrial and Operations Engineering, University of Michigan, Ann Arbor, Michigan, 48104, 313-763-2189, B.M.E., Ohio State University, 1963, Mechanical Engineering, Ph D., Ohio State University, 1971, Industrial Engineering. 1 Air & Surface Vehicle Operator Behavior (A) 2. Industrial Operations-Inspection and Monitoring (A) 3 Markouian Search and Scan (I). a. Portable TV Corneal Reflection b. Scleral Reflection

Mocharnuk, John B., Engineering Psychology Department, McDonnell Douglas Astronautics Co , Box 516, St. Louis, Missouri, 63166, 314-232-6340, B A., University of New Mexico, 1969, Psychology, M.A., New Mexico State University, 1974, Experimental Psychology, Ph D , New Mexico State University, 1976, Engineering Psychology. 1. Search (A) 2. Display positioning (I) a. Biometrics IR b EOG.

Mohler, Charles, N.I.H., Building 36, 1D02, Bethesda, Maryland, 20014, 301-496-4864, B.S , Purdue University, 1966, Engineering, Ph D., Case Western Res., 1971, Biomedical Engineering, M.D , Case Western Res., 1972, Medicine. 1 Vision 2. Eye Movements 3 Neurophysiology. a. EOG

Monty, Richard A., Behavioral Research Directorate, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, 21005, 301-278-4478, B.A., Boston University, 1956, Physics; M A., Columbia University, 1957, Experimental Psychology, Ph.D., University of Rochester, 1961, Experimental Psychology 1 Reading (A) 2. Search (A) 3 Memory (A). a. Lambert Oculometer

Moore, Robert K., Hunter Lab., 89 Waterman St., Providence, Rhode Island, 02912, 401-863-3012, B.S., Dalhousie (Canada), 1972, Psychology. 1. Saccadic suppression (A) 2. Stabilization (A). a. EOG b. SRI Eyetracker.

Mortimer, Rudolf G., Highway Safety Research Institute, University of Michigan, Ann Arbor, Michigan, 48105, 313-764-4158, B.A., New York University, 1959, Industrial Psychology; M.A., New York University, 1961, Experimental Psychology; Ph.D., Purdue University, 1963, Industrial/Experimental Psychology. 1. Day and Night Driving Eye Fixations Patterns (A) 2. Effects of Drugs on Eye Fixations in Driving (A) 3. Aviation (A). a. CCTV Eye Marker.

Mourant, Ronald R., 632 Putnam, Wayne State University, Detroit, Michigan, 48202; 313-577-3822; B.A., University of Florida, 1963, Psychology; M.A., University of Florida, 1965, Psychology, Ph.D., Ohio State, 1971, Industrial Engineering. 1. Driver Eye Movements (A) 2. Search (I). a. Automobile television system b. Computer controlled lab unit.

Murphy, Brian J., Department of Psychology, University of Maryland, College Park, Maryland, 20742; 301-454-5351, B.S., Hobart College, 1971, Psychology, M.A., University of Maryland, 1973, Psychology 1. Perception of motion (A) 2. Vision and maintenance of vision (A) 3. Stimulus effects on control of eye movements (search) (A). a. Electronic contact lens optical lever b. EOG.

Naitoh, Paul, Naval Health Research Center, San Diego, CA, 92152, 225-6671, Ph.D., University of Minnestoa, 1964, Physiological Psychology. 1. Eye movements as an index of fatigue (A) 2. reading (I).

Nakayama, Ken, Smith-Kettlewell Institute of Visual Sciences, 2232 Webster Street, San Francisco, California, 94115, 415-563-4321, B.A., Haverford College, 1962, Psychology, Ph.D., UCLA, 1968, Physiological Psychology. 1. Kinematics (A) 2. Neurophysiology (A). a. Photographic (3 degrees of freedom).

Newell, Allen, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 15213, 412-621-2600 Ext. 562, B.S., Stanford University, 1949, Physics, Ph D., Carnegie Institute of Technology, 1957, Industrial Administration. 1. Problem Solving (A). a. Corneal Reflection.

Newsome, Sandra, Psychology Department, New Mexico State University, Las Cruces, New Mexico, 88003, 505-524-7822, B.A., University of Texas (Austin), 1975, Psychology. 1. Reading (I) 2. Search (I)

Nodine, Calvin F, Department of Radiology, Temple University School of Medicine, Philadelphia, Pennsylvania, 19140, 215-221-4011, A.B., Bucknell University, 1954, Psychology, M A., Bucknell University, 1959, Psychology, Ph D, University of Massachusetts, 1962, Psychology 1 Reading research (A) 2. Visual search (A) 3. Picture perception (A). a. Mackworth wide-angle camera b. Narco Eye Trac interfaced to PDP 11/40.

O'Hanlon, James F., Human Factors Research, Inc., 6780 Cortona Drive, Goleta, California, 93017, 805-968-1071, B.A., University of California at Santa Barbara, 1961, Psychology, M.A., California State University at Los Angeles, 1963, Experimental and Physiological Psychology, Ph D., University of California at Santa Barbara, 1970, Biological Sciences. 1. Visual Search (A) 2. Fatigue (A) 3. Sleep (REM) (A). a. EOG.

Olson, Richard K., Department of Psychology, University of Colorado, Boulder, Colorado, 80302, 303-492-8865, A.B., Macalester College, 1963, Psychology, M.A., University of Oregon, 1967, Psychology, Ph.D, University of Oregon, 1970, Psychology 1. Reading (A) 2. Form perception (A) 3. Visual search (A). a. Whittaker 1992S

O'Regan, J. K., Laboratoire de Psychologie, 54 Bd. Raspail, Paris 6, France, B.Sc , Sussex University, 1969, Physics, Ph.D., Cambridge University, 1976, Psychology 1. Reading (A) 2. Integration across fixations (A) 3. Constancy of visual direction (A). a. Photocell and PDP-12.

Osaka, Ryoji, Department of Aerospace Psychology, Institute of Environmental Medicine, Nagoya University, Nagoya 464, Japan; 052-781-5111, ext. 6390, B.A., University of Tokyo, 1943, Visual perception, M.A., University of Kyoto, 1950, Visual perception, D. Litt., University of Tokyo, 1961, Celestial Illusion. 1. Search (A) 2. Higher mental activity (I) 3. Apparatus (A) a. Corneal reflection (photo) b. EOG c. Computerized in near future.

Paap, Kenneth, Psychology Department, New Mexico State University, Las Cruces, New Mexico, 88003, 646-1925, B.A., University of Wisconsin, 1968, Psychology; M.S., University of Wisconsin, 1972, Psychology, Ph.D., University of Wisconsin, 1975, Psychology. 1. Reading (A) 2. Space Perception (A)

Parker, Richard Elias, Department of Psychology, UCSD, La Jolla, California, 92093, 714-452-2992, B.A., Williams College, 1973, Psychology and Mathematics, M.A., UCSD, 1975, Psychology. 1. Picture perception (A). a. Computerized I.R. Photoelectric.

Pavlidis, George Th., Department of Psychology, University of Manchester, Manchester M13 9PL, England, 0044-061-2733333, ext. 328, B.A., Aristotelean University of Thessaloniki, 1972, Psychology - Education, Ph.D., University of Manchester, 1976, Psychology. 1 Eye movements and language use and comprehension in young children (A) 2. Reading research (A) 3. Picture Perception (A). a. Photo-electric b. Pavlidis' Biodigitizer c. EOG.

Pena, Augustin de la, Psychology Service, Audie Murphy Memorial Veterans Administration Hospital, San Antonio, Texas, 78229, 512-696-9660, Ext. 525, B.A., University of Texas (Austin), 1964, Experimental Psychology, Ph.D., Stanford University, 1970, Psychophysiology. 1. Developmental aspects (I) 2. Differences between psychiatric populations (A) 3. Significance of REM sleep (A) a. Beckman Dynograph (EOG) b Mackworth Eye Marker Camera c. Infrared microsaccadic detector.

Perlmuter, Lawrence C., Department of Psychology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 24061, 703-951-6849, B.A., Boston University, 1960, Psychology, M.A., Syracuse University, 1964, Experimental Psychology; Ph.D., Syracuse University, 1965, Experimental Psychology 1. Pupilometrics (A) 2. Visual search/memory (A).

Pola, Jordan, Department of Basic Optometric Sciences, State University of New York, State College of Optometry, 122 East 25th Street, New York, New York, 10010, 212-673-4500, B.S., Columbia University, 1966, Philosophy, Ph.D., Columbia University, 1973, Experimental Psychology 1. Neurophysiology (A) 2. Perceived direction during eye movements (I). a. D. A. Robinson's electro-magnetic system.

Pollack, Irwin, Mental Health Research Institute, University of Michigan, Ann Arbor, Michigan, 48104, 313-763-1143, Ph.D., Harvard University, 1949, Psychology 1. Visual Search (A) 2. Reading (I).

Porterfield, James L., AMRL/HED, Wright Patterson Air Force Base, OH, 45433, 513-255-5770, A.B., Stanford University, 1960, Psychology, M.A., San Jose State, 1962, Psychology. 1 Aiming Weapon Systems (A) 2. Control of sensors (A) 3. Eye tracking performance (A). a. Honeywell Oculometer b. NAC Eye Mark Recorder c. SRI Prukinje Image Eye Tracker.

Potter, Mary C., E10-037, MIT, Cambridge, Massachusetts, 02139, 617-253-5526, B.A., Warthmore, 1952, Psychology; Ph.D., Radcliffe, 1961, Psychology. 1. Simulating eye movements with rapid visual presentation (I) 2. Search (I) 3. Picture recognition and reading (A).

Putz, Vernon R., National Institute for Occupational Safety and Health, 1014 Broadway, Cincinnati, Ohio, 45202, 513-684-2155; B.S., University of Wisconsin - Madison, 1965, Psychology; M.S., University of Wisconsin - Madison, 1967, Psychology; Ph.D., University of Wisconsin - Madison, 1969, Psychology. 1. Eye as a Control System (I) 2. Search-Scan (A) 3. Reading (I). a. Photo-electric b. EOG c. Biometric Device.

Rappaport, Maurice, Research Department, Agnews State Hospital, San Jose, California, 95114, 408-246-0630, B.S., New York City College, 1950; M.S., Ph.D., Ohio State University, 1954; M.D., Stanford University 1962. 1. Attention (A) 2. Reading (A) 3. Brain Dysfunction (A) a. Mackworth Eye Movement Camera b. Saccadic Eye Movement Camera.

Rayner, Keith, Department of Psychology, University of Massachusetts, Amherst, MA , 01003, 413-545-2175, B.A., University of Utah, 1968, Psychology, M.S., University of Utah, 1970, Psychology; Ph.D , Cornell University, 1974, Psychology. 1. Reading (A) 2. Visual search (A) 3. Picture perception (I). a. SRI Eyetracker b. Biometrics.

Reinecke, Robert D., Department of Ophthalmology, Albany Medical College, Albany, New York, 12208; 518-445-5223, O.D., Illinois College of Optometry, 1951, Optometry, A.B., University of Kansas, 1955, Chemistry, M.D., University of Kansas, 1959, Medicine, Residency, Mass. Eye & Ear Infirmary, 1961-1963, Ophthalmology. 1. Phoria measurements (A) 2. Online computer 4-prism diopter testing (A) 3. Afferent eye muscle responses (A). a. Infrared photocell system b. Digital storage on computers c. Eye tracking.

Richards, W., MIT, Department of Psychology E10-135, Cambridge, Massachusetts, 02139, 617-253-5776, Ph.D., MIT, 1965, Psychology. 1. Vergence 2. Binocular vision 3. Squint. a. EOG b. Photocell.

Riggs, Lorrin A., Psychology Department, Brown University, Providence, Rhode Island, 02912, 401-863-2512, A.B., Dartmouth College, 1933, Psychology, M.A., Clark University, 1934, Psychology, Ph.D., Clark University, 1936, Psychology. 1. Saccadic suppression (A) 2. Stabilized images (I) 3. Physiological nystagmus (I). a. EOG b. Corneal reflection.

Ritty, J Michael, 18 North Shafer, Athens, OH, 45701, 614-593-8300; B.A., University of Akron, 1971, History, M.Ed., Cleveland State University, 1976, Language Arts/Reading. 1. Reading (A) 2. Cognitive process (I). a. Reading Eye I b. Reading Eye II.

Robinson, David A., Department of Ophthalmology, Johns Hopkins University School of Medicine, Baltimore, Maryland, 21205, 301-955-3587, B.A., Brown University, 1947, Applied Mathematics; M.S., Johns Hopkins University, 1956, Electrical Engineering, Dr. Eng., Johns Hopkins University, 1959, Electrical Engineering. 1. Oculomotor neurophysiology (A) 2. Modeling of eye control (A). 3. Cerebellar physiology (A). a. Magnetic field coil b. Infrared pupil tracker c. EOG.

Robinson, David Lee, Neurobiology Department, Armed Forces Radiobiology Research Institute, National Naval Medical Center, Bethesda, Maryland, 20014, 301-295-1334, B.S., Springfield College, 1965, Biology, M.S., Wake Forest University, 1968, Physiology, Ph.D., University of Rochester, 1971, Neuroscience. 1. Neural Control (A) 2. Role in Vision (A) 3. Measurement (I). a. EOG.

Robinson, Gordon H., Department of Industrial Engineering, University of Wisconsin, 1513 University Ave., Madison, Wisconsin, 53706, 608-262-3768, B.S E.E., Wayne State University, 1954, Electrical Engineering, M.S.E.E. University of Michigan, 1955, Electrical Engineering; Ph.D., University of Michigan, 1962, Instrumentation Engineering & Engineering Psychology. 1 Dynamics of eye/head coordination (A) 2. Search (A) 3. Required movement as interruption of other processing (A). a. Biometric corneal reflection b Potentiometer on head via bicycle helmet.

Rockwell, Thomas H., Department of Industrial and System Engineering, Ohio State University, Columbus, Ohio, 43210, 614-422-6080, B.S , Stanford University, 1951, Chemical Engineering, M.S., Ohio State University, 1953, Industrial Engineering, Ph.D., Ohio State University, 1957, Industrial Engineering. 1 Driver Eye Movements (A) 2. Search (A) a. Corneal Reflection b Biometrics.

Rosen, Larry D , Psychology Department, California State College, Dominguez Hills, California, 90747, 213-532-4300, B.A., University of California at Los Angeles, 1971, Mathematics, Ph.D., University of California at San Diego, 1975, Psychology 1. Memory (A) 2. Role of eye fixation data in cognitive psychology (A) 3. Decision and judgement (I). a. Russo-Mathews scleral reflector.

Rothkopf, Ernst Z., Bell Laboratories, Murray Hill, New Jersey, 07974, 201-582-3750; A.B , Syracuse University, 1948, Psychology; M.A., University of Connecticut, 1951, Experimental Psychology, Ph.D., University of Connecticut, 1953, Experimental Psychology. 1. Reading (A) 2. Cognition (A) 3. Instructional theory (A) a. PDP-11 linked EOG

Russo, J. Edward, Graduate School of Business, University of Chicago, Chicago, IL, 60637, 312-753-3600, B.S., California Institute of Technology, 1963, Math, M.S , University of Michigan, 1966, Math, Ph D., University of Michigan, 1971, Psychology 1 Cognitive Processes (A) 2. Reading (I) 3. Measurement (A). a. Russo-Mathew (limbus reflection) b. Whittaker Eye View Monitor.

Schrier, Allan, M., Psychology Department, Brown University, Providence, Rhode Island, 02912, 401-863-2511, B.A , New York University, 1952, Psychology, M.S , University of Wisconsin, 1954, Psychology, Ph.D , University of Wisconsin, 1956, Psychology 1 Discrimination learning in monkeys (A) 2. Search in monkeys (A) a. LINC-8 computer monitoring corneal reflection.

Schumacher, Gary M., Department of Psychology, Ohio University, Athens, Ohio, 45701, 614-594-3821, B.S., Iowa State University, 1965, Mathematics, M.S., Purdue University, 1968, Mathematics, Ph.D , Iowa State University, 1970, Psychology 1 Prose retention (I) 2. Learning from prose (I). a. Reading Eye I.

Schwank, Lt. Col. Jock, DFBL, USAF Academy, Colorado, 80840, 303-472-3860, B.S., USAF Academy, 1960; M.S., University of Oregon, 1971, Exp (Human Factors), Ph.D , University of Oregon, 1975, Exp. (Human Performance). 1 Peripheral processing (A) 2. Search (A) 3. Stress effects (A). a. IR Tracker b Head position sensor c. Pupilometer.

Schwartz, Joddy, Department of Health Science, Brooklyn College CUNY, Brooklyn, NY 11210; 212-780-5026, B.S., CCNY, 1968, Psychology, M.S., CCNY, 1972, Educational Research, Ph.D , Hofstra, 1977, Educational Research. 1. Reading (A) 2. Visual information processing (A) 3. Visual Psychophysics (A) a. EOG b. Biometrics SG.

Scinto, Jr., Leonard F., Larsen 408, Laboratory of Human Development, Harvard University, Cambridge, Massachusetts, 02138, 617-495-3408/3541, B.A., St. John Fisher College, 1968, English/Linguistics, M.Ed., Harvard University, 1975, Cognitive Psychology/Language. 1. Television (A) 2. Language (A) 3. Perception (A). a. Whittaker Corneal Reflection.

Sedgwick, Harold A., State College of Optometry, 131 East 23rd Street, New York, New York, 10010; 212-673-4500, ext. 845; B.A., Cornell University, 1967, Psychology, Ph.D., Cornell University, 1973, Psychology. 1. Eye movement control system (A) 2. Eye movement information in perception (A) 3. Eye movement adaptation (A). a. Cornsweet/Crane infrared eye tracker b. EOG.

Semmlow, John L., Department of Electrical Engineering, Rutgers University, Piscataway, NJ, 08854, 201-932-2554, B.S , University of Illinois, 1964, Electrical Engineering, Ph.D., University of Illinois Medical Center, 1970, Bioengineering. 1. Vergence control (A) 2. Muscle control (A) 3. Pupilomotor control (I). a. Scleral reflection.

Senders, John W., Department of Industrial Engineering, University of Toronto, Toronto, Canada, M5S 1A4, 416-978-6823, A.B., Harvard University, 1948, Experimental Psychology. 1. Visual attention (A) 2. Scanning (A). a. EOG b. Biometrics - SVG.

Sharma, Satanand, Department of Psychology, University of California at Los Angeles, Los Angeles, California, 90024, 213-825-3053, B.A., University of California at Los Angeles, 1969, Psychology, M A., California State University, Los Angeles, 1971, Psychology; Ph.D , University of California at Irvine, 1973, Psychology. 1. Scanning Patterns/Drugs (A) 2. Vision/Driving (A). a. Biometrics.

Shebilske, Wayne L., Department of Psychology, University of Virginia, Gilmer Hall, Charlottesville, Virginia, 22901, 804-924-3374, B.A., University of Wisconsin, 1965, Psychology, M.S., University of Wisconsin, 1972, Psychology, Ph.D., University of Wisconsin, 1974, Psychology. 1. Oculomotor Control (A) 2. Space perception (A) 3. Reading (A). a. Scleral Reflectance b. EOG.

Sheena, David, Gulf and Western, Applied Science Laboratories, 335 Bear Hill Road, Waltham, Massachusetts, 02154, 617-890-5100; S.B., Massachusetts Institute of Technology, 1964, Electrical Engineering; S.M., Massachusetts Institute of Technology, 1965, Electrical Engineering, Ph.D., Massachusetts Institute of Technology, 1969, Electrical Engineering. 1. Eye movement monitor (A) 2. Counterroll measurement (A) 3. Pupilometry (A) a. Whittaker Eye View Monitor.

Shinar, David, Institute for Research in Public Safety, Indiana University, Bloomington, Indiana, 47401, 812-337-3908, B.A , Hebrew University, 1968, Psychology, M.A., Ohio State University, 1970, Psychology, Ph D , Ohio State University, 1973, Psychology 1. Driver Eye Movements (I) 2. Visual Search (A) 3. Peripheral Acuity (A).

Sidowski, Joseph B., Psychology Department, University of South Florida, Tampa, Florida, 33620, 813-988-5698, B.A., Pomona College, 1951, Experimental Psychology, M S., University of Wisconsin, 1954, Experimental Psychology, Ph.D , University of Wisconsin, 1956, Experimental Psychology 1. Reading (I) 2. Complex Processes (I) 3. Psychophysiological correlates (I).

