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Arthur D. D'Amaro
Pacific University

Michael D. Moore
Pacific University

Henry Pedack
Pacific University

Clyde B. Slavin
Pacific University

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Abstract

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Chifton Schor

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THE ESTABLISHMENT AT PACIFIC UNIVERSITY OF AN EYE MOVEMENT MONITOR AND PROCEDURES FOR ITS USE

by

Arthur D. D'Amaro

Michael D. Moore

Henry Pedack

Clyde B. Slavin

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ADVISORS:

Dr. Chifton Schor   Clifton M. Schor

Dr. Frank Thorn

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THE ESTABLISHMENT AT PACIFIC UNIVERSITY OF AN EYE MOVEMENT MONITOR AND PROCEDURES FOR ITS USE

A basic aspect of an optometric testing routine is the "chair skills" which includes the evaluation of the patient's ocular motility. The method employed by the clinician is simple, he merely observes the patient's eyes while the patient fixates a moving or stationary object. Whether a particular series of eye movements are significantly abnormal is dependent on the subjective judgement of the examiner.

Over the years there have been a number of methods employed in an effort to qualify and quantify eye movements in both clinical and research areas. After images, mechanical attachments, photographs and light sources have been used. Each of these methods have draw backs and advantages. Currently, there are a number of different techniques employed depending on the amount of accuracy necessary and the total extent of the excursion of the eye.

The most accurate method of monitoring eye movements is by use of a contact lens to which a small plane mirror is attached. Light reflected from this mirror can be photographed and analyzed. The smallest measurement capable are those less than one degree, however, the total extent of movement which can be accurately recorded is five degrees. The limitation of range is due to the slipage of the contact lens. This method is not used in a clinical situation due to the difficulty in adapting the equipment to the patient and the discomfort from the lens.

In monitoring eye movements from one degree to twenty degrees, photo electric devices are most useful. The explanation of their working will be presented later in the paper. It will suffice for now to say that they operate on light which is reflected from the cornea and sclera and is sensed by photo diodes which can change differences in reflected light into electric current. It is the change in current which indicates the movement of the eye. There are many different kinds of monitoring devices which use this technique.

Electro-oculography is the method of choice for very large eye movements, those movements larger than twenty degrees or when the limbus is obscured by the lids or canthi. The mechanism involved is the difference in potential between the cornea and the retina. Electrodes placed on the skin around the eye pick up the difference in potential which then can be interpreted as eye movements. There is some lack of linearity and some electro-myographic artifacts which make up the major disadvantage with this method.

The photo electric technique lends itself most easily to the clinical situation. Pacific University College of Optometry has such an instrument, The Eye Track, manufactured and developed by Biotronics Inc. This instrument has been engineered to be utilized by untrained individuals which means that a minimum of adjustments and understanding are necessary to operate the instrument. Due to the simplification process, the examiner is limited to the attachments available and to the tests that the developers feel are important.

The authors feel that an instrument should be available in the clinic which is simple enough for an optometry student to use on patients and also sophisticated enough to use in research. Some of the maneuvers and manipulations that we feel are needed in this proposed instrument are as follows:

1. Ability to monitor smaller eye movements than can be measured with instruments now commercially available.
2. Wider variation in kinds of stimuli which can be more precisely controlled.
3. Ability to measure vertical eye movements and combinations of vertical and horizontal.
4. Monitoring of stimulus as well as the responses so that direct comparison can be made.
5. A channel for convergence and divergence movement.
6. More variability in speed and timing mechanism of the recording device.

The remainder of this paper will endeavor to explain how and what has been done to develop and test instrumentation that would fulfill the requirements as stated above.

APPARATUS:

The eye movement monitoring system consists of a

Biotronics model SGH/V-2 Eye Movement Monitor coupled to a Honeywell 1508 A Visicorder. An oscilloscope is also coupled directly to the monitor for initial adjustment and calibration. A Wavetek model 131A VCG Generator is used to control the stimulus galvanometer. The wave generator is also connected to the Visicorder, making a total of four channels on the readout. All inputs to the Visicorder are through a safety box containing a fuse and a voltage limiting device for each channel. (Figure 1)

The monitor unit is basically an amplifier for the small voltages generated in the sensors mounted in a ophthalmic zyle frame with an elastic head band before the patient's eyes. (Figure 4) It consists of a separate channel for each eye, and each channel is controlled by variable "gain" and a "position" control mechanism which determines the amplitude and base line voltage of the output.

