5-10-1973

Dynamic visual evoked response

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Abstract

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Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Frank Thorn

Subject Categories

Optometry

DYNAMIC VISUAL EVOKED RESPONSE

Presented to the faculty of
the College of Optometry at
Pacific University

In partial fulfillment of requirements
for the degree of
Doctor of Optometry

by:

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May 10, 1973

ACKNOWLEDGEMENTS

Our sincere gratitude is extended to Dr. F. Thorn for developing this system. We also thank Dr. C. Schorr and the computer staff for their assistance and advice.

Approved by Frank Thorn
Thesis Advisor

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INTRODUCTION

The system designed and proposed by this paper is to show a method of using Visually Evoked Response (VER) to accurately measure refractive error and binocular visual function of clinic patients. The procedure proposed is as follows:

1. Measure refractive error by a Badal optometer system that can determine a near objective best refraction. This is done monocularly and with VER data feedback to control lens powers.

2. At far, using the objective best visual refraction measured from step one, a series of binocular measurements can be made. This will be done objectively with VER data feedback.

Review of Literature

Spehlmann (1965) has shown that a patterned stimulus could elicit a visually evoked cortical response. The study compared the late waves (180-375 msec) of the VECR under diffuse light stimulus conditions with checkerboard patterns consisting of checks of varying angular subtense. The results showed that the late wave of the VECR corresponds closely with the size of the checks, whereas the diffuse light condition produced very insignificant small late waves. A +10.00 D lens was placed before the eye to degrade the contour of the checkerboard. The response was similar to that of a diffuse light stimulus. Thus the basis is set for other investigators to develop and refine techniques to measure the refractive error of the eye using the VER.

Harter and White measured the VER with checkerboard patterns of varying angular subtense. The patterns were tachistoscopically flashed by back illumination onto a screen, 60 cm. from the Ss. The evoked responses were picked up by scalp electrodes and averaged by the Mnematron CAT. The active electrode was placed 2.5 cm. above the inion and 2.5 cm. to the right of the midline. The reference electrode was placed on the right earlobe. The VER (90-100 msec, 180-200 msec) was found to be sensitive to contour sharpness and check size. Further, an optimal check size was determined for varying amounts of defocusing of the checks. Not only did the angular subtense (5' to 120') of the individual checks influence the VER, but the amount of induced refractive error (+5.00 to -5.00 D.) also influenced the VER. The greatest response was obtained when the checks were in sharp focus (emmetropia) while using checks

of 10' to 20' angular subtense. Larger check sizes were necessary for a maximal response when the induced refractive error was increased, either in the myopic or hyperopic direction. The degrading of the target was accomplished by two methods; 1) by putting a frosted glass plate over the checkers, and 2) by adding small amounts of plus and minus lenses. Component 'A' of the VER was found to be sensitive to check size when the checks were slightly degraded but was insensitive to check size when the checks were focused. Component 'B' was sensitive to check size when the checks were focused but not when they were degraded.

Millodot and Riggs experimented with the VER by using a sinusoidally modulated stimulus which involved the alternation of adjacent portions of the test pattern. The stimulus was made by oppositely polarizing adjacent checkers, above which a single sheet of polaroid was rotated. The average luminance of the stimulus remained constant and the adjacent checks alternately flashed. The mean luminance of the target was 100 fl and subtended and angle of 14 min of arc. The VER resembled sine waves and the median amplitude, trough to peak, was measured for each lens condition. As lenses were placed before the eye, the change in the VER was averaged by a signal averaging computer and displayed on an X-Y plotter. The results showed that when the subjective response of perfect clarity was obtained, the VER was at its maximum amplitude. The VER was very sensitive to 0.25 D of defocusing the image if no accommodative effort was made. For the two subjects involved it was found that the amplitude of the VER decreased 25% to 30% for each diopter of defocusing. Not only did this study explore VER's but simultaneously ERG was recorded.

The data points are very close but the VER showed a much higher sensitivity to focusing.