Sigman, Marian, Department of Pediatrics, UCLA Medical School, Los Angeles, California, 90049, B.A., Oberlin College, 1963, Ph.D., Boston University, 1970, Psychology 1. Infant perception (A) 2. Visual search in children (A) 3. Picture recognition (A).

Simmons, Ronald R., U.S. Army Aeromedical Research Laboratory, P.O. Box 577, Ft. Rucker, Alabama, 36362, 205-255-6504/3211, B.S., Jacksonville State University, 1974, Psychology; M.S., Troy State University, 1975, Criminal Justice. 1. Visual cues for helicopter flight (A) 2. Visual cues for simulated flight (A) 3. Reduction of pilot visual workload (A). a. NAC Eye Mark Recorder.

Skavenski, Alexander A., 440 UR - Psychology Department, Northeastern University, Boston, Massachusetts, 02115, 617-437-3043, B.S., University of Maryland, 1965, Psychology, Ph.D., University of Maryland, 1970, Psychology. 1. Perception of direction (A) 2. Miniature eye movements (A) 3. Motor-Control (I). a. Magnetic field - search coil b. Contact lens - optical lever

Slater, Alan M , Department of Psychology, University of Exeter, Exeter EX4 4PG, Devon, England, Exeter 77911, ext. 619, B.S., Swansea University, 1970, Psychology, Ph D , Durham University, 1974, Psychology. 1. Development (A) 2. Scanpaths (A) 3 Form perception (I) a EOG b. infrared corneal reflex C.C.T.V Device.

Smith, Stanley W , Institute for Research in Vision, 1314 Kinnear Rd., Columbus, Ohio, 43212, 422-6424 or 2057, B A., Oberlin College, 1950, Psychology and Physiology, M.A., Oberlin College, 1952, Psychology, Ph.D., University of Michigan, 1961, Psychology 1 Monitoring fixation (A) 2. Visual search (A) 3 Visual tâsk performance (A). a. SRI Prukinje Eyetracker 2. Iris-sclera reflection photocell detection system.

Snyder, Harry L., 130 Whittemore, Virginia Polytechnic Institute, Blacksburg, Virginia, 24061, 703-951-5358, A.B., Brown University, 1958, Psychology, M.A., Johns Hopkins University, 1960, Psychology, Ph.D , Johns Hopkins University, 1961, Psychology 1 Display Evaluation (A) 2. Search (A). a. Biometrics b DPI Eye Tracker

Spady, Amos A., 301 Pinehurst Drive, Yorktown, Virginia, 23692, 804-827-3871, B.S., Randolph-Macon College, 1958, Physics. 1 Pilot Scan (A) 2. Pilot Workload (A) a Honeywell Mark III.

Stark, Lawrence, University of California, 226 Minor Hall, Berkeley, California, 94720, A.B , Columbia University, 1945, Zoology, M D , Albany Medical College, 1948, Medicine, Am Board in Psychiatry & Neurology, 1957, Neurology 1 Saccades (A) 2. Control (A) 3 Scanpath (A) a. Photocell b EOG c TV Camera.

Steinbach, Martin J. Department of Psychology, Atkinson College, York University, Downsview, Ontario, 416-667-3693, B S , City University of New York, 1963, Psychology, M A , Connecticut College, 1965, Psychology, Ph D , MIT, 1968, Experimental Psychology 1 Pursuit (A) 2. Comparative studies (A). a. Contact lens (Optical lever) b. Photoelectric (biometrics).

Steinman, Robert M., Department of Psychology, University of Maryland, College Park, Maryland, 20742, 301-454-5351, D.D.S , St. Louis University, 1948, Dentistry, M.A., New School for Social Research, 1962, Psychology, Ph D., New School for Social Research, 1964, Psychology 1 Fine grain performance (A) 2. Physiological basis (A) 3. Scanning (A) a. Contact lens optical lever b Purkinje image tracker c. Developing a revolving field search coil

Stern, John A., 1420 Grattan, St. Louis, Missouri, 63104, 314-621-4211, Ph.D , University of Illinois, 1953, Psychology. 1. Reading (A) 2. Visual Search (A) 3. Cognition (A). a. EOG.

Stillman, Richard, W A. White Bldg. 532, St. Elizabeth's Hospital, Washington, D. C. 20032; 547-7628, M.D., Yale University, 1964, Medicine, 1 Scanning (A) 2. Drugs (A) 3. Memory (A) a. Whittaker.

Sutker, Louis W., Department of Psychology, University of Victoria, Victoria, British Columbia, Canada, 604-777-6911, B.A., Tulane University, 1964, Psychology, M.S., University of Georgia, 1967, Psychology, Ph.D., University of Georgia, 1970, Psychology. 1. Visual Halt-Field Perception (A) 2. Brain Damage (A) 3. Attention (A). a. Biometric Eye Movement Monitor b. Polymetric Fixation Monitor.

Taylor, Richard L., Institute for Research in Human Abilities, Memorial University, St. John's , Newfoundland, Canada, 709-753-1200, ext. 3500, 2639, 3311, B.A., Occidental College, 1960, Psychology, M.A., Occidental College, 1965, Psychology, Ph.D., University of Oregon, 1968, Psychology 1 Programming Saccades (A) 2. Aural Control of Fixation (A). a. On-Line EOG and Head Mounted Electro-optic Sensors (Biometrics)

Taylor, Stanford E , Hawk Drive, Lloyd Harbor, New York, 11743, 516-549-4363, BFA, Pratt Institute, 1951, Art Education, M A., New York University, 1952, Communications. 1. Reading (A) a. EDL Reading Eye I (photographic) b EDL Reading Eye II (electronic)

Templeton, William B., Department of Psychology, York University, Toronto, Ontario, Canada, 416-667-2450, B.A., Queens, Belfast, U K., 1960, Psychology; M.S., Durham, England, 1962, Psychology, Ph.D , Durham, England, 1969, Psychology. 1. Saccadic Mechanisms (A). a Biometrics infrared monitor.

Tole, John R., Biomedical Engineering Center, Room 20A-113, Massachusetts Institute of Technology, Cambridge, MA, 02139, 617-253-7421, B.S.E.E., Drexel University, 1968, Electrical Engineering, S M , MIT, 1970, Instrumentation, Sc.D., MIT, 1976, Instrumentation. 1. Computer analysis of nystagmus (A) 2. Clinical neurological testing (A) 3. Tracking (I) a. EOG b. Photoelectric (biometrics).

Trabold, Jr , Frederick, W., Human Factors Engineering Staff, Martin Marietta Aerospace, P O Box 5837, Orlando, Florida, 32805, 305-352-2382, B A., Union College, 1947, Psychology, M.A., University of Minnesota, 1950, Experimental Psychology. 1 Search patterns for target acquisition (A)

Troster, Joel, Institute of Biomedical Engineering, Roseburgh Building, University of Toronto, Toronto, Ontario, Canada M5S 1A4, 416-928-3113, B.A.Sc., University of Toronto, 1972, Electrical Engineering, M.A.Sc , University of Toronto, 1974, Biomedical Engineering. 1. Drug effects of saccadic eye movements (A) 2. Diurnal variations (A) 3. Vergence movements (I) a. Lab-developed corneal reflection system b. Mackworth/Llewellyn-Thomas head camera c. EOG.

Tuecke, Manfre, Universitaet Osnabrueck, Fachgruppe Psychologie, Neuer Graben, Schloss, D-4500 Osnabrueck, Germany, 0541-6084207, D.R.P , University of Marburg, 1974, Medical Statistics. 1. Eye movements and reading disabilities (A). a. Gulf & Western 1994S.

Tulanay-Keesey, Ulker, Department of Ophthalmology, University of Wisconsin Medical School, 1300 University Avenue, Madison, Wisconsin, 53705, 608-263-2328, Ph D., Brown University, 1959, Psychology. 1 Micro eye movements (A) 2. Effect in sensitivity (A) a. Plane-mirror contact lens b. Optical lever c. EOG.

Varanasi, Murali R., Department of Electrical Engineering, Old Dominion University, 5215 Hampton Boulevard, Norfolk, VA, 23508, 804-489-6481, B.Sc., Andhra University, 1957, Physics, D M I.T , Madras Inst. of Tech., 1962, Electronics, M.S., University of Maryland, 1972, Electrical Engineering, Ph.D , University of Maryland, 1973, Electrical Engineering. 1. Corneal reflections (A) 2. Perception (A) 3 Behavioral pattern classification (A) a. Oculometer

Vaughan, Jonathan, Psychology Department, Hamilton College, Clinton, New York, 13323, 315-859-4225, B A., Swarthmore College, 1966, Psychology; M.A., Brown University, 1968, Psychology; Ph.D., Brown University, 1970, Psychology. 1. Search (A) 2. Reading (A) 3. Discrimination Learning (I) a. EOG b Photoelectric reflectance measurement c. Corneal reflection

Volkmann, Frances C., Clark Science Center, Smith College, Northampton, Massachusetts, 01060, 413-584-2700, A.B., Mount Holyoke College, 1957, Psychology, M.A., Brown University, 1959, Psychology, Ph.D , Brown University, 1961, Psychology 1. Vision during saccades (A) 2. Search (I). a. EOG b. Corneal reflection

Waller, Marvin C., NASA, Langley Research Center, Hampton, Virginia 23666, 804-827-3871, B.S., Norfolk State College, 1965, Physics, M.S., George Washington University, 1974, Aerospace Engineering. 1 Pilot scanning behavior (A). a. Oculometer (Honeywell)

Walton, Howard N , 3840 Main Street, Culver City, California, 90230, 839-2090, O D , Illinois College of Optometry, 1949, Optometry, M.S., Chicago College of Optometry, 1951, Optometry, Physiological Optics. 1 Reading (A) 2. Learning Disabilities (A) 3 Research (A) a. Eye Trac b Reading Eye Camera.

Wang, William, 2222 Piedmont Avenue, University of California, Berkeley, California, 94720, 415-642-5937, Ph.D , University of Michigan, 1960, Linguistics 1 Cognition (A) 2. Reading (A) 3 Orthography design (A). a. EOG

Ward, Frank, Department of Psychology, Wright State University, Dayton, Ohio, 45431, 513-873-2179, B.A., University of Washington, 1963, Chemistry, M A., Wesleyan University, 1970, Psychology, Ph.D , University of Rochester, 1974, Psychology 1 Position (A) 2. Timing (A) 3. I-R Reflecting Equipment.

Weertz, Ted, Department of Psychology, University of Iowa, Iowa City, Iowa, 52240, 319-353-4198, B.S., University of Wisconsin, 1965, Psychology, M.S , University of Wisconsin, 1970, Experimental Psychology, Ph.D , University of Wisconsin, 1973, Psychophysiology. 1. Visual imagery (A) 2. Tracking (I) 3. Search (I) a. EOG.

Whalley, Peter C., Text Research Group, IET, The Open University, Milton Keynes, England, 0908863777, B.Sc., Brunel University, 1975, Psychology. 1. Reading complex texts (A) a. Corneal reflection b page- and book-level recorder

White, Charles W., Graduate Faculty, New School for Social Research, 65 Fifth Ave., New York, New York, 10003, B.A., Rice University, 1966, Psychology, Ph.D., Stanford University, 1971, Experimental Psychology. 1. Visual masking (A) 2. Localization (A) 3. Visual illusions (I). a. SRI Purkinje eyetracker b. EOG.

Williams, Evelyn, Department of Psychology, New Mexico State University, Las Cruces, New Mexico, 88001, 505-646-2636, B.S., University of New Mexico, 1969, Psychology, M.A., University of New Mexico, 1971, Psychology, Ph.D., University of New Mexico, 1973, Psychology. 1 Reading (A) 2. Memory (A) 3. Peripheral vision (A). a. Biometrics.

Williams, Leon G, Honeywell, Inc., 2600 Ridgeway, Minneapolis, Minnesota, 55417, 612-331-4141, ext. 5034, B.S., University of Michigan, 1949, Math, M A., University of Michigan, 1952, Psychology, Ph.D , University of Michigan, 1956, Psychology. 1. Visual search (A) 2. Math modeling (A) a. Honeywell Oculometer b. Honeywell eye movement device.

Winterson, Barbara J., Department of Psychology, University of Maryland, College Park, Maryland, 20742, 301-454-5351, ext. 30, B.S., University of Maryland, 1971, Psychology. 1. Comparative oculomotor performance (A) 2. Saccadic suppression (A) 3. Oculomotor physiology (A). a Robinson's magnetic search coil b Contact lens optical lever c. EOG

Wise, Marion A., Mail Stop 152D, Langley Research Center, Hampton, Virginia 23665, 804-827-3871, A.E., CREI, 1961, Electronics. 1. Hardware (A) 2. Human Factors (A) a. Honeywell Mark II b. Biometrics.

Wisher, Robert A., Code 9306, Navy Personnel Research & Development Center, San Diego, California, 92152, 714-225-7122, B.S., Purdue University, 1971, Mathematics, Ph.D., University of California, 1976, Psychology. 1 Reading (A) 2. Cognitive Processes (I) 3. Search (I). a. Whittaker.

Wolff, Michael, Department of Psychology, Brooklyn College, Brooklyn, New York, 11210, 212-780-5042, B.A., Brooklyn College, 1965, Psychology, Ph.D , Graduate Center, City University of New York, 1974, Social Psychology 1. Social Organization of Looking in Public Places (A) a. Sanyo slow-motion video-tape b. Super-8 and 16mm film

Wood, Joan Susan Baizer, Room 1D-02, Building 36, Laboratory of Neurobiology, NIMH, Bethesda, Maryland, 20014, 301-496-4864, B.A., Byrn Mawr College, 1968, Psychology, M S , Brown University, 1970, Psychology, Ph D , Brown University, 1973, Psychology 1 Neurophysiology of target selection and EM programming (A) 2. EM and perception (A) 3. EM and visuomotor coordination (I) a. Silver-silver chloride implanted EOG electrodes.

Worthington, B.S., Department of Morphology, Nottingham University, England, (0602) 56101, B Sc , London University, 1960, Physiology, M B.B.S , London University, 1963, Physiology, D M R.D , Conjorort Board, 1967, Radiology, F R.C.R., Conjorort Board, 1969, Radiology 1 Search patterns during reporting of radiographs (A) 2. Vigilance tasks (A) 3 Properties of visual memory (A). 1 I I.M.C., N A.C Recorder, Model 4

Wurtz, Robert H., Room 1D-02, Building 36, NIMH, Bethesda, Maryland, 20014, 301-496-4864, Ph D., University of Michigan, 1962, Psychology. 1. Neurophysiology (A). a. EOG.

Yasui, Syozo, Department of Physiology & Biophysics, University of Texas - Medical Branch, Galveston, TX, 77551, 713-765-1717, B S, University of Tokyo, 1963, Aeronautics and Astronautics, M S., MIT, 1967, Control Engineering, Ph D, MIT, 1974, Biomedical Engineering. 1. Nystagmus (I) 2 Tracking (I) a. EOG b. Infrared photoelectric.

Young, Laurence R., MIT, Man-Vehicle Lab, 37-207, Cambridge, Massachusetts, 02139, 617-253-7759, A.B, Amherst College, 1957, Physics; S B, MIT, 1957, Electrical Engineering, S.M, MIT, 1959, Electrical Engineering, Sc.D, MIT, 1962, Instrumentation 1. Math models (A) 2. Vestibular nystagmus (A) 3. Neurophysiology (A). a. EOG b Photoelectric (Biometrics)

Zahn, Joseph R., Bascom Palmer Eye Institute, University of Miami, Department of Ophthalmology, Miami, Florida, 33152, 305-547-6517, B.A., Regis College, 1968, Psychology, M A., San Jose State University, 1971, Psychology, Ph.D, Indiana University, 1975, Physiological Optics. 1 Neurological aspects of eye movements (A) 2. Bio-feedback and eye movements (A) 3 Auditory input to the saccadic system (A) a. IR photoelectric b EOG

Zee, David, Johns Hopkins Hospital, Baltimore, Maryland, 21205, 301-955-3282, B A., Northwestern University, 1965, Chemistry, M D., Johns Hopkins University, 1969, Medicine 1. Pathological eye movements 2. Neurophysiology. a. Infrared pupil tracker b. D C, EOG

Ziedman, Kenneth, Southern California Research Institute, 2033 Pontius Ave., Los Angeles, California, 90025, 213-478-1414, B S, California Institute of Technology, 1955, Physics, M A, University of California (LA), 1963, Psychology, Ph.D, University of California (LA), 1966, Psychology 1 Visual search (A) 2 Driving (A) 3 Drugs (A). a. Biometrics.

Zola, David, Stone Hall, Department of Education, Cornell University, Ithaca, NY, 14853, 607-256-2207, A.B, Fairfield University, 1969, English, M A, Fairfield University, 1972, Communications. 1. Reading (A) 2 Saccadic suppression (A) a. Limbus reflection via biometrics b EOG c Purkinje tracker no longer at Cornell, no [illegible] being done

Zwahlen, Helmut T., Department of Industrial and Systems Engineering, Engr. Bldg., Ohio University, Athens, Ohio, 45701, 614-594-5232/6583, B.S, Institute of Technology, Switzerland, 1962, Mechanical Engineering; M S, Ohio University, 1968, Industrial and Systems Engineering, Ph D, Ohio State University, 1972, Industrial and Systems Engineering. 1. Driver eye movements (A) 2 Visual perception and distance judgment (A) 3 Visual cues in learning psychomotor tasks (A) 1 Corneal reflection technique television EM b. Biometrics with various interfaces

Appendix C

COMPARISON OF EYE MOVEMENT MEASURING TECHNIQUES
(Table 1 from "Survey of Eye Movement Recording Methods"
by Laurence R. Young and David Sheena)
appearing in "Behavior Research Methods
and Instrumentation 1975," Vol. 7(5), 397-429

This Page Intentionally Left Blank

Table 1

COMPARISON OF EYE-MOVEMENT MEASURING TECHNIQUES

Method	Measurement Range (deg) Verti-cal	Measurement Range (deg) Hori-zontal	Accuracy Verti-cal	Accuracy Hori-zontal	Speed or Frequency Response	Interference with Normal Vision	Glasses Accept-able	Contact Lens Accept-able	Subject Variation Problems Eye Color, Etc	Subject Cooper-ation Required	Subject Train-ing Re-quired	Usable with Young Children
1 Corneal reflex (Mackworth Camera)												
Polymetric Lab V1164	±9	±9	5 deg	5 deg	Photographic rate 12-64 frame/sec Television 60 fields/sec	Medium	?	Possible source of error	None	High	Low	?
Polymetric Mobile V0165	±10	±10	1 deg	1 deg	Same as above	High Weight on head, optics near eye	No	Possible source of error	None	High	Low	No
NAC-REES	±10-20	±10-20	2 deg	2 deg	Same as above	High Weight on head	No	Possible source of error	None	High	Low	No
2 Contact lens with						High		No	Eye must accept contact lens	High	High	No
lamp or radiant spot	Both ±10-30	±10-30	Precision 3 sec	3 sec	High		No					
coil	Larger than others		15 sec	15 sec	High		Yes					
mirror	±10	±10	2 sec	2 sec	High		No					
3 EOG	±50	±50-80	2 deg	1 5 deg	dc or 01-15 Hz limited by filtering	None	Yes	Yes	Medium placement of electrodes and calibration is variable	Medium	Low	Yes
4 Limbus boundary												
G&W Eye Trac		±10	4 deg	2 deg	2 msec, 30 msec with recorder	Medium	Yes	Yes	Iris coloration a factor	High	Low	Yes
G&W Model 200	+10 -20	±20	2 deg	1 deg	4 msec, 26 msec with filtering	Medium	No	Yes	Iris coloration a factor	High	Low	Yes
5 Wide-Angle Mackworth Camera												
Polymetric V1166	40	40	2 5 deg	2 5 deg	Same as Method 1	Medium Subject looks through apertures, special lighted stimuli are required	?	Possible source of error	None	High	Low	Yes
6 Pupil-center-corneal-reflection distance												
Honeywell Oculometer	+30 -10	±30	1 deg	1 deg	1 sec time constant	Low	Yes	Possible source of error	Low	Low	Low	Yes
Whittaker Eye View Monitor	±15 higher possible	±22	1 deg	1 deg	30-60 samples/sec	Low	Yes	Same as above	Low	Low	Low	Yes
U S Army Human Engineering Lab	30	40	2 deg	2 deg	60 samples/sec filtered	Low	No	Same as above	Low	Low	Low	Yes
7 Double Purkinje image eye tracker	25 deg diam	25 deg diam	Noise of 1 min		300 Hz	Low	Autocorrection possible		Low	Low	Low	Yes