The sensors operate on the difference of reflectance between the cornea and sclera. A central source of infrared (IR) light reflects from the ocular surfaces and are picked up by the photo sensors. With the eye in the primary position, equal amounts of IR are reflected into the two sets of sensors mounted before each eye. If they are properly adjusted, the consequent electrical potential between the sensors is zero. When the eye turns, more sclera (higher reflectivity) is exposed to one sensor than to the other, and a difference of potential is created. The monitor amplifies this small voltage into a useable voltage which can show the effects of minute ocular movements as small as six minute arc.

The maximum input to the Visicorder is much smaller than the maximum output of the monitor when the gain is turned up for optimum sensitivity. This necessatates the use of a protective device at the Visicorder input which will pass voltage only within the range of the recorder. The voltage limitation is dependent upon the galvanometer pins used in the Visicorder, and is in the case of the M1600 galvanometers, 2.6 volts maximum.

A reduction of voltage could be brought about simply by the use of series resistors in the safety box, but this drastically reduces the sensitivity of the instrument combination. A better safety device has been constructed which incorporates two protective measures without reducing the available sensitivity. The first protective device in each circuit is a 1/8 amp fuse, and the second is a shunt of Zener diodes which short circuits whenever the voltage in the circuit reaches a critical value. If the amplitude of the output response is too great, the diodes will cut out that portion of the response which is above the critical level, causing a squared-off wave appearance.

Zener diodes were used in channels one, two, and three, while the fourth channel uses a series resistor to cut the stimulus voltage to an acceptable level.

The Visicorder is simple in principle. It uses extremely small fluid filled mirror galvanometers to reflect narrow beams of light onto the moving photosensitive record.

The recording paper is sensitive to the greenish-yellow light beams, providing a record of dark blue lines as it develops upon leaving the machine. Development is hastened by a small fluorescent light mounted above the recording paper.

By using the very small galvanometers, the inertial components which accompany pen recorders are almost eliminated, and extremely high frequency recordings can be attained. This is facilitated further by the high variability of readout speeds. Amplification of the motion of each mirror is accomplished simply by placing the recording plane at a distance from the mirrors.

The two adjustments to be made with the galvanometers are easily accomplished with the special screw driver in the galvanometer compartment. The location of the recording spot on the paper is adjusted by turning the galvanometer while watching the recording plane. Brightness of the trace is adjusted either at the control panel, or by tilting the galvanometers independently with the screwdriver. (Figure 2)

The control panel has further adjustments for the paper speed and the time base which is automatically printed on the paper.

The oscilloscope is used in parallel with the Visicorder for initial adjustments of the spectacles and the controls of the eye movement monitor. A simultaneous comparison and balance of the two eyes is achieved by using the vertical and horizontal channels of the oscilloscope. A balance is achieved when the path of the spot is in the 45 degree meridian.

To balance the monitor, one must first zero the scope. This is done by grounding both the veritical and horizontal plus channels, and centering the spot with the "position" controls of the scope.

With the spectacles in place, and one side of the scope set at DC, and initial adjustment of the sensors for one eye can be made. It is done by watching the deviation of the spot as the subject changes fixation over the standard calibration pattern. The pattern involves five fixations, one central, and two at each side, spread out over a predetermined subtense. The "position" control on the eye movement monitor must be changed to recenter the spot each time the sensors are moved, and the "gain" should be set to give a deviation within the range of the scope when it is set at .2v./cm.

Lateral adjustment of the sensors is based on the previously stated principle that the voltage is determined by the ratio of exposed sclera to exposed cornea. With the sensor centered for the primary position of the eye, one watches the deviations of the spot while the subject fixates the extremes of the calibration pattern. Overshooting in a particular direction implies that there is more sclera exposed when the eye rotates in that direction. To compensate, the sensors are moved in the same direction as the overshooting direction of gaze, thus exposing less sclera to the overacting sensor.

The linearity of the monitor's output is determined by the equality of deviations when fixation is varied between the five equidistant stimulus points.