Duffy and Rengsdorff attempted to develop a specific technique to determine refractive error, including measurement of astigmatism, using the VER to patterned stimuli. The goals were to narrow the range of error and suggest a technique for automatic refractive measurement by computer. The equipment set up was essentially that of Harter and White. The target patterns were checkerboards, variable from 53.8 min to 1.5 min visual angle. Astigmatism was tested with patterns of alternating black and white parallel lines of 5 min separation. The initial screening was done with a 5 min check size at a distance of 20 feet, which would allow for prediction of the needed correction. Two diopter lens intervals were used between +6.00 D and -6.00 D. and the stimulus presentation time was 50 msec with inter-stimulus intervals ranging between 750 msec and 2,500 msec in a pseudo-random manner. Retesting and refining of the refraction was accomplished by using 2.5 min check size at a 20 foot distance, with 0.25 D lens intervals over a 2.0 D. range. Of the two electrode placement configurations attempted, it was found that the Oz - Pz configuration gave the maximal VER. All four subjects showed VER refractions within the range of uncertainty of 0.25 D, but these values were between 0.25 D to 1.00 D more myopic than the standard refraction in all cases. The study did not show that cylinder power could be determined, but did show that cylinder axis could be accurately determined.

Ludlam and Meyers, in their study of VER refraction, employed a technique similar to that proposed by Duffy and Rengsdorff. Their

technique has been used for climical evaluation of refractive errors and other visual functions. The VER is obtained by a computerized subtractive process which takes the response differences between a diffuse light target and a patterned stimulus checkerboard pattern. The VER is separated from the ongoing cortical noise by averaging 20 responses. The refractive error can be obtained with infants and uncooperative subjects, with or without any other refractive data. The working distance was 20 feet and the subject viewed the screen, 4' x 4', which subtended approximately 12^{o} at the subject's eye. The exam was done in a double shielded room to filter out any outside electrical interference. With one eye occluded, a broad scan is accomplished with 1.0 D lens intervals between -4.0 D and with a check size of 12'. The lens that gives the maximum amplitude response is used as the gross sphere refraction. The astigmatic axis is determined by putting parallel lines at various orientations for brief periods. The astigmatic axis is set where the amplitude is maximal. A 1.0 D cylinder is placed at the gross cylinder axis. The parallel lines are placed at this axis and also at 90^{o} away. If the amplitude is larger or smaller in either condition, the cylinder power is increased or decreased accordingly. A bracketing technique is then used to refine the axis. The final cylinder power and axis was determined by using lines of smaller angular subtense and dioptric increments of 0.50 D. A checkerboard pattern with smaller checks was used for the fine evaluation of the spherical component. The other eye is refracted in the same manner. Ludlam and Meyers stated that the refraction can be determined to 0.25 D sphere, 0.50 D cylinder power, and $\pm$ 10^{o} cylinder axis. The examination could be completed, on a cooperative individual, in about 40 minutes.

Lombreso, Duffy and Redd (1968) presented electrophysiological data collected from children with amblyopia ex anopia. The subjects, twenty two amblyopic and ten normal wore their subjective best refractive corrections. In the children with amblyopia normal response to both plain and patterned light was found in the unaffected eye. The amblyopic eye showed some changes from the normal patterns. There was a slight increase in 36% of the children, and a slight decrease in 42% and no change in 22% of the amblyopic eyes to plain light. The VER wave complexity in the amblyopic eye was similar to the normal light when plain light was used. There was more variation in the patterns when using the amblyopic eye and a patterned stimulus. Fifty percent of the children showed a lack of the wave form complexity which is usually associated with pattern stimulation, and in the other 50% there was actually a degradation of both amplitude and wave form complexity in response to patterned stimulation. According to Lombroso, et.al., "If one accepts average power of the VER as an indicator of underlying cortical activity, then there would appear to be cortical suppression of electrical activity induced by patterned images when the amblyopic eye is stimulated." But this does not totally exclude some degree of defect in amblyopic at the peripheral levels.