Table 1 (Concluded)

Method	Calibration and Setup Time	Head Attachments Required	Head Stabilization Requirement	Subject Discomfort	Subject Awareness	Pupil Diam Output Also	Form of Output	Status	Cost of Operation	Remarks	Source of Further Information
1 Corneal reflex (Mackworth Camera)											
Polymetric Lab V1164	Low	Chinrest or bite-board	High head restraint or biteboard	Medium	High	No	Photographic or videotape, low-resolution digital output	Commercially available	High for film		
Polymetric Mobile V0165	High bite-board	Bite-board	None	High	High	No	Same as above		High for film	Higher resolution digital output is possible with other instruments	
NAC-REES	Medium fit headband, set light source	Head-mounted optics	None	Medium	High	No	Same as above		High for film	Head-mounted TV camera REES Inst Ltd Westminister House, Old Woking, Surrey, United Kingdom	Instrumentation Marketing Corp 820 South Mariposa Burbank, CA 91506
2 Contact lens with											
lamp or radiant spot	High lens must be filtered	Contact lens	High	High	High	No	Photographic or electrical	Some commercial devices available	Lens grinding may be costly	Negative pressure application may be hazardous	
coil			Low								
mirror			Low								
3 EOG	High requires electrode stabilization and light adaptation	Yes, 2-6 electrodes	Low	Low	High	No	Electrical record	Commercially available	Low	More suitable for eye motion than eye position	Grass Instrumentation, Quincy, MA 02169
4 Limbus boundary											
G&W Eye Trac	Low	Head bracket, and chin-rest	High	Low	High	No	Analog and digital	Commercially available	Low	Vertical position of eyelid is used to approximate vertical eye position	Gulf & Western Applied Science Labs 335 Bear Hill Road Waltham, Mass 02154
G&W Model 200	Low	Spectacles	None	Low	High	No	Analog and digital	Commercially available	Low		Gulf & Western
5 Wide-Angle Mackworth Camera											
Polymetric VI166	Low	Viewing through aperture	Medium, head must be kept still	Low	High	No	Photographic or videotape, low-resolution digitizer available	Commercially available	High for film	Point of regard output without head motion artifact	
6 Pupil-center-corneal-reflection distance											
Honeywell Oculometer	Low higher for maximum linearization	None	Mark II head free, 1 in^3 Mark III head free, 1 ft^3	Low	Low	Yes	Digital, analog, and fixation pointer on TV image of scene	Commercially available	Low	Computer-based system Mark III tracks head motion and has auto focus	Honeywell Radiation 2 Forbes Rd Lexington, MA 02172
Whittaker Eye View Monitor	Low	None	Head free up to 1 ft^3	Low	Medium	Yes	Same as above	Commercially available	Low	Tracks head motion and has auto focus available	Gulf & Western
U S Army Human Engineering Lab	Low	None	1 ft^3	Low	Low	Yes	Digital, analog, videotape, and graphic	Research laboratory	NA		U S Army/HEL Aberdeen Proving Ground, MD
7 Double Purkinje											
image eye tracker	Low	Chinrest or bite-board	None, head free 1 cm^3, Biteboard for high precision	Low	Medium	No	Analog output	Small production	Low	Has auto focus, field and operation are dependent on pupil size suitable for image stabilization	SRI International Menlo Park, CA 94025

Appendix D

HONEYWELL OCULOMETER LITERATURE

This Page Intentionally Left Blank

AN OCULOMETER NOW UNOBTRUSIVELY REVEALS WHAT YOU ARE LOOKING AT

JANUARY 1977

HONEYWELL
Radiation Center
2 Forbes Road
Lexington, Massachusetts 02173

AN OCULOMETER NOW UNOBTRUSIVELY REVEALS WHAT YOU ARE LOOKING AT

The Eyes - A Window Into The Mind

Unlike a TV camera (which "sees" everything within its field of view equally clearly), the human eye must be aimed quite accurately if the detail of interest is to be seen with maximum clarity. For example, try reading a portion of this text without moving your eyes. That is, keep your eye fixed on one letter and then try to read adjacent letters and words. You will notice two things. First, the area of best vision (foveal vision) is very small - you will probably feel the need to move your eye, just to see the letter immediately adjacent to the particular letter onto which you are trying to keep your eye fixed. Second, the impulse to move your eye, to see adjacent letters, is almost irresistible.

The largely subconscious angular movement of our eyes reveals what it is that we are attending to - how we are absorbing visual information from our environment. It is, after all, a matter of common experience that our eyes not only let us see out, but allow others to "see" into us.

The Remote Oculometer

By looking at another person's eyes, you can tell where he is looking. An electro-optical device, called an Oculometer, can now do this automatically - generating a continuous measure of the x-y coordinates of a subject's instantaneous point of fixation, together with a continuous measure of his pupil diameter.[1]

The Oculometer, developed by Honeywell Radiation Center for the USAF Aerospace Medical Research Laboratory, is remote from the subject (several feet away, or more). Eye direction is measured whenever the eye is within a designated cubic foot volume of space. This cubic foot of "eye space" coverage of the Remote Oculometer is sufficient so that, in many applications, the subject is free to move in a completely normal fashion. The subject may not, necessarily, even be aware that his eye direction is being measured. The fact that the Remote Oculometer does not interfere with the normal activities of the subject makes it particularly useful for human factors research - for example, the flight research now being performed by NASA at their Langley Research Center.

NASA scientists have installed a Remote Oculometer in the cockpit of an aircraft simulator.[2] The output signals from the Oculometer define the coordinates, on the instrument panel, of the pilot's point of fixation at any instant. From the

---

1 "Remote Measurement of Eye Direction Allowing Subject Motion Over one Cubic-Foot of Space," John Merchant, Richard Morrissette, James L. Porterfield, IEEE Transactions on Biomedical Engineering, Vol. BME-21, No. 4, July 1974, pp 309-17.

2 "Preliminary Report on Airline Pilots Scan Patterns During ILS Approaches," Amos A. Spady, Jr., pp 603-616, (In Aircraft Safety and Operating Problems, NASA SP-416, 1976).

known coordinates of the various instruments, this Oculometer data is converted into parameters such as instrument-fixation-frequencies, fixation-transfer-probabilities (between instruments), etc for detailed analysis of the pilot's visual task.

The Oculometer output can also be used to annotate a TV picture of the instrument panel with a marker dot showing the pilot's instantaneous point of fixation. This annotated TV picture can be recorded on video tape to provide a continuous, graphic record of the pilot's fixation scan. Pilot fixation data is useful because it indicates, as no other data can, how the pilot is absorbing information from his flight instruments. Flying can be thought of as a multi-degree-of-freedom manual control task. The pilot must control the angular attitude (elevation, roll, and yaw), the velocity (horizontal speed and heading, and vertical velocity) and, of course, the altitude of his aircraft.

During an approach and landing most, if not all, of these flight parameters are changing and each one must be promptly and accurately corrected. In bad weather the pilot must rely, completely, on his flight instruments for information on the current value of these flight parameters. This requires a constant, rapid, and systematic fixation scan by the pilot over his primary flight instruments.

By recording and analyzing pilot eye fixation data, NASA hopes to be able to answer questions such as:

- How should the primary instruments be arranged on the panel in front of the pilot? Are there better ways (then conventional dials) of displaying the flight data?
- How should the pilot divide his attention between the various instruments? Is there a preferred fixation scan pattern over the flight instruments?
- Can the stress on the pilot be estimated from measurements of his fixation behavior and/or pupil diameter changes?

In the near future, NASA plans to install an Oculometer in an aircraft to record the pilot's through-the-window fixations in actual flight. In this case, the Oculometer data will show what elements of real-world detail the pilot uses under VFR conditions. This will help NASA optimize the design of the visual out-of-the-window display for their flight simulator.

How The Oculometer Works

If you shine a flashlight at someone's eye, and ask them to rotate their eye (that is, to change their point of fixation) you will see a movement in the eye. Because the eyeball is quite small (about one inch in diameter) the amount of such eye movement, per degree of eye rotation, is very small. Even more of a problem is the fact that a similar movement of the eye occurs whenever the head is translated. How is an electro-optical eye tracker to sense the small movements of the eye due to eye rotation, and then distinguish them from the generally much larger, but similar, movements of the eye caused by head displacement?

In some eye-tracking devices this problem is (often only partially) solved by clamping the tracker to the subject's head. In the Oculometer the problem is overcome by tracking two elements of eye detail - the pupil/iris boundary and the reflection in the eye of the source used to illuminate the eye.

To demonstrate this principle, ask a subject to look directly at your flashlight. You will notice that the highlight (corneal) reflection of the light appears to be at the center of his pupil. When the subject looks away from the light, you will see that the reflection moves, correspondingly, away from the center of the pupil. It is easily verified that this is independent of head position. In other words, eye direction can be determined, independently of head position, simply by measuring the displacement of the corneal reflection (of the radiation used to illuminate the eye) relative to the center of the pupil.

To avoid dazzling the subject, the Oculometer uses near infrared (0.8 m) radiation to illuminate the eye. This is almost invisible - the subject sees only a dull red light in front of him.

A standard TV camera is used to sense the eye detail, and by a special optical arrangement, the pupil of the eye is seen as "bright" - not black, as in a normal view of the eye (Figure 1). (In this technique, the pupil is effectively back-lighted by the retinal image of the infrared source.) With suitable black-level adjustment of the camera video output, the TV picture of the eye generated by the Oculometer reduces to just two circular areas against a black background. One circle-the pupil yields a video level of about 300 mV. The other - the much smaller corneal (high-light) reflection - is at a video level of about 1 volt. As we have seen, eye direction is proportional to the displacement of the corneal reflection from the center of the pupil. The Oculometer electronics unit analyzes this relatively simple TV picture of the eye to deduce eye direction according to this principle.

The Oculometer electronics unit is, basically, a standard general purpose mini-computer. A special interface card, which plugs into a spare slot in the mini-computer, converts the video signal from the Oculometer TV sensor into digital format, and enters the resultant eye data directly into an area of the minicomputer memory. The specialized processing of the video eye data is then performed (in real time) entirely by software in the general purpose minicomputer.

The advantages of minicomputer processing are low cost, reliability, easy maintenance, flexibility for incorporating improvements, and processing power. The processor not only estimates the relative positions of the centers of the pupil and of the corneal reflection, it also handles special, "difficult" cases - as when the corneal reflection falls on (and thereby distorts) the pupil/iris boundary, or when the top and/or bottom of the pupil is partially obscured by the eyelids. It solves the complex geometrical equations relating "raw" eye direction and the coordinates of the intercept of the fixation vector on some specified plane. The processor also provides the means for quick, three-point, calibration for each new subject as well as compensation for the nonlinearities in the relationship between eye direction and relative corneal reflection position within the pupil.

As mentioned earlier, the motion of the eye, due to eye rotation, is small. In the effect used by the Oculometer, the scale factor is approximately three thousandths of an inch of relative corneal reflection displacement per degree of eye rotation. The resolution of the TV sensor is limited by the approximately 500-600 scan lines in the picture. It is clear that if the TV sensor is to have sufficient resolution to be able to sense eye movements to an accuracy of 1^{o}, its field of view at the eye must be quite small - of the order of one square inch. It turns out that the depth of focus of the Oculometer is also about one inch. Thus, the instantaneous field of view at the eye (eye space) is inherently limited to the order of one cubic inch.

In order to provide an effective eye space coverage of one cubic foot, a two-axis moving mirror system and a servo-controlled focusing lens are added to the basic Oculometer system. These opto-mechanical elements are controlled, automatically, by the minicomputer to keep the eye always centered within the instantaneous (cubic inch) eye space of the sensor, as the eye moves over the cubic foot of effective eye space. An auxiliary TV camera, with a wide-angle lens, is also located in front of the subject to provide the minicomputer with additional information for rapid acquisition of the eye and for automatic focusing of the Oculometer.

Installation

The angular range of the Oculometer is $\pm 30^{o}$ (x) and 0^{o} to $+30^{o}$ (y) relative to a line joining the eye to the Oculometer. This means that, for maximum angular coverage, the Oculometer should be placed at the bottom center of the fixation field. It may not always be convenient to locate the Oculometer sensor (with its TV camera, IR Source, moving lens and mirrors, etc) at this point - particularly when the fixation field is the crowded instrument panel of an aircraft simulator. For this reason the Indirect Remote Oculometer (Figure 2) has recently been developed. The path length from the eye to the sensor has been increased to 90 inches. With this system, it is necessary to locate only the moving mirror in front of the subject. The Oculometer sensor itself can be located behind or to the side of the subject, "seeing" the eye by reflection in the mirror. There is generally more room for the Oculometer sensor away from the fixation field and, of course, the sensor will not then obstruct the subject's view of the fixation field.

In future developments, the conventional (vidicon) TV camera in the Oculometer Sensor may be replaced by the much smaller CCD (solid-state) TV cameras that have recently become available. This will make it easier to install the Oculometer in confined areas, such as the cockpit of an aircraft. The CCD camera will also make it possible to integrate an Oculometer into a pilot's flight helmet, using the parabolic visor to reflect rays from the miniaturized Oculometer sensor onto the pilot's eye. A helmet mounted Oculometer would permit the eye direction of the pilot to be measured with unlimited angular and linear motion of the head.

Other Applications

The Remote Oculometer has been used to record driver eye fixations in an automobile. The output signals from the Oculometer were used to annotate a TV picture of the road, generated by a camera mounted just behind the driver. A video tape recording of this annotated driver's-eye-view of the road ahead allowed researchers to study how their test subjects performed the visual tasks involved in driving.

The Oculometer has also been used to study how people look at TV commercials. An Oculometer was set up near a TV set in a shopping mall and shoppers were invited to watch a series of 10 30-second commercials (Figure 3). The Oculometer determined which section of the TV screen the test subject was looking at, at each instant. In the course of a week the TV fixation data from 200 subjects was recorded for subsequent statistical analysis. As the data was being recorded, the advertising researchers were able to see an annotated version of the commercial being viewed by the test subject at that time (Figure 4). The annotation mark showed the subject's instantaneous point of fixation. In this way they were able to see, immediately, what features in the commercial people tended to concentrate on, and what features people tended to ignore - potentially important information for those trying to capture the viewer's fleeting attention and concentrate it on the product being advertised.

Eye-Control

The ability of the Oculometer to measure a subject's eye direction, without interfering with the subject, offers the interesting possibility of using the eye for control, in place of the hands.

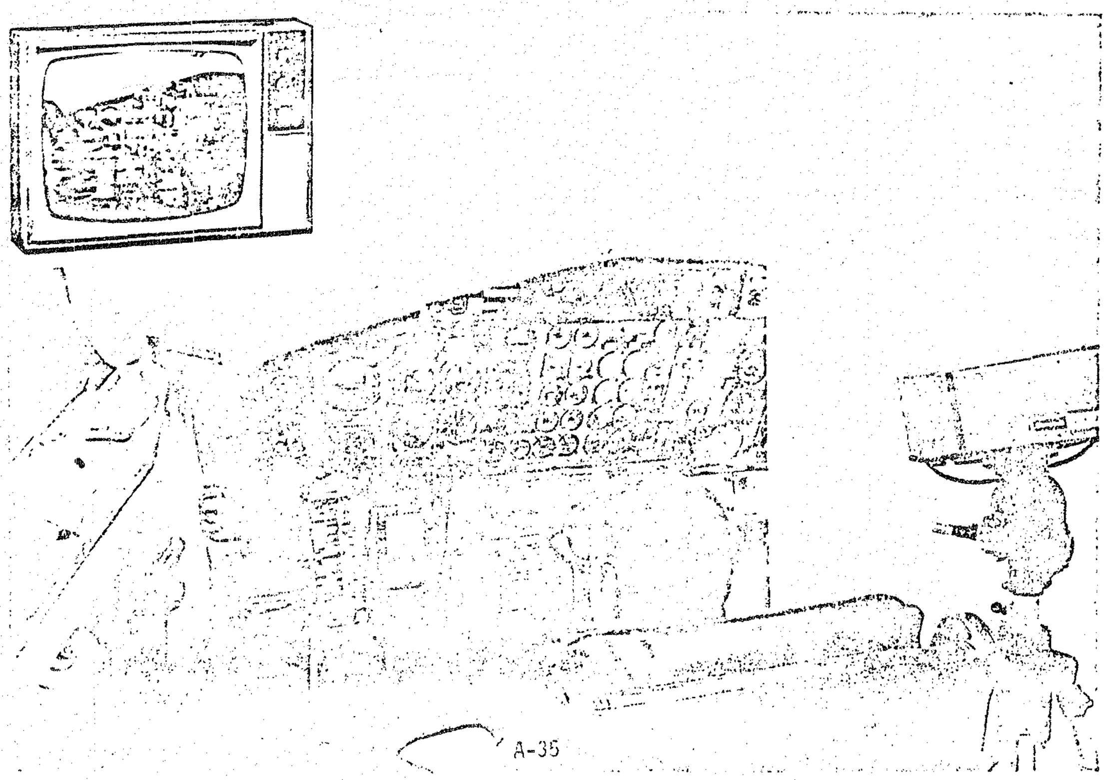
The angular direction of the eyeball is controlled by a sophisticated neuromuscular system. In addition to freeing the hands (for other tasks) eye-control might offer faster reaction than conventional manual control - particularly for aiming tasks in which the eye must be aimed, anyway, as part of the normal act of vision.

Conclusion

There are two basic aspects of human performance in any man/machine system - what sensory information is he receiving, what motor action is he generating? The motor (output) from the man is relatively easy to record. The Remote Oculometer - by unobtrusive measurement of eye direction - now provides a practical method for recording the visual interaction of the subject with his visual environment, thereby indicating the nature of the visual information that is he absorbing. In this way the Oculometer is contributing to research aimed at understanding, and improving, human performance.