When one eye has been calibrated in this manner, the oscilloscope is adjusted to measure the contralateral eye. The eye movement monitor's gains should be adjusted so that equal left and right eye excursions produce equal output voltages. When both eyes are calibrated, the oscilloscope is used to equalize the voltage output measured from the patient's eyes.

By taking the difference between each eye's output, vergence eye movements are recorded. (Channel 3) The vergence record should be stable during lateral movements with normal subjects, and will deviate when tropic responses are initiated. When stinulus conditions are properly controlled, a direct measure of convergence performance is available.

STIMULUS CONTROL:

The Wavetek generator is capable of three wave forms, varying in amplitude and frequency from zero to far above the abilities of the stimulus galvanometer. A pinhole slide mounted in a projector provides a small stimulus spot which is reflected from a mirror mounted on the stimulus galvanometer. A direct record of the stimulus is taken on channel four of the Visicorder.

DISCUSSION:

Several subjects were tested with the apparatus; two eighteen and one ten year old esotrope, one seven year old developmental V.T. patient, and two twenty-five year old normal subjects. The range of subjects and their responsiveness indicates that the apparatus lends itself to use with all but the very young and/or uncooperative or feeble minded patients. A certain degree of understanding and cooperation is necessary for the delicate calibration and tracking necessary for meaningful readings.

The combination of instruments and wiring used facilitates an analysis of eye movements to a degree greater than with any of the commercial single unit equipment available. Comparitive specifications are listed below for the office model EYE - TRAC and the type SG - EYE MOVEMENT MONITOR as used in this investigation.

	EYE - TRAC	TYPE SG - EYE
POWER	115 VAC 60 cps	Rechargeable NICAD Battery
WEIGHT	30 lbs.	18 lbs.
DIMENSIONS	29" L x 20" H x 8" W	$14\frac{1}{2}$" x $12\frac{1}{4}$" x $7\frac{1}{4}$"
RECORDING Medium	Heat sensitive paper 2.5" W 100' roll	extermal recording instrument necessary, Honeywell Visicorde used
RECORDER Speed	10 mm per sec.	Min. 3.7 mm Max. 3,000 mm per sec.
RANGE From center	not available	$\pm$ 20 Horiz., +10 (up) -20 (dow
OUTPUT SIGNAL	not available	300 mv/degree
DRIFT	not available	50 mv/hr.
RESPONSE Time	not available	16 milliseconds filter in 2 milliseconds filter out
RESOLUTION	$\frac{1}{2}$ Horiz., $1\frac{1}{2}$ Vert.	$\frac{1}{4}$ Horiz., 1 Vert.

CONCLUSION:

It is the feeling of the authors that the advantages of the combined equipment used in this study; ie. increased accuracy, better control of readout and tracking, and greater versatility in positioning of sensors, out weigh the disadvantages of overall component size and cost, and that for academic investigation, the equipment used is superior to any clinical models, like the EYE - TRAC, presently available. It is also our belief that compiling readings on a large number of all types of problem patients (as well as normals) may well lead to a better understanding of the relationships between specific visual problem and apparent eye movements in both a causitive and diagnostic sense.