THE HONEYWELL/INDIRECT REMOTE OCULOMETER

For Eye Fixation Measurement and Recording
with no Interference to Normal Subject Activity



INDIRECT REMOTE OCULOMETER
AUTOMATIC VERSION

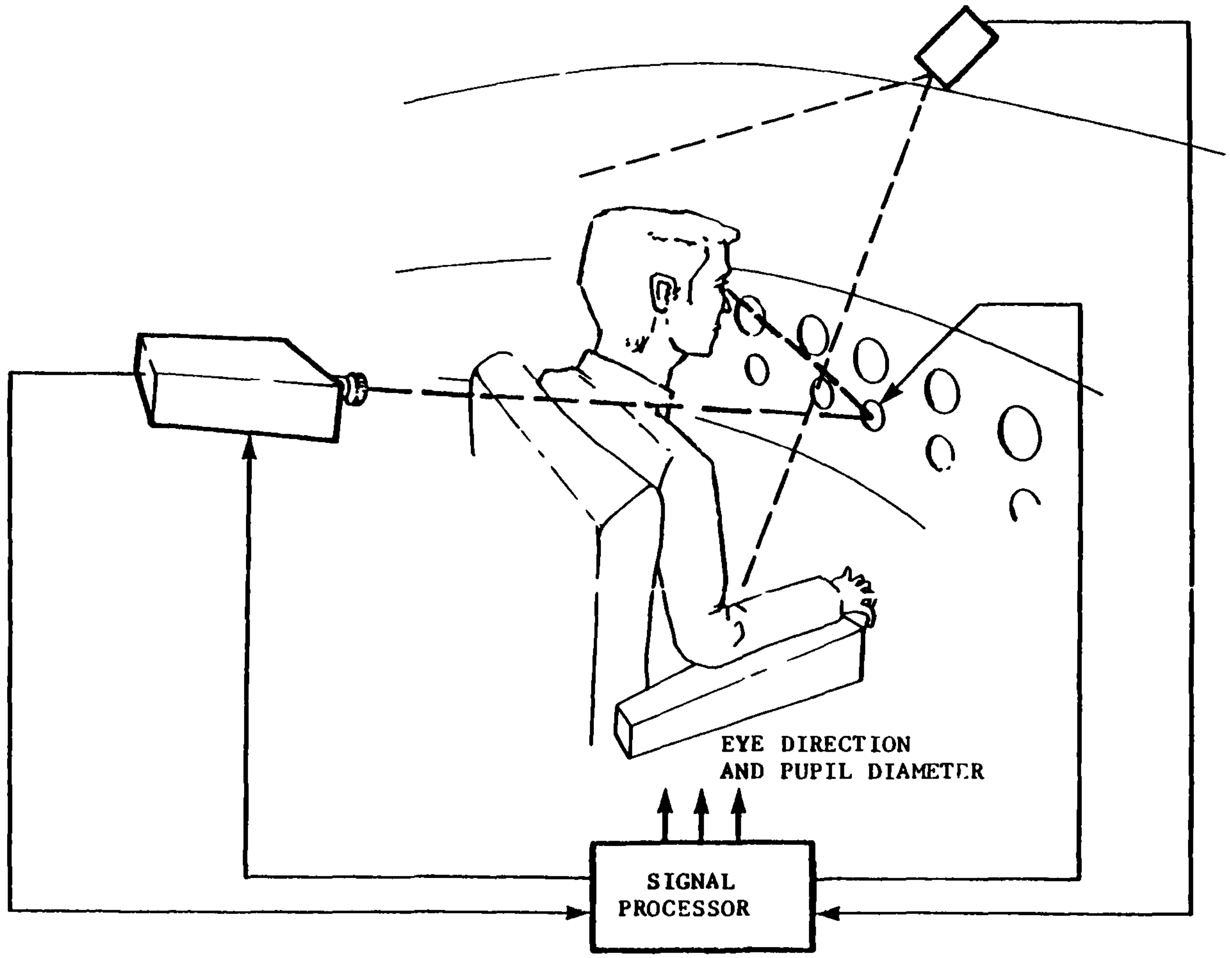


FIGURE 3 INDIRECT REMOTE OCULOMETER, AUTOMATIC VERSION (CONTINUOUS MEASUREMENT OF EYE DIRECTION WITH ONE CUBIC FOOT OF HEAD MOTION)

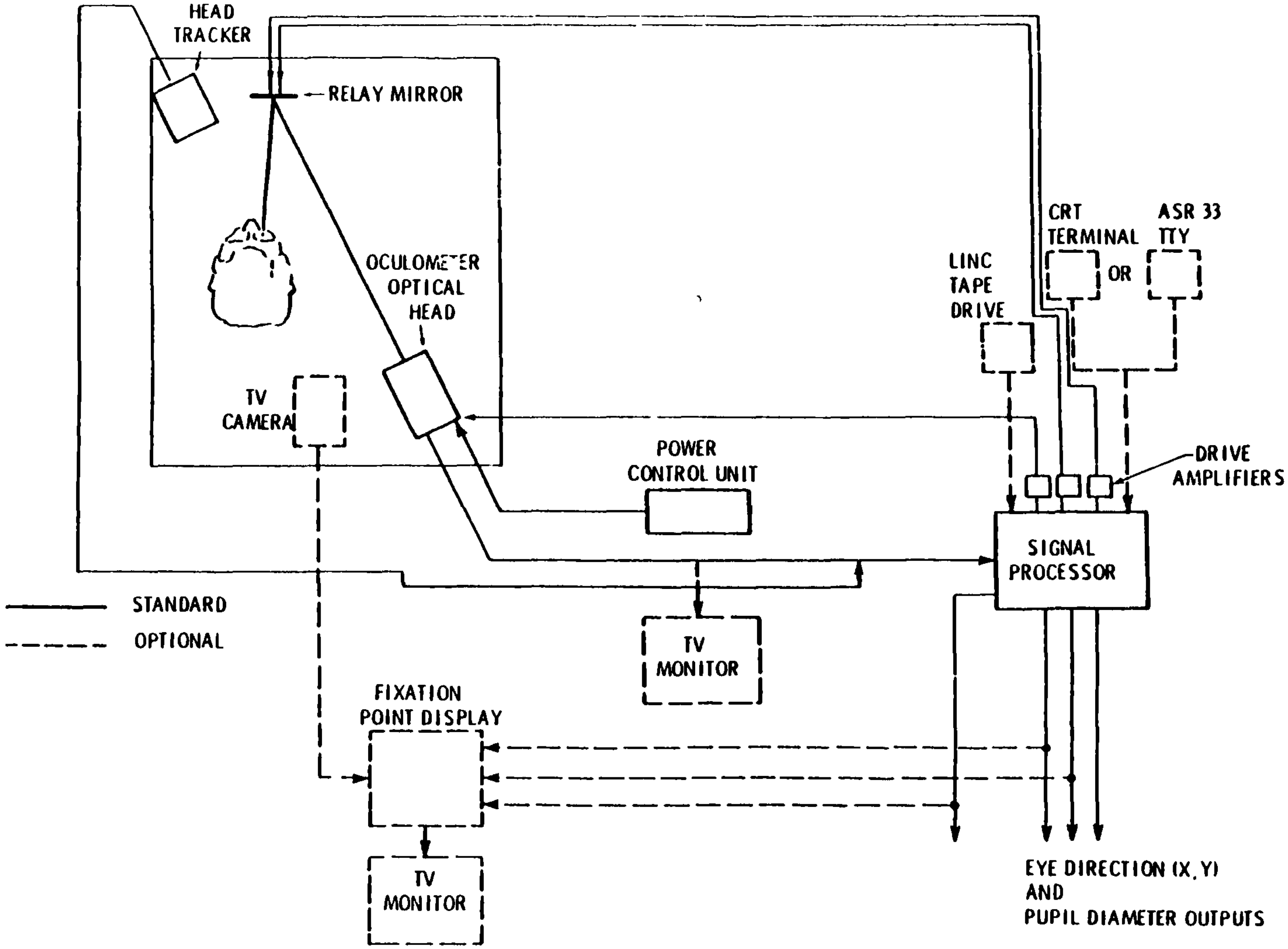


Figure 6 AUTOMATIC INDIRECT REMOTE OCULOMETER SYSTEM

SECTION 3

OCULOMETER SPECIFICATIONS

3.1 HONEYWELL STANDARD INDIRECT REMOTE OCULOMETER SPECIFICATIONS

SYSTEM RANGE (from eye to optical head): 90 ± 6 inches[1] (adjustable)

RMS NOISE LEVEL: 0.5 degree (measured with artificial eye)

SYSTEM TIME CONSTANT: 0.1 second

ANGULAR RANGE: (Horizontal) ±30 degrees[2]
(Vertical) : -10 to +30 degrees[2]

SYSTEM ACCURACY: within 1 degree[3]

OUTPUT SCALE FACTOR: adjustable 10 degrees/volt (nominal)

OUTPUTS: X eye direction, ±5 volts max
Y eye direction, ±5 volts max
Pupil diameter 0-10 volts (digital outputs also available)

EFFECTIVE AREA COVERAGE: one cubic foot[1]

ILLUMINATION: complete darkness to moderate office light (pupil diameter 3 mm or greater)

POWER REQUIREMENTS: 115 volts, 60 Hz; or 230 volts, 50 Hz

3.1.1 Dimensions and Weights

UNIT	SIZE (inches)	WEIGHT (lb)
OPTICAL HEAD	18-1/2 x 14-1/2 x 5-1/4	30
RELAY MIRROR[4]	4.1 x 3.7 x 3.1	--
POWER CONTROL UNIT	12 x 8-3/4 x 4-1/2	12
SIGNAL PROCESSOR[5] AND INTERFACE	10-3/4 x 19 x 24	52

CONNECTING CABLES AND OPERATING AND MAINTENANCE MANUAL PROVIDED.

NOTES:

1. The one-cubic-inch instantaneous field of view at the eye can be manually adjusted (prior to calibration) over an

area of one cubic foot at the eye by tilting the relay mirror and adjusting the focus control in the optical head. After calibration, the eye should remain within the one-cubic-inch instantaneous field of view at the eye.

2. Beyond 20-degrees horizontal or below 0-degree vertical, operation may be limited for some subjects due to tears or eyelash obscuration.

3. Over the range ±20 degrees (X) and 0-20 degrees (Y). Contact lenses cannot be used. Eyeglasses can be used under certain conditions.

4. Supplied with an adjustable mount. Smaller mirror size can be specified depending on range and angle of intended use. Special, transparent, relay mirrors can also be provided.

5. Standard 16-bit minicomputer. 8K mirror. General-purpose software (e.g., Fortran) available.

3.2 HONEYWELL AUTOMATIC INDIRECT REMOTE OCULOMETER SPECIFICATIONS

SYSTEM RANGE (from eye to optical head): 90 ± 6 inches[1]

RMS NOISE LEVEL: 0.5 degree (measured with artificial eye)

SYSTEM TIME CONSTANT: 0.1 second

ANGULAR RANGE: (Horizontal): ±30 degrees[2]
(Vertical) : -10 to +30 degrees[2]

SYSTEM ACCURACY: within 1 degree[3]

OUTPUT SCALE FACTOR: adjustable 10 degrees/volt (nominal)

OUTPUTS (three sets, selectable) (X,Y: ±5 volts max; P_D: 0-10 volts max).

- X,Y coordinates of the intercept of the fixation vector on any specified fixation plane, pupil diameter.
- Azimuth and elevation of the fixation vector, pupil diameter.
- Three direction cosines of the fixation vector relative to fixed axes.

Digital outputs also available.

EFFECTIVE AREA COVERAGE: one cubic foot[1]

AMBIENT ILLUMINATION: complete darkness to moderate office light (pupil diameter 3 mm or greater)

POWER REQUIREMENTS: 115 volts, 60 Hz; or 230 volts, 50 Hz.

3.2.1 Dimensions and Weights

UNIT	SIZE (inches)	WEIGHT (lb)
POWER CONTROL UNIT	12 x 8-3/4 x 4-1/2	12
OPTICAL HEAD	18-1/2 x 14-1/2 x 5-1/4	43 (approx)
RELAY MIRROR	See Note 4	--
SIGNAL PROCESSOR[5] AND INTERFACE	10-3/4 x 19 x 24	95
MOVING MIRROR AND LENS DRIVE AMPLIFIERS (3)	8-1/2 x 9 x 3-1/4 (each)	4.5 (each)
HEAD-TRACKER[6]	4-1/4 x 14 x 5-3/4	--

CONNECTING CABLES AND OPERATING AND MAINTENANCE MANUAL PROVIDED.

NOTES:

1. The instantaneous one-cubic-inch field of view at the eye automatically acquires and continuously tracks the designated eye of the subject over one cubic foot of space centered at the nominal eye position.

2. Beyond 20-degrees horizontal, or below 0-degree vertical, operation may be limited for some subjects due to tears or eyelash obscuration.

3. Over the range ±20 degrees (X) and 0-20 degrees (Y). Contact lenses cannot be used. Eyeglasses can be used under certain conditions.

4. In the Automatic Indirect Remote Oculometer, the direction of the relay mirror is controlled automatically in two dimensions by the signal processor. The moving (relay) mirror consists of two mirrors (approximately 2.5 inches x 2.5 inches) each mounted to a 2.6-inch x 1.75-inch x 1.25-inch actuator. These two moving mirror assemblies are supplied mounted to a baseplate. The mirror assemblies

can be removed from the baseplate for customer installation in front of the subject. Customer installation allows selection of an optimum location for the optical head and minimum obscuration of the fixation area by the moving mirror assemblies. [Special moving (relay) mirror systems can also be supplied. For example, a single, two-axis mirror (transparent in the visible) for minimum obscuration of the fixation field].

5. Standard 24-K 16-bit minicomputer. General-purpose software (e.g., Fortran) available.

6. The automatic head-tracker is a TV camera located in front of the subject. Positioning is not critical provided that the camera has a clear view of the subject's face and is at least 30 degrees, in bearing, away from the relay mirror. A small head marker is also supplied for fastest acquisition, but system will operate with no head marker. Ultra-small head-tracker (5-7/8 inches x 2-3/4 inches x 4-1/2 inches) also available.

SECTION 4

PARTIAL LIST OF OCULOMETER USERS

- Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio.
- National Aeronautics and Space Administration, Langley Research Center, Langley, VA.
- Rome Air Development Center, Rome, NY.
- Federal Aviation Administration, Atlantic City, NJ.
- Cunningham and Walsh Inc., New York, NY.
- Forschungs Institut Feur Antropotechnik, Meckenheim, W. Germany.
- Delft University of Technology, Delft, The Netherlands.
- Naval Air Station, Patuxent River, MD.
- Systems and Research Center, Honeywell, Inc., Minneapolis, MN.

Appendix E

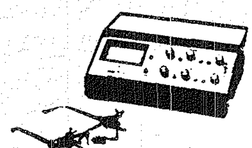
GULF AND WESTERN "EYE-TRAC" LITERATURE

This Page Intentionally Left Blank

A Broad and Flexible Range of Eye Movement and Pupillometry Instrumentation Systems.

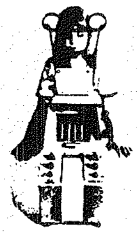
The Applied Science Laboratories Eye Movement Monitors serve an expanding need and a growing number of applications for precise instruments to measure eye movements and pupil diameter. Various types of devices are available which can serve many different requirements, depending on the application, the type of subject population, the experimental constraints, and the desired outputs. These range from simple laboratory instruments to complete eye movement recording laboratories and associated analysis support.

The following is a summary of the various instrument classes — refer to the detailed description and specifications for each model.



eye-trac

Model 200



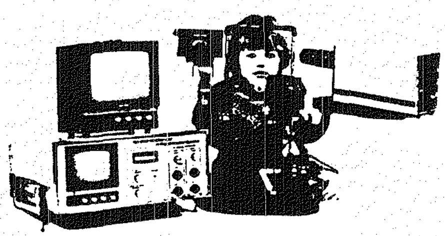
Model 106

Photoelectric Limbus Tracking Eye Movement Monitors

Instruments which detect the iris-sclera boundary on the eye and give a position indication based on its movement.

Model 106
A laboratory instrument, primarily intended for reading studies, which measures the horizontal or vertical eye positions of both eyes.

Model 200
A system consisting of photoelectric sensors mounted on spectacles. The system provides horizontal or vertical eye position information on both eyes.



Series 1900

Eye Movement Monitor Systems

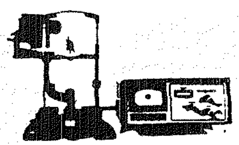
Sophisticated instruments which operate by viewing the eye with a television camera and processing the video information to obtain eye position independently of head motion.

Model 1992 Basic model. Subject's head is steadied by chin-headrest assembly.

Model 1994 Remote model allowing the camera and other apparatus to be removed from the subject by two or three feet.

Model 1996 Computer based remote system allowing automatic calibration, greater head motion, increased eye motion, and improved tracking of eye position under various conditions.

Model 1998 Adds a head tracking mirror capability to the Model 1996 system allowing even greater freedom of head movement.



Series 1000

TV Pupillometer Systems

A reliable, simple-to-use instrument for accurate, real-time measurement and display of pupil diameter. The pupil is continuously monitored, and pupil diameter is shown directly on a panel meter and also provided in digital and analog forms. Measurement is independent of eye movement and other variation over a large field of view.

APPLICATIONS

The study of eyes is as old as Archimedes and continues to be extremely exciting, provoking much study and research. Since the human brain is not open to simple exploration, the eyes are useful as permanent probes providing clues to some very complicated psychophysiological processes.

Eye movement and pupillometry studies have been a vital tool in various research, clinical, and commercial applications. The Applied Science Laboratories Eye Movement Monitors provide a convenient means for quantitative analysis of eye movement, especially where this information must be directly related to the point of gaze of the subject. The output is suitable for computer processing eliminating the need for tedious measurement of photographs or videotape frame by frame.

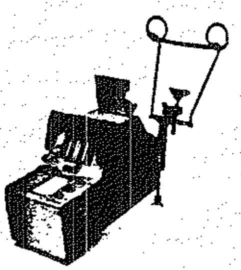
Research applications include studies of vision, perception, television viewing, reading, image scanning, simulator training, problem solving, work load and stress. Children and infants may also be tested with the Eye View Monitors. Eye motion dynamics, pursuit, nystagmus, and saccades may be studied.

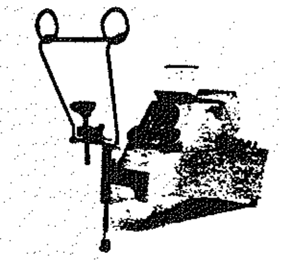
Many diseases, such as schizophrenia, apparently affect scanning patterns, and eye movements as well as pupillometry, are increasingly used as tools in the study of this and various other neurological disorders.

Commercial applications include human factors design of control panels or other equipment and preparation of advertisements and presentation materials. Measurement of eye position and pupil diameter can indicate the amount of interest the subject shows in a particular picture, what he is fixating and for how long, etc.

Changes in pupil diameter, which indicate psychological activities, may be recorded along with eye position to correlate such a psychological response with exactly what the subject is viewing. Pupil diameter appears to be a more sensitive, reliable, and practical measure than traditional parameters such as galvanic skin response or heart rate.

Eye Movement Monitoring System





Its simple non-contacting photoelectric operation means:
- **No film to develop**
- **No electrodes to paste on the subject**
- **Use on subjects with or without glasses**

In a matter of minutes you can obtain objective, quantified and permanent recordings of the key elements of binocular visual function and performance. Your aide or paramedical technician can run the test for your subsequent examination and diagnosis.

The Eye-Trac, Model 106 is used most widely in reading diagnosis and evaluation of visual perceptual development.

How well does Johnny read?

What reading speed — with what mprehension?

At what grade level — how efficiently?

Does he have dynamic binocular coordination?

What type of remediation is needed?

All this in a three to five minute test. And the permanent recordings provide objective data for evaluation of remedial progress.

Additional and more sophisticated measurements can be made with Model 106 Stimulator Attachments:

Dynamic Visual Acuity	Tropias
Coarse and Fine Fusion	Smooth Tracking
Saccadic Fixations	Near-Far Fixations
Pursuit Movements	Color Perception
Binocular Fixation Ability	Phorias

And the effects of surgery, lens prescription, medication, drugs, alcohol, fatigue, etc., on these functions.

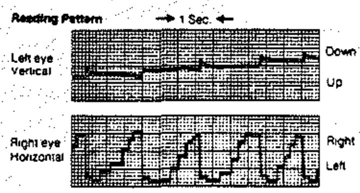
The Eye-Trac Model 106 uses a filtered, incandescent light source and non-contacting photodiode receptors for tracking eye movements, the results of which are instantaneously recorded on a built-in, two-channel heat writing recorder.

External outputs are provided for computerized data acquisition systems.

The Standard Model 106 provides for measurement of horizontal eye movement of both eyes. As an optional extra, it can be supplied in a configuration permitting measurement of horizontal or vertical movement of each eye.

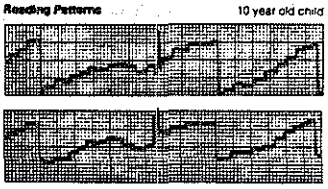
In normal operation no regular maintenance is required except for replenishment of recording paper.

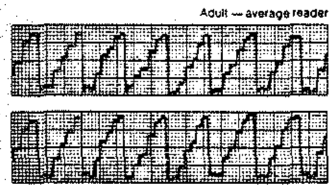
The Eye-Trac will resolve horizontal eye movements to better than one-half of a degree. Vertical movement resolution is in the order of one degree.

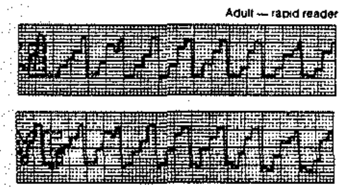


READING PATTERNS

An illuminated easel designed to hold reading cards or similar test material is supplied as part of the basic Eye-Trac. From a reading pattern recording one can determine reading rate, number and duration of both fixations and regressions, and many other aspects of oculomotor performance. A set of 64 reading selections (grade 1 through college), along with associative normative data, are available for use with the Eye-Trac.

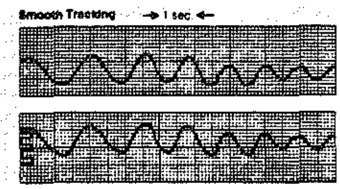






SMOOTH TRACKING

Using the Acuity Stimulator and a suitable rget one can induce and record tracking vements. The speed of the stimulator is variable, and it can be operated in either the vertical or horizontal mode, to stimulate either type of tracking movements.



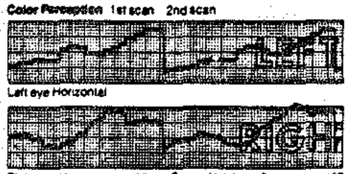
OTHER MEASUREMENTS

The Eye-Trac may also be used for many applications and measurements other than those previously noted. Various kinds of neurological, cognitive, and psychological performance may be evaluated through the use of eye movement recording. For example, the complexity and nature of the eye movement pattern produced in solving a graphical problem give significant insight into the logical steps involved. Similarly, the sequence of eye movements employed in viewing paintings, advertisements, or X-ray plates bears directly on the mental processes of the viewing individual. Eye movement measurements are, therefore, a most useful diagnostic in many areas including ophthalmology, neurology, psychology, optometry, vision research, human engineering, and reading diagnostics and enhancement.

COLOR PERCEPTION

By recording the eye movements of a patient who is visually tracing the standard Ishihara serpentine patterns, one can note the presence or absence of a characteristic eye movement signature. An objective record of the patient's color perception is thus obtained.

Color Perception 1st scan 2nd scan



Left eye Horizontal

Right eye Vertical Visual Scan of Ishihara Serpentine #37

OPTIONS

1. Nystagmus Drum:
   For inducing and recording optokinetic nystagmus.
2. Reading Analysis Package:
   Documentation, charts and tables for testing and analysis.
3. Automatic Digital Fixation and Regression Counter:
   Provides automatic digital presentation of reading speed, number of fixations and number of regressions for use in conjunction with reading analysis.
4. Vertical Eye Movement Measurement:
   Capability for vertical as well as horizontal eye movement recording.
5. Electrical Analog Outputs:
   For connection to external instruments or computer systems.
6. External Inputs to Stripchart Recorder:
   For recording stimulus data along with eye position data.
7. Dynamic Visual Acuity Tester:
   Oscillating grids of varying spatial frequency used to induce a tracking response.
8. Vergence Tester:
   Motorized target to induce vergence motion.
9. Variable Rate Fixation Stimulator:
   Panel of LED's which flash at a controlled rate to induce fixations.

SPECIFICATIONS

Power		105-125 VAC @ 60 Hz, 1 amp (210-250 VAC @ 50 Hz avail)	
Weight		25 pounds	
Maximum Dimensions		31" L x 23" h x 11" w	
Headrest		Fully adjustable with both gross and fine elevation adjustments, chin cup tilt adjustment, and built-in lateral head supports	
Eye Illumination		IR-filtered incandescent lamps 15 cp, GE 94 IF	
Photo sensors		Silicon photocells	
Electronics		Solid-state, plug-in printed circuit boards	
Recorder		Response — 40Hz Paper speed — 10mm/sec Medium — heat-sensitive paper 2.5 inches wide, 100 foot roll	
Output signal		Typical range — ± 3.0 V Typical scale — 300 mv/degree Output impedance — 1000 ohms	
Resolution		Horizontal	Vertical*
		½°	1°
Range from Center	linear	±10°	±10°
	usable	±20°	±15°
Response		40 Hz/sec. or 30 ms with recorder, 1000 Hz/sec. or 2 ms without recorder (electrical output signal)	
Artifacts		Blinks, head movements, ambient light variation	

*Applies to units with vertical modification

Research Eye Movement Monitor

- **Measures Horizontal or Vertical Eye Movements— simultaneously monitors both eyes.**
- **High Sensitivity, Accuracy, Resolution— minutes of arc possible — millisecond response.**
- **Analog and Digital Outputs Available— compatible with most display and recording devices and computerized data systems.**
- **Non-Contacting Photoelectric Technique— does not require electrodes or attachment to the eye.**

APPLICATIONS

The Eye-Trac Model 200 has many useful research applications for example measuring the eye movement pattern of a pilot flying under IFR conditions in evaluation of an aircraft instrument panel design Other uses include

Scan Patterns
Drug Effects
Fatigue
Psycholinguistics
Human Factors Engineering
Dominance
Advertising Consumer Reaction
Vigilance Testing
Anxiety
Fixation & Gaze Avoidance
Perception
Tracking
Others

DESCRIPTION

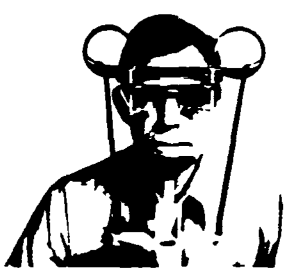
The Eye-Trac Model 200 Research Eye Movement Monitor measures both horizontal and vertical eye movements by employing a non-contacting photoelectric technique The outputs produced are simultaneous analog voltages (digital optional) which are direct functions of the position and movement of each eye

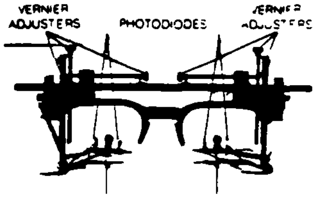
The instrument consists of a sensing assembly and an associated electronics control package connected by an eight foot flexible cable

The monitor does not require attachments to the eye or skin nor does it significantly interfere with the subject's head movements or vision Low level invisible modulated infrared eye illumination and synchronous detection of the reflected signal minimize both subject distraction and ambient illumination artifacts

The Model 200 measures direction of gaze horizontally by utilizing the differential reflectivity of the iris and the sclera It measures horizontal position of the eyes over a range of approximately ±20° with a resolution of better than one quarter of a degree The resolution can be improved to a few minutes of arc with a rigid head mounting fixture (bite board or good head and chin rest) Vertical eye movement recording is accomplished by monitoring either upper or lower eyelid movement In this case the difference in reflectivity between the lid and sclera is employed to make the measurement Vertical range is +10° (up) and −20° (down) with a resolution of approximately 1°

Crosstalk between horizontal and vertical





measurements can normally be kept under 10% by careful alignment and set-up of photosensors Additional electronic crosstalk reduction is provided for and is adjustable by front panel controls The time constant of the instrument is approximately four milliseconds Front panel filter switches allow the response time to be increased to 26 milliseconds in order to minimize 60 or 120 Hz interference

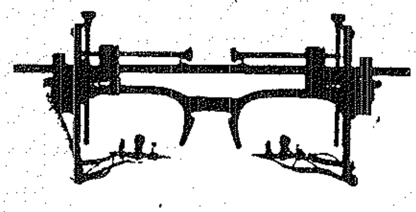
A front panel selector switch allows the output signal from either channel to be presented on the monitoring meter The analog signals from both channels are simultaneously available at rear panel binding posts and front panel jacks These signals are suitable for direct interfacing to most recorders oscilloscopes magnetic tapes and other common recording / display devices The optional digital outputs (both channels available simultaneously) appear on a rear mounted connector The analog and digital signals produced by the Model 200 are compatible with almost all recording and data acquisition systems

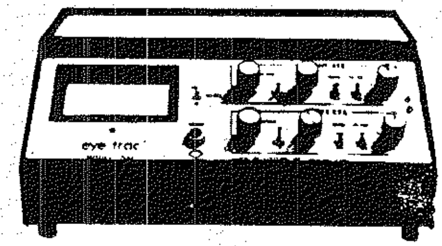
All Model 200 sensor assemblies are now supplied in the Clip-on configuration and may be used by subjects with or without corrective spectacles In addition three-way vernier adjustment of each sensor assembly facilitates alignment and calibration procedures

The Model 200 requires only modest set-up and calibration Preparation consists of placing the spectacle assembly on the subject adjusting the position of the photoelectric sensors and setting the front panel operating controls

SCAN PATTERN ON X-Y PLOTTER

The Model 200 can be utilized to superimpose a subject s eye movement pattern directly on the viewed material This is accomplished by placing a copy of the material in the bed of an X-Y recorder and connecting the Model 200 horizontal and vertical output signals to the respective horizontal and vertical inputs of the plotter The result of this procedure is an immediately available hard copy of the subject s scan pattern superimposed on the viewed scene



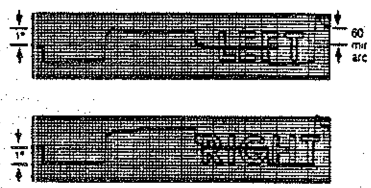


OUTLINE TRACING

A subject's eye movements may be recorded as he visually traces the outline of geometric figures (after Yarbus). This recording was made by the Model 200 Eye Movement Monitor and an X-Y Plotter set-up as described above.

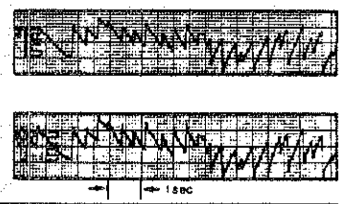
MINIATURE EYE MOVEMENTS

The Model 200 is capable of reliably measuring changes in horizontal eye position as small as a few minutes of arc. Such measurements do require effective restraint of the subject's head to prevent movement artifacts. The recording shown of a 1° eye movement was made with the subject's head restrained in a Model 115 Head Rest. This particular device utilized a chin cup rather than the traditional bite plate. The Model 115 head restraint system is much more comfortable than a bite plate and yet fixes the head quite reliably. Furthermore, it does not require the elaborate and unsanitary dental wax impressions necessary with a bite plate.



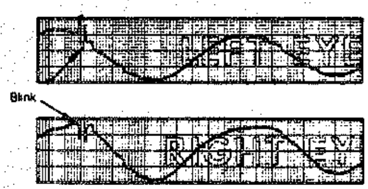
NYSTAGMUS

Oscillatory eye movements of both spontaneous and induced types are readily and accurately recorded with the Model 200 Eye Movement Monitor. Nystagmus recordings are most useful in diagnosis of neurological problems (tumors, lesions, etc.), vestibular studies, motion and position effects, inner ear malfunctions (Meniere's Syndrome, etc.), and drug and fatigue studies.



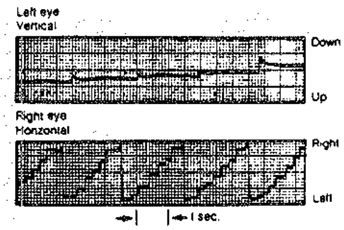
PURSUIT MOVEMENTS

A subject's ability to track a moving target is of significant interest to neurologists, psychologists, ophthalmologists, and human factors engineers. The Model 200 provides for a simple, straightforward and noise-free recording of tracking performance. Pursuit movements, like nystagmus, are most useful in neurological, oculomotor, vestibular, drug and fatigue studies.



READING PATTERNS

Eye movement patterns produced by reading activity have long been of interest to educators and psychologists. Such patterns are most useful for analysis and research on reading difficulties, learning disabilities, dominance, comprehension, perception and other aspects of psycholinguistics. The Model 200 produces reading eye movement recordings of truly superior quality. The figure illustrates one such recording in which the left eye is being monitored for vertical movement and the right for horizontal movement.

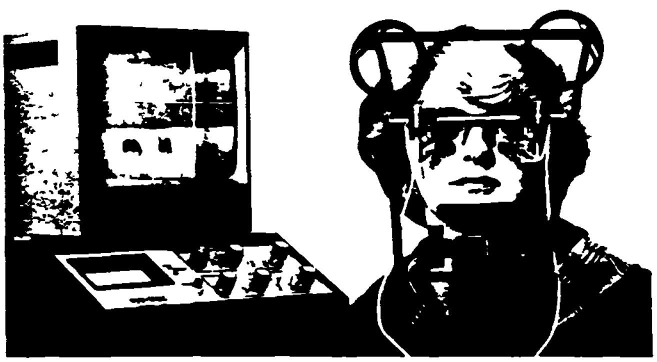


TYPICAL SPECIFICATIONS

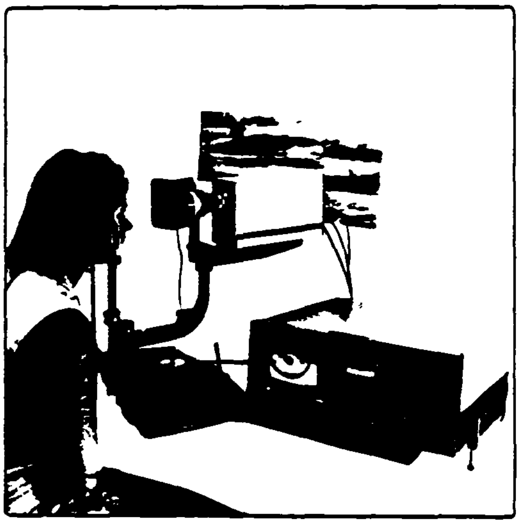
	HORIZONTAL	VERTICAL	REMARKS
Range (From Center)	±20°	+10° (up) −20° (down)	
Resolution	0.25°	1°	A few minutes of arc possible with rigid head restraint
Accuracy	1°	2°	
Response Time — With Filter	4 milliseconds 26 milliseconds		
Output Signals (Both Channels Simultaneously Available) Analog Digital (Optional)	 300 mv /degree 8 bit binary-DTL /TTL Compatible		Both outputs updated once each millisecond — busy-bit signal during updating
Instrument Drift	10 mv /hr		
Crosstalk	Adjustable to less than 10%		Controlled by sensor position and electronic controls
Power Requirements	105-125V AC 50-60 Hz		230-250V AC 50 Hz optional
Weight	8lbs		
Dimensions	12" wide × 10" deep × 4 5" high		
Artifacts	Blinks (readily distinguished) Squinting		
Accessories & Options (Consult Factory)	Digital Outputs, Optical Sensor Filters Head Restraint Systems (bite board and chin rests) and Recording-Display Systems		

VIDEO FIXATION POINT DISPLAY UNIT (Optional)

This device presents the subject s eye position in a very convenient visual display format It provides a cursor in the form of crosshairs or a spot superimposed over a television monitor image of the scene being viewed by the subject The meter on the Model 200 control panel indicates the position of one eye at a time in a form not directly related to the scene When the Video Fixation Point (VFP) unit is added a dramatic Point of Gaze display is also produced This feature can be used to determine the accuracy of the Model 200 system at various points in the scene and greatly simplifies calibration of the device In addition the VFP display allows video recording of eye movement data as well as the standard analog and digital recording formats Also provided is a linearizing circuit which may be used to make the gains symmetrical about the vertical and horizontal centers This is in addition to the cross-talk correction on the front panel of the control unit



TV Pupillometer System



- **Simplicity of Operation**
- **Adaptable for Lab Animals**
- **High Degree of Subject Comfort**
- **Pupil Delimeters and Other Indicators to the Operator**
- **Unique Pupil Recognition Circuitry**

APPLICATIONS

Measurement of changes in pupil diameter has become an extremely powerful tool for studying human response to various conditions and stimuli It has been widely used in clinical research psychological experiments drug studies ophthalmology physiology, and neuro-sciences

Pupil diameter is an indicator of at least three stimuli retinal light intensity, accommodation and psychological state It has been used in studies relating to all three but it offers a unique psychological indicator which is completely uneffected by conscious or subjective considerations It is more reliable and practical than traditional techniques such as measurement of galvanic skin response or heart rate Specific applications have been in drug treatment of hyperactive children measurement of drug efficacy, various aspects of learning, determination of vigilance and work load studies under stress and fatigue

DESCRIPTION

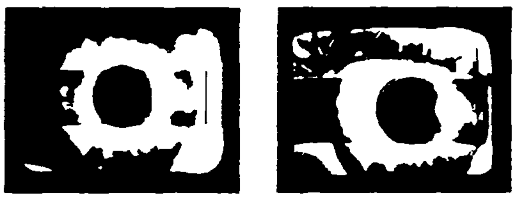
The TV PUPILLOMETER is a reliable simple-to-use instrument for accurate real-time measurement and display of the absolute diameter of the pupil The pupil is continuously monitored and pupil diameter is shown directly on a panel meter and also provided in digital and analog forms Measurement is independent of eye movement and other variations over a large field of view

The TV PUPILLOMETER utilizes a closed circuit low light level silicon matrix tube television system to observe the eye and a special Pupil Recognition Circuit to automatically acquire the pupil from the iris the eyelids and other noise with minimum operator adjustment A TV monitor displays the image of the eye with superimposed Pupil Delimiters to clearly indicate the accuracy of the measurement The automatic circuitry will maintain proper measurement for a large range of settings and conditions

A bibliography of Pupillometry Research is available from ASL

SYSTEM OUTPUTS

On all models pupil diameter is presented as a direct readout on the analog panel meter with a scale of 0 to 10 mm The model 1071 and 1081 chart recorder versions also record pupil diameter on single and dual pen stripchart recorders The chart recorder models can be adjusted by the operator to display either the full 0 to 10 mm range or an expanded sub-interval of the measurement range An external pupil diameter output signal scaled at 1V/mm diameter and a digital output signal are furnished on all models An optional 3 character digital video display superimposed on the TV monitor is also available



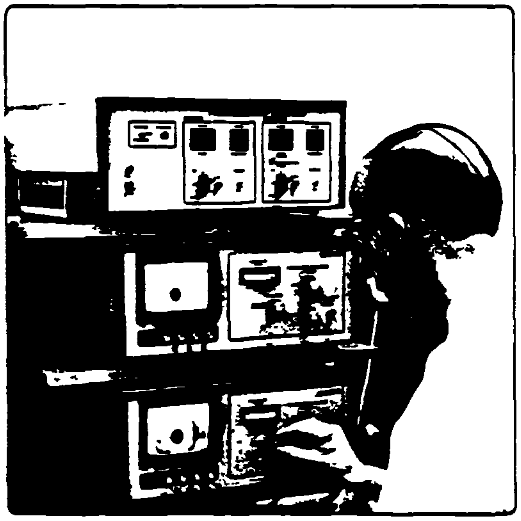
WITHOUT NOISE WITH NOISE

PUPIL RECOGNITION CIRCUIT ACQUIRES PUPIL IN PRESENCE OF ARTIFACTS AND NOISE

OPERATION

The subject places his head in a chin rest or in a dentist type headrest and has an unobstructed view of the scene being presented

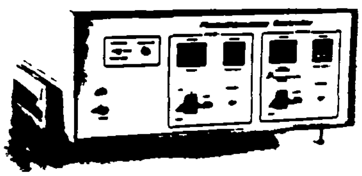
The operator obtains a picture of the subject s eye After setting the TV monitor for a clear image the operator adjusts the wide-range Discriminator control until a crescent appears at the left edge of the pupil and Delimiters appear in the monitor on top of and below the pupil As long as the Delimiters are properly positioned in spite of other noise and artifacts, the measurement is correct Pupil diameter in millimeters is displayed on a panel meter and provided as analog and digital signals



BINOCULAR TV PUPILLOMETER

The Binocular TV Pupillometer is composed of two mechanically electronically and optically integrated pupillometers which are capable of functioning together or independently The Binocular System can be used to simultaneously monitor pupil diameter of both eyes Binocular studies are particularly useful in detecting drug or neurological effects that show an imbalance in pupillary response of the two eyes When the Pupillometer system is coupled with a Binocular Photostimulator this type of imbalance may be "quantified "

MONOCULAR AND BINOCULAR STIMULATOR AND CONTROLLER



PHOTOSTIMULATOR AND CONTROLLER

The Series 1100 Photostimulator and Controller is a powerful laboratory and research device for experiments involving the placement of controlled and programmed pulses of stimulus light into one or both eyes of a subject The beams of light are controllable in exposure frequency pulse width focus beam diameter and intensity

One or both eyes may be stimulated and the controls for the two channels may be synchronized in any desired phase and temporal relationship in order to test binocular responses

There is an integrated aiming capability for placement of the beam into the pupil of the subject Focusing produces a parallel beam or allows beam focus on some other plane in or out of the eye e g a Maxwellian view

A general purpose filter holder is provided for the insertion of any desired filter This holder may be conveniently swung out of the way A neutral density wedge may also be used for continuous intensity control

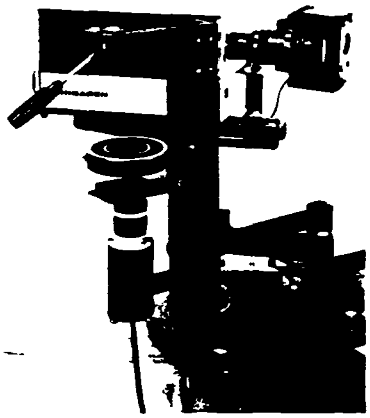
A virtual point source tungsten concentrated arc lamp is used with appropriate optics to provide the collimated beam of light

The Controller provides a very convenient way of programming the shutter exposure times for one or two channels The pulse width and the period may be controlled for each channel and the phase relationship between the two systems can also be determined This provides virtually any pulse profile that may be desired Continuous cyclic operation or single pulse actuation is possible The two channels may be locked phase or randomly related

The Photostimulator is suitable for studies of pupil diameter response to light stimuli under various subject conditions such as during drug administration

For pupillometry the Photostimulator is integrated with the Series 1000 TV Pupillometer