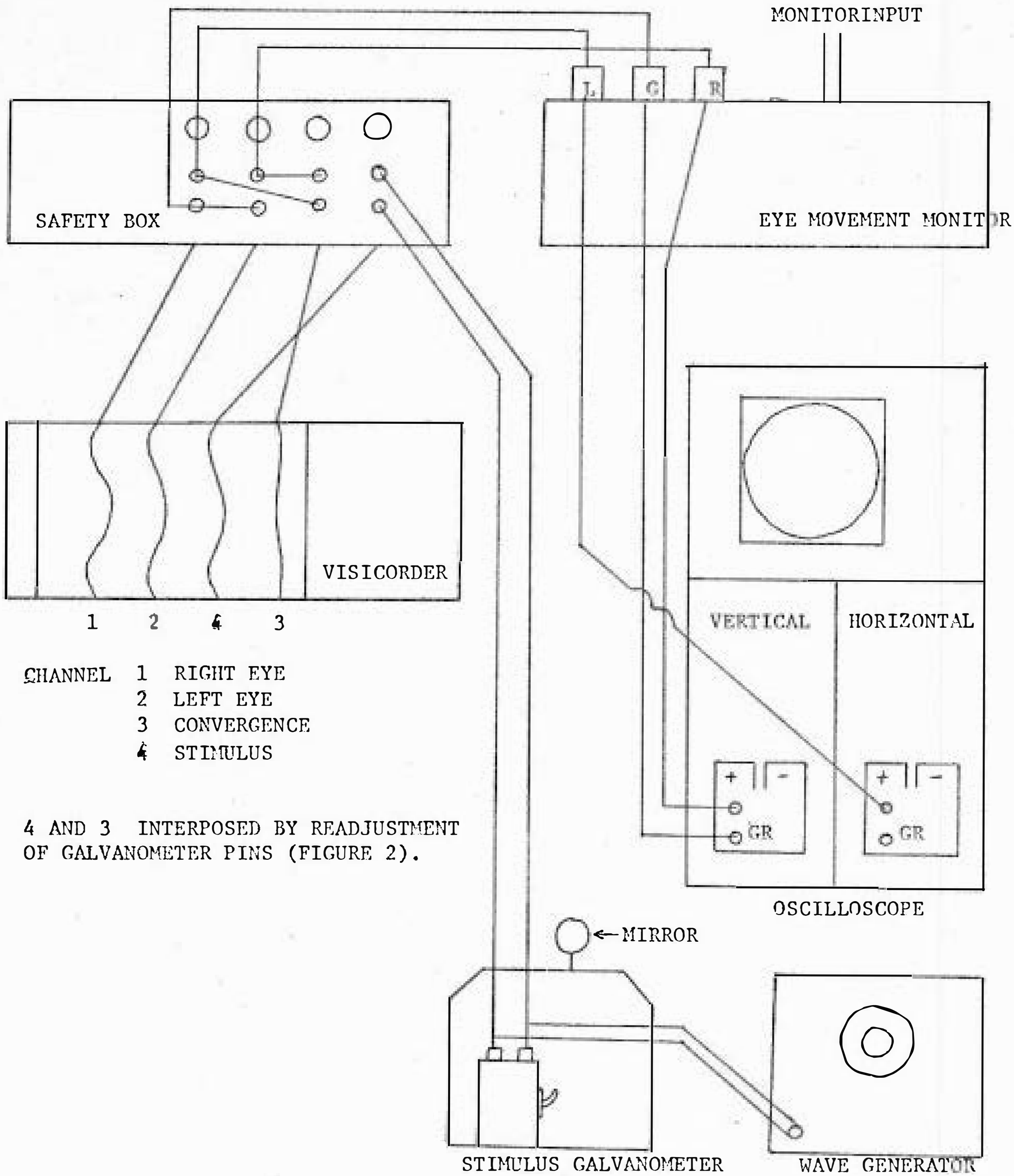

FIGURE 1

SCHEMATIC DRAWING OF EQUIPMENT USED

FIGURE 2. HONEYWELL 1508 A VISICORDER GALVANOMETER LOCATION & ADJUSTMENT

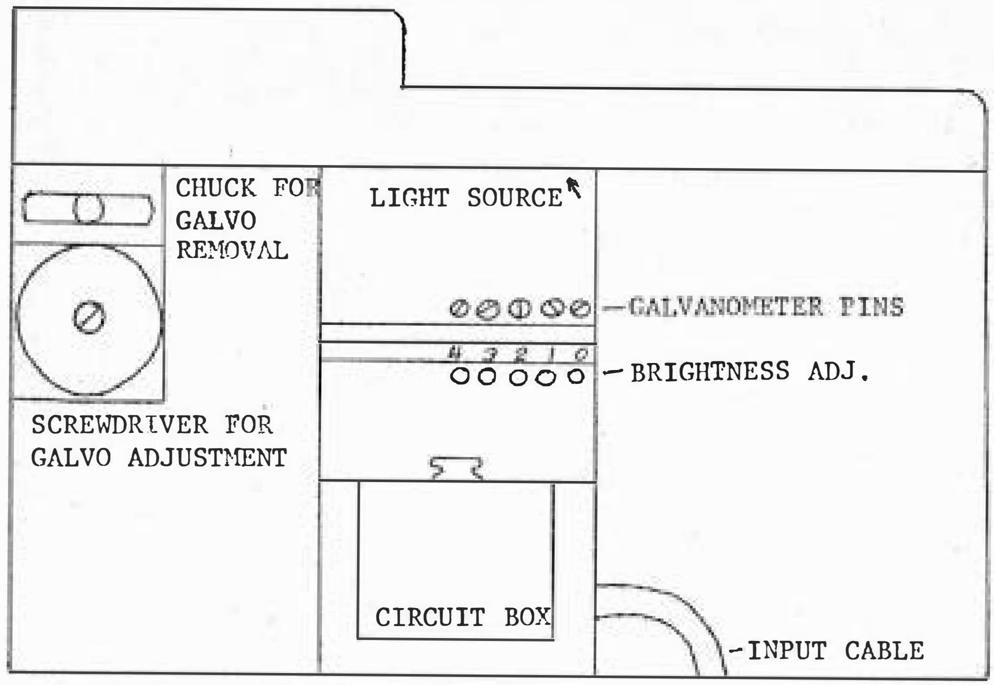