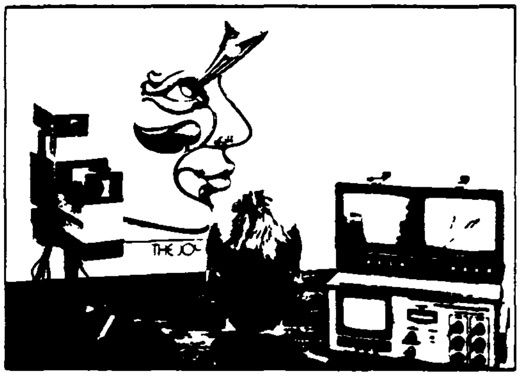
Consult ASL for further specifications



PHOTOSTIMULATOR ATTACHED TO TV PUPILLOMETER

Eye Movement Monitoring System

- **Unobtrusive Measurement**
- **Modular and Expandable System**
- **Computerized Processing and Control**
- **Accepts Wide Subject Population**
- **Rapid Subject Setup and Calibration**
- **Visual Video Analog and Digital Outputs**
- **Free Head Motion**



Series 1900 Eye View Monitors

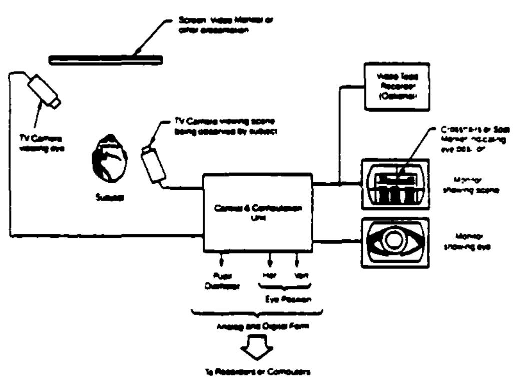
These instruments are advanced, television based eye movement monitoring devices They constitute complete systems for unobtrusive measurement of a subject s eye position and pupil diameter while allowing free head motion A number of convenient output formats allow easy correlation of pupil diameter with fixation point

Eye position pupil diameter and various other status indicators are provided in analog, digital and visual forms The visual output may be recorded on videotape showing both a digital display of pupil diameter (optional) and cross hairs to indicate fixation point The analog outputs are easily recorded on strip-chart recorders x-y recorders or storage oscilloscopes Digital outputs may be handled by the integral computer (Model 1996) or by an external digital computer digital tape recorders or any other digital devices

SYSTEM CONFIGURATION

As shown by the adjacent schematic a television camera views one eye of the subject which is illuminated by a near infrared invisible illuminator The resulting picture of the eye is displayed on a 5" TV monitor A second camera views the scene presented to the subject

The system uses a sensitive silicon matrix tube television camera which functions at very low illumination to view the eye The illuminator does not annoy or distract the subject In the Remote System (Models 1994 1996 and 1998) the illumination is coaxial with the camera and produces an image of a backlighted bright rather than dark pupil



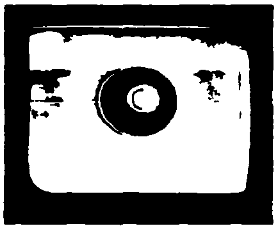
PRINCIPLE OF OPERATION

The subject s eye rotation (as opposed to translation resulting from head motion) and consequently his point of fixation is determined by the measurement of the center of the pupil with respect to the center of the corneal reflection The two features of the eye move together with head motion but move differentially with eye rotation hence the difference in their positions is indicative of the eye s point of fixation Eye position is therefore independent of head position as long as the pupil image is contained within the field of view of the camera This allows the system to tolerate small head motion talking, etc and to continue the measurement without the necessity of recalibration Without such a capability an eyeball translation of 0 1 mm resulting from head motion (or eyeball motion within the socket) would falsely indicate eye rotation of about 1°

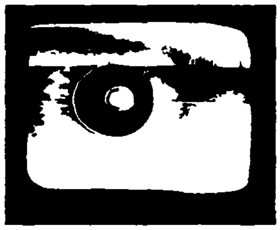
The position information is presented to the operator in the form of cross hairs or a spot superimposed on a 9" television monitor image of the scene being viewed by the subject The operator can control the position of the cross hairs on the monitor By asking the subject to fixate various points the computed eye position is calibrated manually or automatically and may then be recorded

SPECIAL RECOGNITION CIRCUITRY

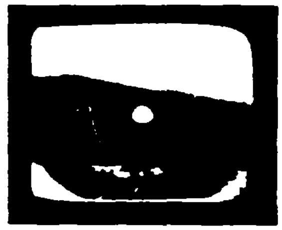
Special Recognition Circuitry (software) detects the pupil and the corneal reflection from the video signal The horizontal scan lines which intersect them are selected to the exclusion of scan lines which intersect the eyelids eyelashes or other noise The Recognition Circuitry allows operation for a broad range of subjects and under varying conditions with minimum operator adjustments It superimposes Delimiters and other indicators on the eye TV image to clearly show the operator that the system is functioning properly



ACCEPTABLE



ACCEPTABLE



UNACCEPTABLE

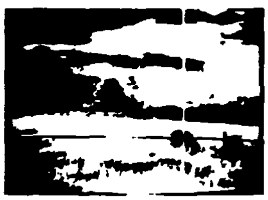
Operator indicators superimposed on TV image of eye as a function of threshold setting showing status of measurement Measurement is good when pupil is properly delimited.

OUTPUTS

The output is available in digital analog, and visual forms for recording on stripchart recorders x-y recorders storage oscilloscopes digital tape or directly into a digital computer This data can be processed at the time of the experiment or recorded for later analysis by computer Also provided is a monitor showing the scene being viewed by the subject with superimposed cross hairs indicating the subject s point of gaze in real time

This is available to the operator both for adjusting and calibrating the experiment and as an output suitable for study or videotape recording if desired A spot may also be displayed in place of the cross hairs as the point of gaze indicator

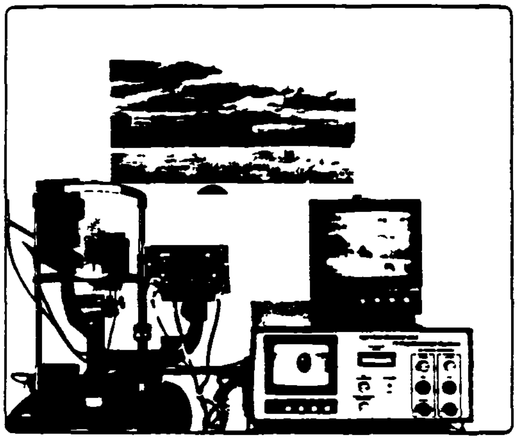
A scan pattern may be obtained by using an x-y recording over a picture of the scene being viewed



X-Y Recording of Eye Fixation as Subject Scans a Number of Diagonal Lines

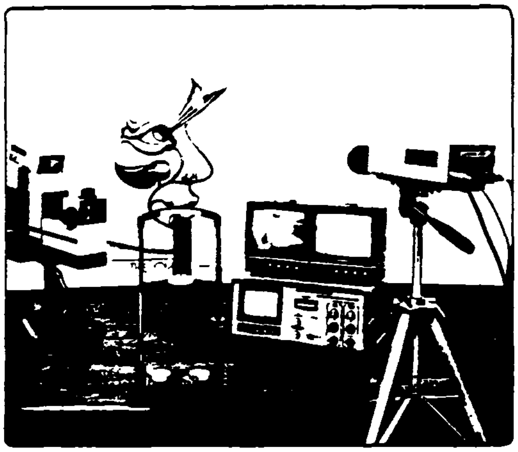
FIXED HEAD MEASUREMENT

Additional precision and accuracy can be obtained by using the Series 1900 Eye View Monitors in the fixed head mode If head motion freedom is not required and a suitable restraining device such as a bite plate is used performance improves dramatically Noise is reduced and precision and accuracy increase by a factor of three or four



Model 1992 Basic Eye View Monitor

The subject steadies his head with a chin rest and views the scene presented him A special low-light-level television camera with silicon matrix vidicon, views one eye as it is illuminated by an invisible infrared illuminator Special circuitry extracts the centers of the pupil and corneal reflection, then computes and displays eye position



Model 1994 Remote Eye View Monitor System

The subject sits with his head in a headrest or chin rest The optical system is removed two feet or more from the subject's head and is out of his field of view He is physically and psychologically unencumbered, and is less aware of the fact that his eye motion is being monitored This allows the subject to talk, makes for a more natural experimental situation and results in more useful data

A coaxial illuminator is used to obtain a bright, rather than a dark pupil This allows use with a greater subject population and will generally work with eyeglasses and contact lenses The system allows somewhat more head motion and provides greater tolerance of eyelids and other artifacts than the Model 1992

DIGITAL TAPE RECORDER INTERFACE AND CONTROLLER

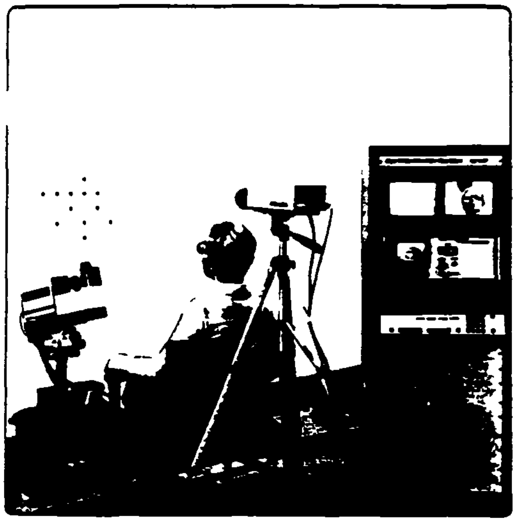
SERIES 1900 EYE VIEW MONITOR WITH OPTIONAL DIGITAL TAPE RECORDER AND CONTROLLER

Digital Tape Recorder for Models 1992 and 1994

The Tape recorder Interface and Controller provides the capability of calibrating the Eye View Monitor outputs and of controlling and recording experiment data and codes on a special or IBM compatible tape recorder

The system contains calibration displays, start and stop controls an abort control a subject number thumbwheel switch an experiment code a real-time clock a slide projector controller with a slide number counter and a reset switch for the clock and slide counter

Contact ASL for complete specifications



MODEL 1996 COMPUTER BASED EYE VIEW MONITOR

The Model 1996 Computer Based Eye View Monitor is an advanced powerful and flexible system for unobtrusive measurement of a subject s eye position and pupil diameter It allows ater subject physical and psychological freedom so that .re is reduced awareness of the testing situation

The subject sits in a high back chair and has considerable freedom of head motion his eye can be in a volume of space of 1 cubic inch (15 cm^3) or more This enables the device to handle a broad range of experiments

Distance from the instrument to the subject is large and the apparatus is therefore unobtrusive The optics are up to 3 feet (91 cm) or more away from the subject's eye and out of his field of view He is allowed to talk and this makes for a more natural experimental situation, resulting in more useful data

The Computer Based System is a great deal more powerful and flexible than the hardware systems because of the very high data handling capability Complicated eye geometries and non-linearities can be processed and the elements of the eye can be picked out from the eyelids eyelashes, noise and other artifacts Eyelid truncation of the pupil, eyeglasses and some contact lenses can be accepted A very broad range of subjects can therefore be accommodated with minimum operator intervention as experimental conditions vary

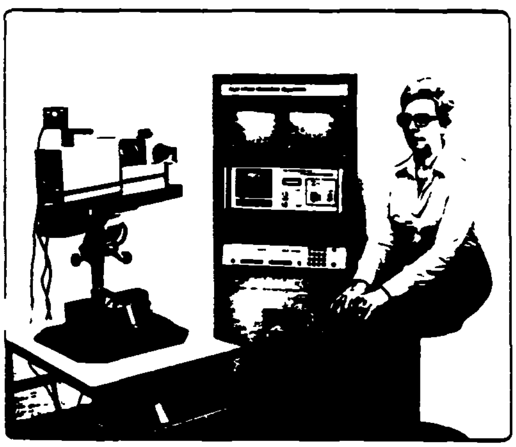
Automatic calibration on the the computer based system allows quick easy, and far more precise calibration of even difficult subjects such as infants, children, and research animals The subject is merely required to fixate a number of calibration points one at a time At each fixation the operator simply pushes a button At the completion of this step which takes only seconds the computer automatically determines the calibration and the experiment can begin

The system supplies a number of convenient outputs including visual analog, and digital eye position and pupil diameter and various other status indicators The visual output may be recorded on videotape, showing both a digital display of pupil diameter (*optional*), and cross hairs to indicate fixation point The analog outputs are easily recorded on the stripchart recorders, x-y recorders or storage oscilliscopes The digital outputs may be handled by the integral computer or by external digital devices

The user may choose to configure the 1996 System with additional input/output and/or storage devices so that data may be stored on tape or on disc in real-time, and then analyzed with the same processor after completion of the measurement The processor can also be used as a general purpose computer when not operating the Eye View Monitor

---

MODEL 1998 COMPUTER BASED SYSTEM WITH HEAD TRACKING MIRROR



In order to increase the subject head motion allowed with the Model 1996 Eye Monitor System a Head Tracking Mirror System in the x-y (lateral) plane may be incorporated For z axis(*camera to subject distance*)tracking see below

The mirror is controlled by a head motion detector and tracking system which is integrated with and receives its control signals from the Eye View Monitor and Processor The position of the head is determined and when it drifts from the center of the visual field of the camera, the mirror will reacquire the eye in most cases

The operator observes the subject s eye in the pupil monitor and in a wide angle view locating monitor He uses this second monitor display, which shows a portion of the subject s face to assist in setup positioning and in reacquisition if the eye becomes lost He accomplishes this positioning with a joystick

Acquisition of the eye is automatic as soon as a sufficient portion of it is visible to the Eye Camera

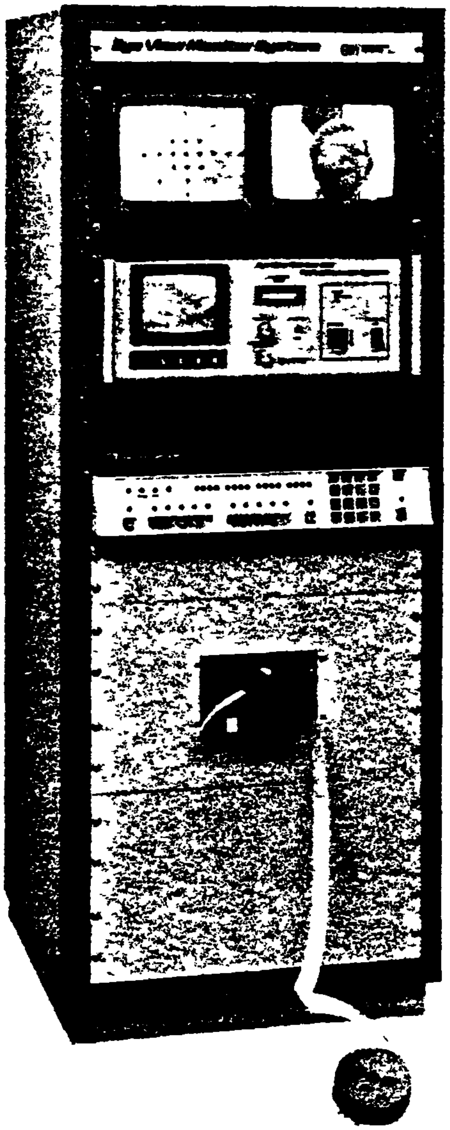
System tracking range is dependent on experimental conditions but up to a foot (30 cm) of head motion can be accommodated in the x-y plane

The Head Tracking Mirror is useful when there is a great deal of head motion in the x-y plane, but little z axis motion for instance, when the subject is seated in a high back chair Should head motion in the z-axis be needed remote manual or automatic focusing capability can be incorporated

Various placements and configurations of the mirror/camera system are possible depending on the physical arrangement of the experimental setup

ADVANTAGES OF COMPUTER BASED MODEL OVER HARDWARE SYSTEMS

The sophisticated Model 1996 offers features that make it superior to the hardware systems resulting in improved performance, more efficient use, higher data output rate, and lower operating cost.



- The Model 1996 accepts increased head motion, eliminates the need for a chin rest, and will work well with a subject seated in a high back chair This makes for increased subject freedom, less awareness of the instrument and produces more natural test results less influenced by the instrument.
- The Model 1996 allows for increased camera to subject distance, again causing less subject awareness
- The computer tolerates a larger number of complications Partially obscured and truncated pupils are generally accepted More noise, blemish, eyelid and lash interference is successfully handled Most eyeglasses and contact lenses are also accepted
- The Model 1996 incorporates automatic calibration in place of the manual calibration on the hardware models This results in a more precise calibration that does not tire or annoy the subject
- The operator of the instrument now has more time to attend to the study because he can pay less attention to the device
- There is reduced error resulting from head motion and non-linearities in the corners of the scene
- The eye movement camera may now be placed in any number of possible positions, one convenient position being below the stimulus
- Future updates can be added and incorporated into the system by merely reading in a program tape whenever new developments are available This is clearly much less disruptive than hardware changes
- The integral 1996 computer is a general purpose device which can do powerful off-line work for analysis of the data or for other computing functions
- The system may be expanded to incorporate a remote head tracking mirror for larger head motion and remote camera focusing for extended z-axis *(camera to subject distance)* range
- The computer system can be integrated with other outside devices for modifying displays, providing for interactive calibration, etc

COMPUTER SYSTEM DESCRIPTION FOR MODEL 1996

The computer for the Model 1996 was chosen for its high operating speed and powerful I/O capability in order to manage the very rigorous computation requirements It was also chosen for its power and flexibility as a general purpose computer which is suitable for handling data generated by the Eye View Monitor as well as for other laboratory applications

The Computer Automation, Model LSI 2/20 was selected It is configured in the standard system with 8K of core memory (up to 32K of memory may be supported), a high speed tape reader (a Teletype ASR-33 terminal is optional), an autoload ROM, a DMA I/O System, and power-up interrupt

The Computer Automation LSI 2/20 can support a floppy disc or IBM compatible magnetic tape The real time eye position data generated by the system can be stored on one of these devices for later off-line analysis

The LSI 2/20 can also be made to communicate with other laboratory computers and can handle interactive subject displays

---

SYSTEM SOFTWARE FOR THE MODEL 1996 EYE VIEW MONITOR

A. Eye Movement Related Software

There are four software packages to be considered

1 THE EYEPOS EYE POSITION MEASUREMENT SYSTEM
This is the real-time software that is the standard package included as part of Model 1996 It operates the Eye View Monitor and generates the various outputs It provides for all the calibration and computation programs and contains a number of service and diagnostic test routines needed for the operation of the instrument

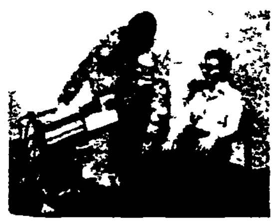
2 THE EYEDAT REAL-TIME EYE POSITION DATA RECORDING SYSTEM (Optional)
This software package is custom designed for the particular user to allow storage of eye position data on a mass storage device, such as floppy disk or magnetic tape In addition to eye position data, various identification codes, experimental variables, status indicators, etc may be entered Also recordable, are stimulus parameters, such as slide number or frame count The EYEDAT option requires the follwing hardware configuration in addition to the standard system
   1) Second 8K of memory
   2) Teleterminal, e g Teletype ASR33
   3) Floppy disk *or* magnetic tape subsystem

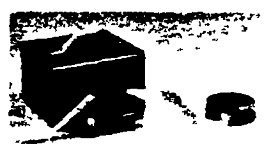
3 THE EYENAL OFF-LINE EYE MOVEMENT DATA ANALYSIS SYSTEM (Optional)
This software package is also custom designed for the individual user and involves reduction of the data to extract information required by the experimenter This may consist, for example, of determining fixation points, making scan pattern studies, computing duration of dwell on various areas of the scene, etc

4 THE EYETV TELEVISION STIMULUS PRESENTATION AND PROCESSING SYSTEM (Optional)
This is a specially configured hardware and software system for handling the presentation of television or real-life moving scenes, such as driving, and allows automated analysis as opposed to manual data reduction of the results Request Applied Science Laboratories literature

B. Standard Computer Automation System Software

Software packages which may be obtained for the Computer Automation LSI 2/20 computer include assembler, editor, a mathematical package, and other standard utilities and diagnostic programs The standard 8K memory will also support BASIC With additional mass storage devices, FORTRAN and an operating system can be supported





GENERAL SYSTEM DESCRIPTION AND CONFIGURATION — Series 1900

	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	•	•
[illegible]	[illegible]	[illegible]	•	•
[illegible]	[illegible]	•	•	•
[illegible]	[illegible]	•	[illegible]	•
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	•	[illegible]	•

* [illegible]

SYSTEM OUTPUTS Series 1900

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			
[illegible]			
[illegible]			

SPECIFICATIONS — Series 1000 TV Pupillometer

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]
±4 volts linearly related to horizontal eye position, gain and zero adjustable ±4 volts linearly related to vertical eye position, gain and zero adjustable Output impedance 75 ohms	*
8 bits TTL compatible representing horizontal eye position in offset binary 8 bits TTL compatible representing vertical eye position in offset binary Output drives up to 4 TTL loads Logical "1" > 2.5 volts Logical "0" < 0.5 volts	*
Cross hairs or spot on Scene Monitor	
Pupil measurement and display range: 2.0 to 10 mm (normal pupil diameter: 2.0 up to 6.5 mm) Analog output signal accuracy: better than 1% Meter accuracy: 2% of full scale. Frequency response: smoothing filter. Flat from 0 to 6Hz, may be switched out External analog signal output: 0 to 10 volt DC (1 volt optional) Scaling: 1.0 volt/mm of pupil diameter	*
9 bits TTL compatible representing pupil diameter in straight binary. (8 bits are sufficient for most applications.) Logical "1" > 2.5 volts Logical "0" < 0.5 volts Output drives up to 4 TTL loads	*
3 digits on Scene Monitor	*
Measurements of eye position and pupil diameter made 60 times/sec. They are averaged over latest 2 fields (1 frame) (33 msec) and the average is updated each field (every 17 msec). (Unaveraged output is available.) The measurements are output 60 times per second, i.e. each field.	Measurements of eye position and pupil diameter are made 60 times/sec. They are averaged over the latest 2 frames (67 msec) and the average is updated each field (every 17 msec). (Unaveraged output is available.) The measurements are output 60 times per second, i.e. each field.
Positive strobe and busy signal are output every 1/60th of a second for transferring data. Data is constant during strobe pulse and changing during busy signal. Strobe pulse is 1.2 microseconds. Busy is 0.5 to 0.8 milliseconds. Output drives up to 4 TTL loads	Strobe pulse is output each field for transferring data.
Indicators showing recognition or loss of pupil and corneal reflection, and status of measurement.	