FIGURE 3. SAFETY BOX

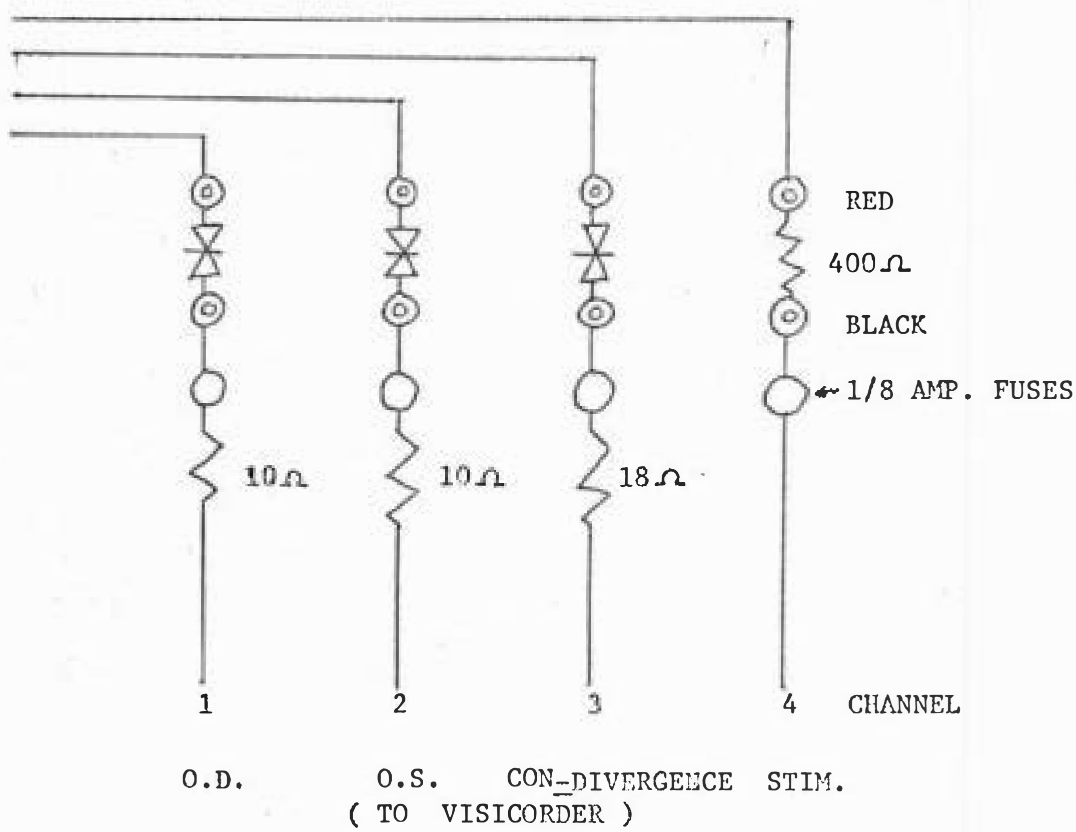

FIGURE 4. SCHEMATIC OF SENSORY APPARATUS ON ZYL FRAME AND LOCATION RELATIVE TO AN EYE

I.

II.

III.