* Same as item to the left

PERFORMANCE SPECIFICATIONS — Series 1900

	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Horizontal 30°; 40° or higher with reduced accuracy. Vertical 25°; 30° or higher with reduced accuracy. Eyelids may limit this range with some subjects	*	Horizontal 40° or more. Vertical 30° or more depending on Pupil Camera placement and eyelids	
[illegible]	Head in Chin Rest	Head in Chin Rest or Head Rest	1 or more square inches in x-y axes, 1 inch in z axis (Higher with reduced accuracy.)	Head tracking handled by mirror. Remote focusing capability available. Up to 1 cubic foot capability depending on configuration
[illegible]	Better than 1/2°		*	*
[illegible]	Worst case spatial error between true eye position and obtained measurement is 1°. Errors are lower if only a small central field, like a TV monitor is used. Error may increase to 2° in peripheral corners		Worst case spatial error between true eye position and obtained measurement is 1	*
[illegible]	5-6 inches (12.5 - 15 cm)	18-25 inches or more (46 - 63 cm)	18-36 inches or more depending on configuration. (46-91 cm)	
[illegible]	Eye level, left of subject (right possible)	*	Variable	
[illegible]	Some	Most	*	*
[illegible]	Some	*	*	*
[illegible]	None	Complete darkness to moderate illumination resulting in pupil diameter greater than 3.0 mm; diameters below 3 mm may result in marginal performance	*	*

* Same as item to the left

Specifications subject to change without notice

REFERENCES

Allen M J Vision and Highway Safety New York Chilton Book Company 1970 page 34

Angel R W and Garland H Transfer of Information From Manual to Oculomotor Control System *Journal of Experimental Psychology* 1972 96 (1) pages 92-96

Brickner C A The Analysis of Eye-Movement Recordings From Samples of Under-Achieving Secondary and Primary Students *AV Communication Review* 1970 18(4) pages 414-424

Elmstrong G What s New Eye-Trac® ' J of Am Optom Assn 1970 41(6) page 562

Fleming M Eye Movement Indices of Cognitive Behavior *AV Communication Review* (1969), 17(4) pages 383-398

Gibbon S Y et al Report of the Conference on Visual Information Processing Research and Technology U S Dept of HEW Nat Inst of Education Report CS-001770 1975

Metz H S Scott A B O'Meara D and Stewart H L "Ocular Saccades in Lateral Rectus Palsy *Arch Ophthal* October 1970 84 pages 453-460

Monty Richard A (ed) Eye Movement and Psychological Processes Erbaum Assoc 1976

Newman J S Eye-Movement Measurements *Medical Electronics and Data* May-June 1970 1(3) pages 82-84

Nodine C F and Lang N J Development of Visual Scanning Strategies for Differentiating Words *Development Psychology* 1971 5(2) pages 221-232

Noton D and Stark L Eye Movements and Visual Perception *Scientific American* 1971 224(6) pages 34-43

Reinecke Robert D Carroll John Beyer Charles K and Montross Richard An Innovation in Eye Care *The Sight-Saving Review*

Schmidt Stephanie A Study of Eye Movement Patterns in Children With a Specific Learning Disability *Journal of Optometric Vision Therapy*, March 1973

Senders J W Fisher D F Monty R A (eds) Eye Movement in the Higher Psychological Function,Erbaum Assoc Hillsdale N J 1979

Spache, George D Evaluation of Eye-Movement Photography in Reading Diagnosis and Reading Training, Research and Evaluation in College Reading The Ninth Yearbook of the National Reading Conference for College and Adults, Fort Worth Texas Christian University Press Reprint No 5 1960

Taylor Daniel M Is Congenital Esotropia Functionally Curable *Tr Amer Ophthal Soc* , 1972 Vol LXX

Taylor Earl A. Ed D The Spans. Perception Apprehension and Recognition as Related to Reading and Speed Reading, *American Journal of Ophthalmology* October 1957 Vol 44 No 4 Part 1

Troost B T Weber R B and Daroff R B Hemispheric Control of Eye Movements *Archives of Neurology*, 1972 27 pages 441-452

Waldstreicher Joel S *Educational Rehabilitation and* Visual Education — an Integrated Approach *The Optical Journal and Review of Optometry* May 1 1962

Winter J D Clinical Use of Direct Recording Oculographic Instruments ' paper presented at the American Academy of Optometry Miami Beach Fla Dec 12-15 1970

Young, L.R and Sheena D Survey of Eye Movement Recording Methods *Behavior Research Methods and Instrumentation* 1975

USER APPLICATIONS

Model 106 eye-trac

- Evaluation of reading and perceptual skills
- Determination of visual efficiency
- Study of binocular smooth tracking and saccadic fixation
- Measurement of nystagmus vergence and other oculomotor functions

Model 200 eye-trac

- Cognitive and learning behavior studies
- Neurological effect of certain drugs on the vestibular system
- Non-verbal communication research
- Fatigue and stress studies
- Human factors engineering
- High frequency eye position measurement

Series 1900 Eye View Monitors

- Visual search and scanning studies
- Detection of pursuit eye movement aberrations caused by certain mental disorders
- Infant development studies
- Research concerning the entertainment and educational quality of children s TV material
- Pilot and driver simulation experiments
- Study of learning disabilities
- Eye position measurements as a control or for correlation in pupillometry

Series 1000 TV Pupillometer

- Research in pupillary response of alcohol and drug users
- Mental work load experiments
- Study of betting and gambling strategies
- Schizophrenia research
- Binocular studies of neurological imbalance
- Pupillary latency measurements

BIO-METRIC EYE TRAC

EYE MOVEMENT MONITOR

Part No.	Description	Price
719-1060	EYE-TRAC, MODEL 106: Standard Model, 120 volts, 60Hz. Measures horizonal eye movements. Complete with integral two-channel heat writing recorder, removable illuminated easel, eye illumination dimmers and Operators Manual	$ 2,288.00
719-1061	EYE-TRAC, MODEL 106: 120 volts, 60Hz. Measures both horizontal and vertical eye movements, Complete with integral two-channel heat writing recorder, removable illuminated easel, eye illumination dimmers and Operators Manual	$ 2,690.00
719-1120	NYSTAGMUS DRUM, MODEL 112: Variable speed stimulator for including optokinetic nystagmus (OKN). Includes three targets of varying spatial frequency.	$ 350.00
719-1121	VERTICAL NYSTAGMUS DRUM ADAPTOR: Bracket for rotating Nystagmus Drum 90° for inducing and measuring vertical nystagmus	$ 65.00
719-1130	VISUAL ACUITY, MODEL 113: For measurement of dynamic visual acuity and evaluation of tracking performance, both monocularly and binocularly. Includes set of 10 target gratings ranging from 20/200 to 20/10.	$ 750.00
719-1240	VERGENCE STIMULATOR, MODEL 124: Stimulates convergence and divergence eye movements.	$ 550.00
719-1150	TABLE MOUNT HEAD RESTRAINT SYSTEM, MODEL 115:	$ 175.00
719-1300	BITE-BOARD ACCESSORY:	$ 80.00
719-0002	TEST SELECTIONS. Set of 64 reading selections, for grade levels 1 through adult prepared by Educational Development Laboratories. Printed on 3.5 x 5 inch cards. Comprehension questions on reverse side.	$ 70.00
719-0001	MAINENTANCE MANUAL, EYE-TRAC, MODEL 106:	$ 3.50
719-0003	RECORDING PAPER: 100 ft. specially printed roll	$ 6.00
719-0004	EYE-TRAC, MODEL 106 DUST COVER:	$ 9.25
719-0005	PORTABLE TRAVEL CASE, EYE TRAC, MODEL 106:	$ 120.75

GW Applied Science Laboratories

Part No.	Description	Price
719-0007	EYE MOVEMENT ANALYSIS RECORD SHEETS (50):	$ 1.15
719-0009	EXAMINER'S COPY, TEST SELECTIONS:	$ 2.90
719-0010	MANUAL, EYE MOVEMENT ANALYSIS WITH READING EYE II:	$ 11.50
719-1050	GRAPH ANALYZER:	$ 2.90
719-1330	STRABISMUS COVER TEST DEMONSTRATOR:	$ 520.00
719-2001	EYE-TRAC, MODEL 200-1: Research Model, 120 volts, 60Hz. Measures horizonatal and/or vertical eye movements. Simultaneously monitors both eyes. Analog Output, Meter Readout	$ 2,995.00
719-2002	EYE-TRAC, MODEL 200-2: Research Model, 120 volts 60Hz. Measures horizontal and/or vertical eye movements. Simultaneously monitors both eyes. Analog and Digital Outputs, Meter Readout	$ 3,395.00
719-2000	EYE-TRAC, MODEL 200 SPECTA-SENSORS™: Clip-on sensor assemblies, with vernier adjustments. This item is supplied with all EYE-TRAC, MODEL 200 Eye Movement Monitors as standard equipment.	$ 1,100.00
719-3000	FIXATION POINT DISPLAY UNIT, MODEL 200-V: Optional video unit for use with all MODEL 200 Systems to display X-hairs or spot, showing vertical and horizontal eye position over a TV Monitor image of the scene. System includes linearization, control circuitry, 9" TV Monitor and camera with standard lens. Output may be videotaped.	$ 1,950.00

F.O.B., WALTHAM, MASSACHUSETTS

PRICES AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

Applied Science Laboratories
A GULF + WESTERN MANUFACTURING COMPANY
335 Bear Hill Road Waltham, Mass.02154

335 BEAR HILL ROAD
WALTHAM, MASSACHUSETTS 02154
TELEPHONE: (617) 890-5100

PRICE LIST

	PRICE
MODEL. 19TR-9 EYE VIEW MONITOR AND PUPILLOMETER SYSTEM 9-TRACK DIGITAL TAPE RECORDER INTERFACE AND CONTROLLER	$3,400.00

Options

1.	Subject Number Indicator:	A 3-digit thumbwheel switch	440.00
2.	Experiment Code:	4 lighted push-button switches yielding 4-bit binary number	310.00
3.	Event or Slide Counter:	This is a counter to index the slide number being presented a subject. It contains 4 binary bits and this may be integrated with a slide projector system. See below.	390.00

4a. Kennedy Model 1600/360 FG 9-Track, 800 BPI, 0-500 steps/second with Fast Gap Option — 5,200.00

NOTE: An incremental tape recorder is rate limited, does not allow reading after writing or prevent errors or bad writing, and loses data during an inter-record gap. A buffered synchronous tape recorder eliminates these problems. (Item b.)

b. Kennedy Series 9000, 9-Track synchronous tape drive and buffered formatter system with read after write check. — 6,490.00

5. 1200-ft reel of 9-Track recording tape — 12.00

6. Intergrated Slide Projector system with proper compatibility and noise free operation
   - a. Single Slide Projector — 650.00
   - b. Double Slide Projector with Dissolve Unit — 1,290.00

7. Rear Projection Screen — 195.00

ALL TERMS, PRICES AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

F.O.B., WALTHAM, MASSACHUSETTS 02154

EVM-9
1/1/77
054

SERIES 1000 TV PUPILLOMETER SYSTEM

Item		Description	Price
1	Model 1050S	TV Pupillometer	$ 10,900.00
2	Model 1050SB	Binocular TV Pupillometer	$ 21,500.00
3	Model 1060SRP	Remote TV Pupillometer	$ 16,000.00
4	Model 1071SG	TV Pupillometer with single channel thermal writing chart recorder	$ 12,500.00
5	Model 1081SG	TV Pupillometer with dual channel thermal writing chart recorder	$ 12,900.00
6	Model 1071SP	TV Pupillometer with single pen potentiometric chart recorder	$ 12,000.00
7	Model 1081SBP	Binocular TV Pupillometer with dual pen potentiometric chart recorder	$ 23,500.00
8	EM1	Single Channel Event Marker	$ 175.00
9	EM2	Dual Channel Event Marker	$ 225.00
		Options	
10		Remote Measurement and Head Tracking	Consult Factory
11	RPS	Rear Projection Screen for presenting stimuli to subject	$ 225.00
12	ATV	Auxiliary External 9" Monitor for viewing the subjects eye	$ 495.00
13	TVP-DSP	Digital Output Calibration and Presentation Unit	$ 295.00
14		Digital Recording Equipment for Computer Processing	Consult Factory
15		Adjustable Subject Stool	$ 195.00
16		Photostimulator and Controller	
		PSC-1 Single Eye	$ 4,950.00
		PSC-2 Binocular	$ 7,950.00
17		Travelling Cases	$ 1,350.00
18		Video Tape Recorder	$ 1,200.00
19		Rack Mounting Adaptors for Control Unit	$ 75.00

FOB Waltham, Massachusetts

Prices and Specifications Subject to Change Without Notice

GW Applied Science Laboratories

7/17/78

SERIES 1900 EYE VIEW MONITOR and TV PUPILLOMETER SYSTEM

Item	Description	Price
1	Model 1992-S, Complete System	$ 18,900.00
2	Model 1994-S, Complete Remote System	$ 23,750.00

Both the above models include:

- Silicon Matrix Tube TV Camera for viewing the eye
- Control and Computation Unit with TV Monitor for eye image
- TV Camera for viewing scene being presented
- 9" Monitor showing scene with crosshairs indicating point of fixation
- Adjustable Camera Base
- All Cables, Accessories and Manuals
- Outputs - Digital and Analog
  - (a) Vertical Eye Position
  - (b) Horizontal Eye Position
  - (c) Pupil Diameter (in millimeters)

Options

Item		Description	Price
3	19TR-9 19TR-7	Digital Tape Data Acquisition Recording system with experiment designation and status words	See Separate List
4	Z	18-90mm Focal Length Zoom Lens for Scene Camera	$ 395.00
5	VTR	Video Tape Recorder	$ 1,200.00
6	RPS	Rear Projection Screen for presenting scene for other stimuli to subjects	$ 215.00
7	TCEVM	Travelling Cases	$ 1,490.00
8	ASC	Adjustable Subject Stool	$ 175.00
9	ATV	External 9" Monitor for viewing eye	$ 495.00
10	RM	Rack Mounting	$ 75.00

Description

*	Model 1996-S, Processor Based Eye View Monitor	$ 39,990.00
*	Model 1998-S, Processor Based Eye View Monitor with Head Tracking Mirror	Consult Factory

*For additional literature and information, write or call:

George S. Leonard, Products Manager
G+W Applied Science Laboratories
335 Bear Hill Road
Waltham, Massachusetts 02154
(617) 890-5100

F.O.B. Waltham, Massachusetts
Terms, prices and specifications subject to change without notice

G+W Applied Science Laboratories

6/1/78

Appendix F

INSTRUMENTATION MARKETING CORPORATION LITERATURE

This Page Intentionally Left Blank

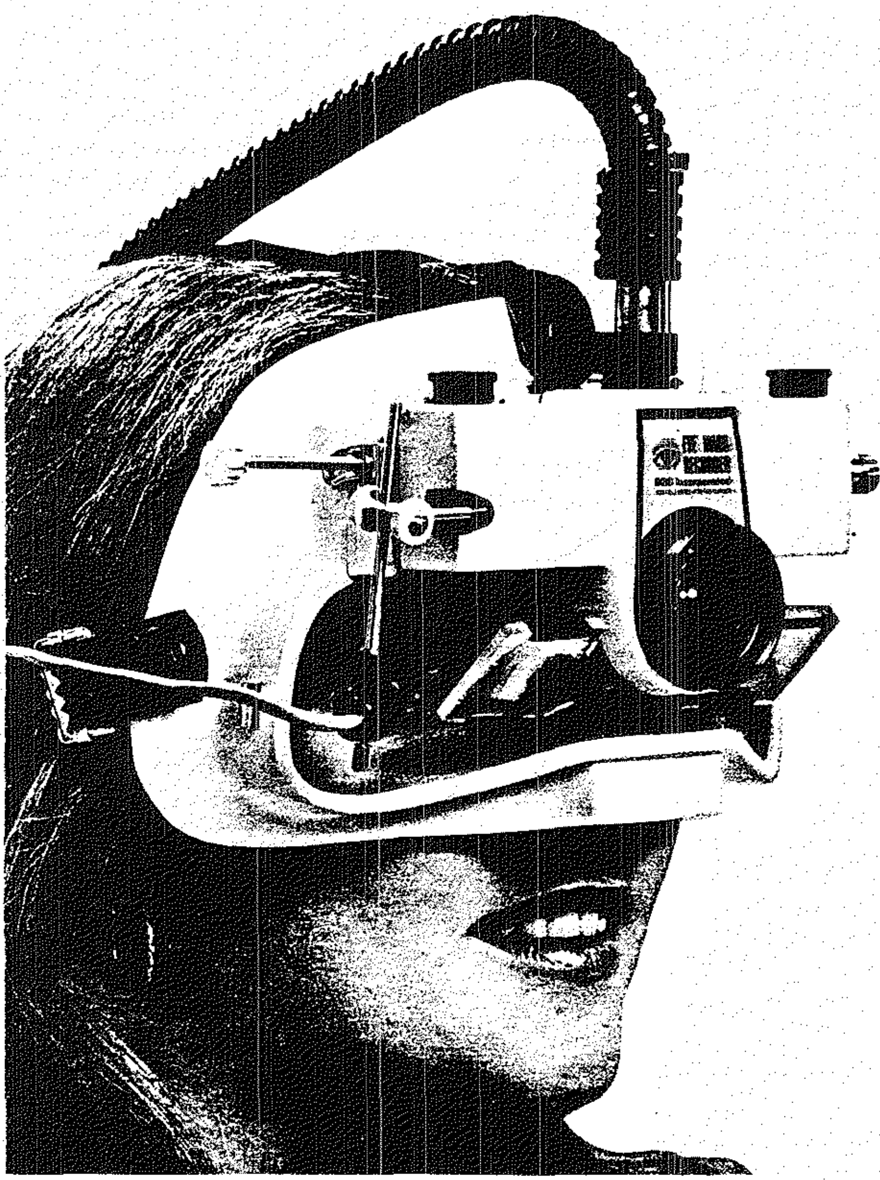
INSTRUMENTATION MARKETING CORP.
Exclusive Distributors
820 S. Mariposa St., Burbank, CA 91506/Phone 213-849-6251, Telex 67-3205

Spec/Data Sheet

January 1977

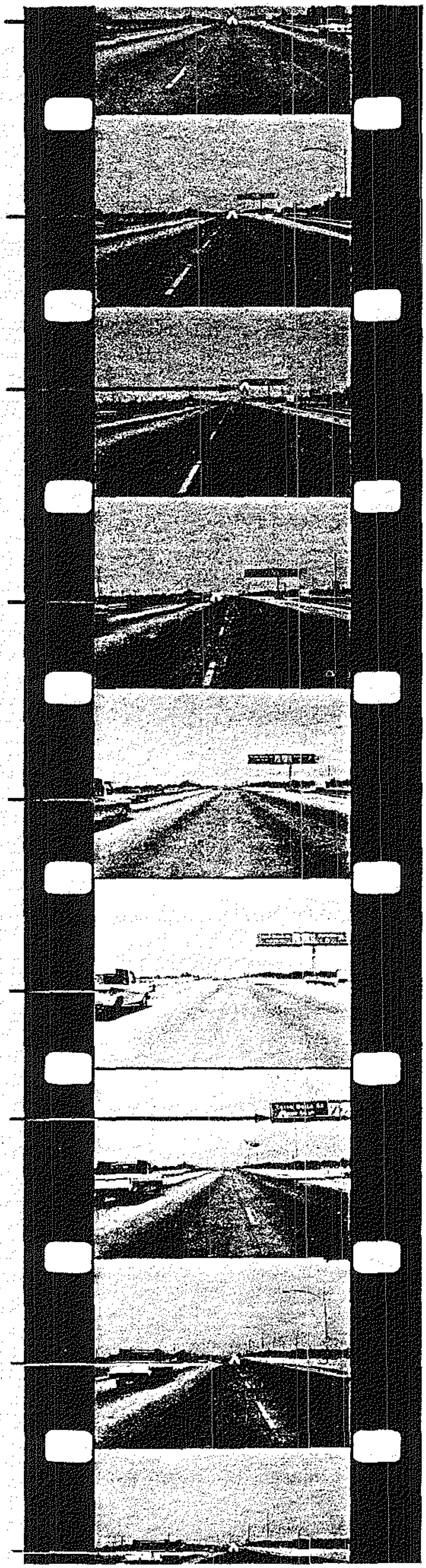
nac Eye Movement Recorder Model 4

The Eye-Mark Recorder simultaneously and continuously records the subject's discreet visual point of interest within his field of view. This is achieved by reflecting an illuminated spot off the eyeball cornea which is superimposed into the field of view. Both field of view and the superimposed illuminated spot are then recorded on 16mm motion picture film, closed circuit TV or can be visually observed.



Applications

- Simulators
- Human factors
- Behavioral studies
- Pattern recognition
- Market research
- Medical research
- Reading therapy
- Highway engineering
- Target acquisition



General Description

The Eye-Mark is extremely versatile with numerous applications, some of which are covered in this brochure. It is light weight, easy to set up — which usually takes about 15 minutes, accurate and moderately priced for such a fine instrument.

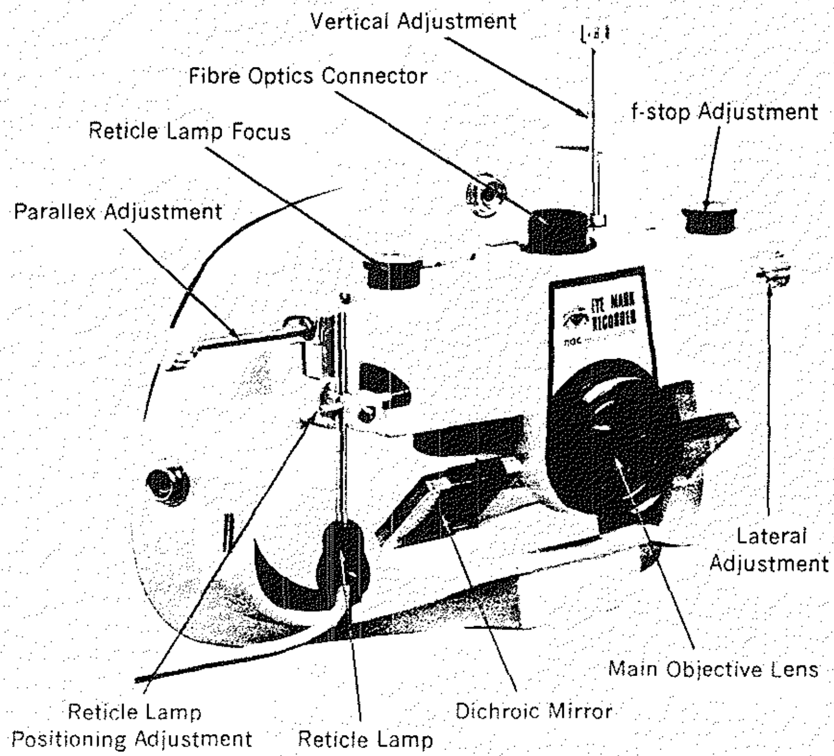
Two basic models are available, one 30° and one 60° which are the primary field angles or total viewing area of the camera lens. The spot travel or eye point of viewing track is approximately 20° around the optical center line of the camera lens in the 30° type and 40° in the 60° type. It is approximate because in some cases, depending on an individual's eyeball, reticle travel may be full field.

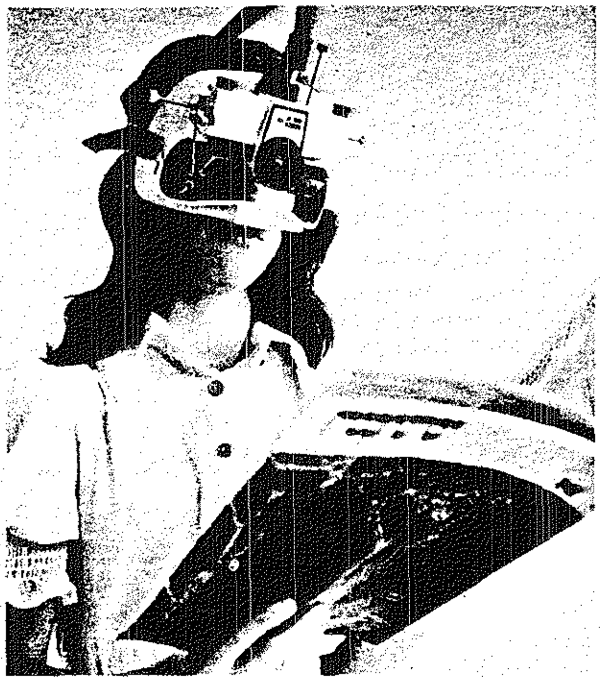
Everything is included, ready to use, with the exception of the recording equipment, i.e., 16mm motion picture camera or TV camera. Through the use of fibre optics the recording camera is remote which allows freedom of head movement and greatly reduces the amount of weight on the subject's head. During set up, provision is made for monitoring through the optical system.

The system is manufactured by NAC, Inc. in Japan, a leading manufacturer of special electro-optical instruments, who originally built the recorder to monitor eye point of interest in railroad simulators.

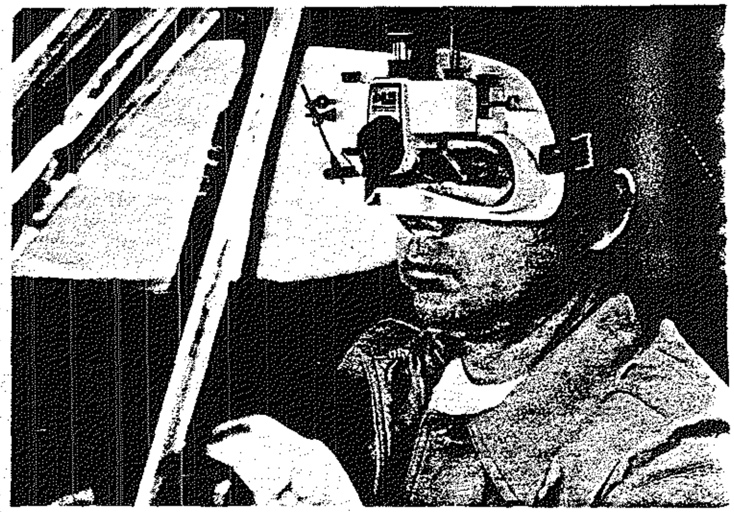
Features

- Lightweight
- Freedom of head movement
- Fast set-up
- Easy calibration
- Spot accuracy ±2°
- Parallex correction
- Remote recorder capability
- Interchangeable nose pieces
- Can be used without eye-spot and mirror
- Depth of field, 10" to infinity
- Completely self-contained



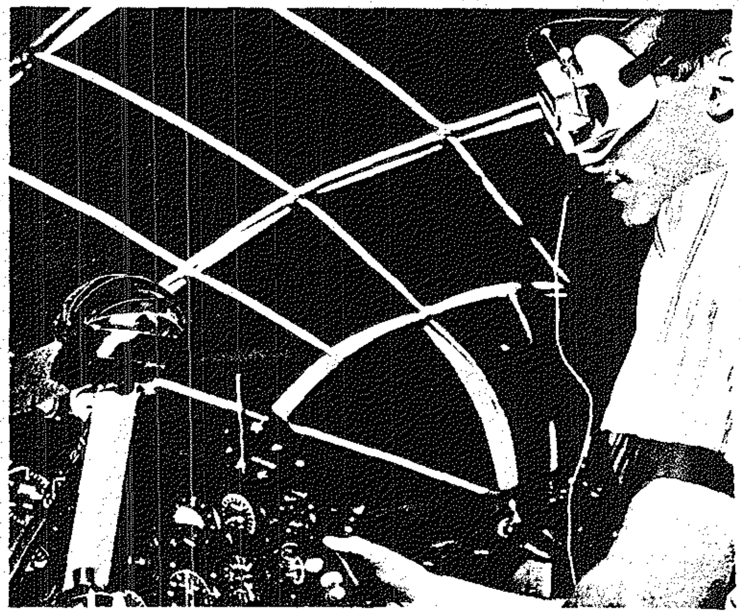


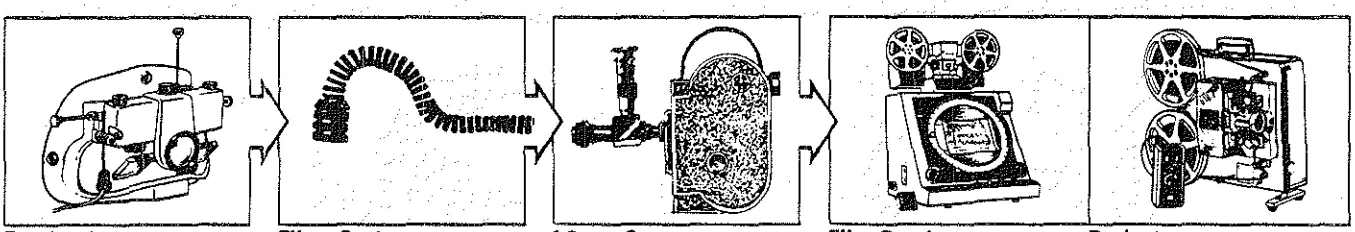
- Reading evaluation
- Comprehension
- Visual perception
- Eye track
- Reading speed



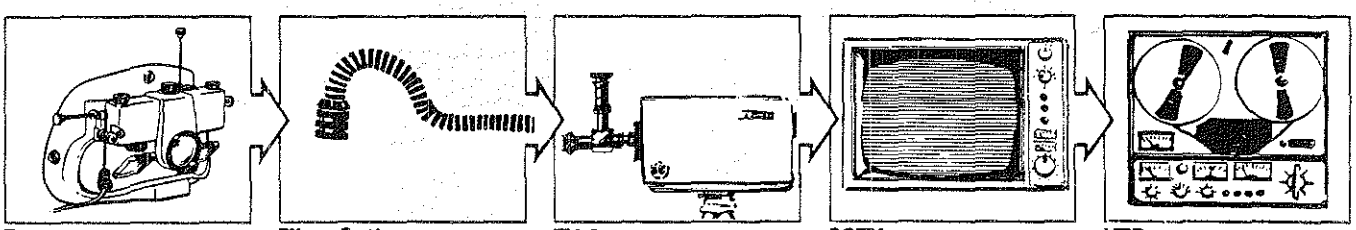
- Highway engineering studies
- Automobile simulator
- Driver education
- Highway safety
- Evaluation of distractions

- Aircraft simulators
- Pilot evaluation
- Human factor studies
- Instrument panel design
- Ratio of outside vs. instrument panel time
- Target acquisition





Eye-Mark **Fiber Optics** **16mm Camera** **Film Reader** **Projector**



Eye-Mark **Fiber Optics** **TV Camera** **CCTV** **VTR**

Specifications

Field of view:
30° type: vertical 22.7°, horizontal 31.4°
60° type: vertical 43.5°, horizontal 60°
Specify when ordering.

Eye mark size: 0.5mm (.02 in.) mark on 16mm film

Aperture: T 8 adjustable with click stops at 11, 16, 22, 32, 45.

Distance between subject and object: 25cm (9.84")-infinity. (Close-up attachment is supplied with 30° type.)

Eye mark correction range: Full frame of 16mm film.

Weight: Body, 380g (13.4 oz.)
Optical fiber, 150g (5.3 oz.)
Camera adapter, 280g (9.9 oz.)

Spot lamp (eye lamp): Special tungsten lamp. Life 100 hours (at maximum voltage).

Mounting adjustment: The device can be adjusted to fit any head size.

Distance between eyeball and optical system: 35mm to 45mm (1.38" to 1.78"). (Distance to mirror.)

Adjustments: X-Y, Parallex and spot focus.

Parallex adjustment range: 15° downward.

Optical fiber: Single strand diameter 20 microm.
Effective picture 4 x 5mm.
Total length 1000mm (39.37")

Power supply: 4 "C" size batteries in series for reticle illumination and alignment function.

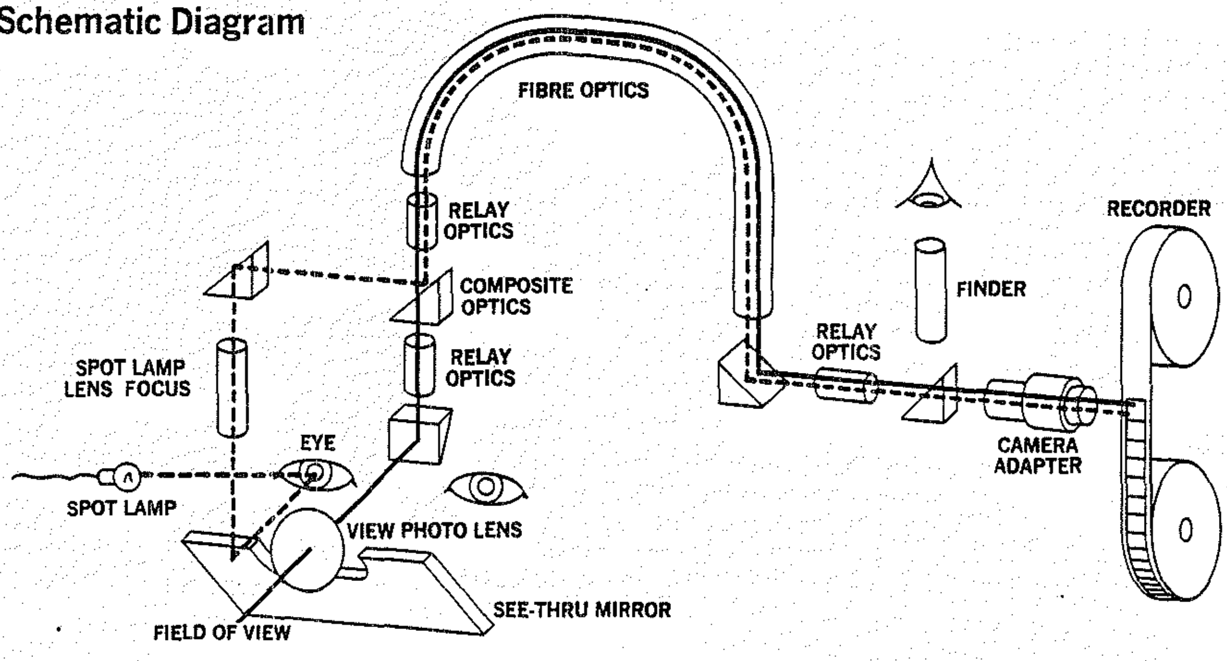
Finder and adjustment optics are supplied.

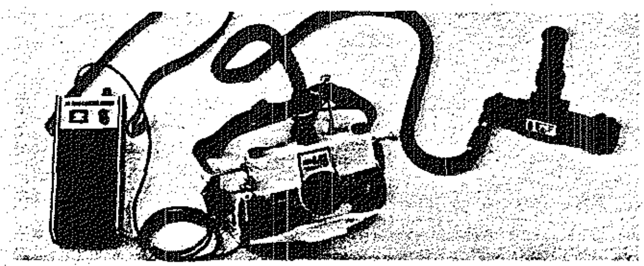
Tracking field:
±10° around optical C/L in 30° type.
±20° around optical C/L in 60° type.
Note: In some cases, tracking ability may be full field.

Accuracy: Accuracy is a function of off axis angle plus the individual's eye, but is approximately 2° within the above given fields.

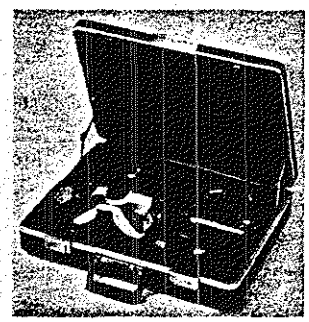
Specifications subject to change without notice.

Schematic Diagram





Eye-Mark Recorder, Fibre Optics, Finder and Adjustment Optics, and Battery Pack.



Complete system fits into a compact, shock-proof carrying case.

Manufactured by NAC INCORPORATED, Tokyo, Japan

Printed in U.S.A.

INSTRUMENTATION MARKETING CORP. **PRICE LIST**

820 S Mariposa St Burbank CA 91506 / Phone 213-849-6251 Telex 67-3205

NAC

EYE MOVEMENT RECORDER

December 1, 1978
FOB Burbank, CA

MODEL	DESCRIPTION	PRICE
IV	Eye-mark recorder, 60° Field of View including all items and carrying case.--	$8,480.00
	The above item includes all of the following components plus carrying case.	
	Main optical body.--	4,490.00
	*Face mask.--	140.00
	*Face pad, (3 different thicknesses).----------------------EA	40.00
	Reticle lamp holder.---------------------------------------	75.00
	Optical fiber.---	4,420.00
	Camera adapter.--	1,355.00
	Power supply.--	140.00
	Alignment light source.------------------------------------	35.00
	Reticle lamp.--	4.00
	Filter.--	5.00
	Reflecting mirror.---	29.00
	*Strap.--	45.00

*Model 3 Eye mark recroders can be converted to model 4 by ordering these items plus requesting bracket and screws.

30° Field of Viewer Eyemark Recorder is a "Special Production" item. Please inquire for delivery information.

(Prices are subject to change without notice,)
(Please confirm before placing orders.)

1 Report No NASA CR-166338	2 Government Accession No	3 Recipient's Catalog No
4 Title and Subtitle Purkinje Image Eyetracking: A Market Survey		5. Report Date March 1979
		6 Performing Organization Code
7 Author(s) Lo. F. Christy		8 Performing Organization Report No
		10. Work Unit No
9 Performing Organization Name and Address SRI International 333 Ravenswood Ave. Menlo Park, California 94025		11 Contract or Grant No NAS2-9846
		13 Type of Report and Period Covered Contractor Rept. Final
12 Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14 Sponsoring Agency Code
15 Supplementary Notes Technical Monitor: Charles C. Kubokawa Mail Stop 200-23, NASA Ames Research Center, Moffett Field, California 94035 (415) 965-5354 FTS 448-5354		

16 Abstract

The SRI eyetracking system is a synthesis of two separate instruments, the optometer that measures the refractive power of the eye and the dual Purkinje image eyetracker that measures the direction of the visual axis. These instruments were developed under NASA sponsorship. A market analysis of the Purkinje image eyetracking system was conducted to determine the potential sales for this system.

17 Key Words (Suggested by Author(s)) Purkinje image eyetracking system eye movement visual sensitivity optometer		18 Distribution Statement Unclassified - Unlimited Subject Category - 85	
19 Security Classif (of this report) Unclassified	20 Security Classif (of this page) Unclassified	21 No of Pages 141	22 Price*

*For sale by the National Technical Information Service Springfield, Virginia 22161

End of Document