Kowasaki, Hirose, Jacobson and Cordella (1970) studied the effects on human visually evoked responses of patterns that could be fused and those that could not be fused by the two eyes. When viewing triangles that are presented to both eyes, that can be binocularly fused, the P2 was observed to be as large or larger than the P1 wave. There was a marked suppression of the P2 wave when the triangle presented to one eye was

reversed in orientation. Then when using a complex target combined of the triangles in both positions and presented binocularly, there was no reduction in P1 or P2 waves. This indicated that the decrease in size of the P2 wave is a function of targets being fusable or not. When a pattern was presented to one eye and diffuse light to the other, P2 was not decreased in size. When one target was simple and of the same shape and the other was complex and of the same shape, the P2 wave was not significantly suppressed. Kowasaki, et.al. concluded that suppression of the P2 wave resulted when corresponding retinal areas viewed dissimilar patterns that were not fusable by the two eyes. But it cannot ve concluded that P2 depends upon binocular summation of fused objects, because when one eye presented with a figure and the other with di-fuse light the P2 wave was still present.

Cobb and Morton (1967) used horizontal and vertical bars. This pattern with horizontal bars presented to one eye and vertical bars to the other is used to create a state of retinal rivalry. This then sets up the condition for one eye to be dominant and the other suppressed. Kaufman et.al., reported that flicker to the dominant eye caused larger occipital evoked responses than when applied to the suppressed eye, but Cobb and Morton found no consistent difference in amplitude of responses to stimulation of the dominant eye or suppressed eye. Having the subject sort out the dominant eye, to determine which eye was receiving information, two stimuli were presented, one 180° out of phase to the other eye. If suppression was complete and if the sorting was perfect, then the evoked responses would be similar to those obtained from either eye alone. Because of the variation in the responses, Cobb and Morton concluded that sorting

was not perfect because of indecision and reaction delay, thus the average occipital potential evoked by stimulation of the suppressed and dominant eyes did not differ significantly.

Sternheim and Cavonius (1971) attempted to measure the temporal modulated transfer function at the retina and occipital cortex using a grating stimulus pattern. The data obtained is compared to the psychophysical function obtained using the same pattern. A pattern of alternating light and dark bars, whose luminance is modulated sinusoidally, was used instead of square wave modulation for two reasons: 1) most of the prior psychophysical data was obtained using sinusoidal stimulus and 2) it is expected that there will be less complex electrical response.

The stimulus pattern was a 0.75 c/deg horizontal square wave grating which filled a 20 circular field presented in Maxwellian view. This will elicit a photopic ERG. The stimuli were generated by a two channel optical system, one channel produced an alternating pattern and the other a steady light to give the desired modulation. The observer viewed the grating through a wide angle telescope eyepiece. Both ERG and VECP responses were recorded with a voltage amplification of 3000, and the responses were cumulated in a conventional response averaged and plotted on an X-Y recorder.

The ERG and VECP responses had very similar waveforms throughout most of the temporal frequencies. At low stimulus freq. (below 6 Hz) secondary peaks were often superimposed on the sinusoidal response. At stimulus freq. below 3 Hz, both ERG and VECP very suddenly ceased to follow

the stimulus leaving a complex waveform which could not be reproduced. The VECP is primarily a response of the central retina since reducing the field diameter to 4^{o} only reduced the response by 50%. The VECP and psychophysical data are in good agreement above 10 Hz. Unlike the ERG the VECP sensitivity drops rapidly as stimulus frequency is increased. The ERG sensitivity functions resembled the photopic sensitivity reported by Sokol and Riggs (1971). ERG sensitivity was lower than psychophysical around 20 Hz.

Both the shape and absolute sensitivity of the high frequency portion of the human VECP transfer function resemble the psychophysical sensitivity when it is measured using the same patterned stimulus.

The ERG does not resemble either of the other responses since its sensitivity decreases less rapidly as stimulus frequency is increased and can be detected at frequencies too high to elicit a VECP or to be perceived as flicker.

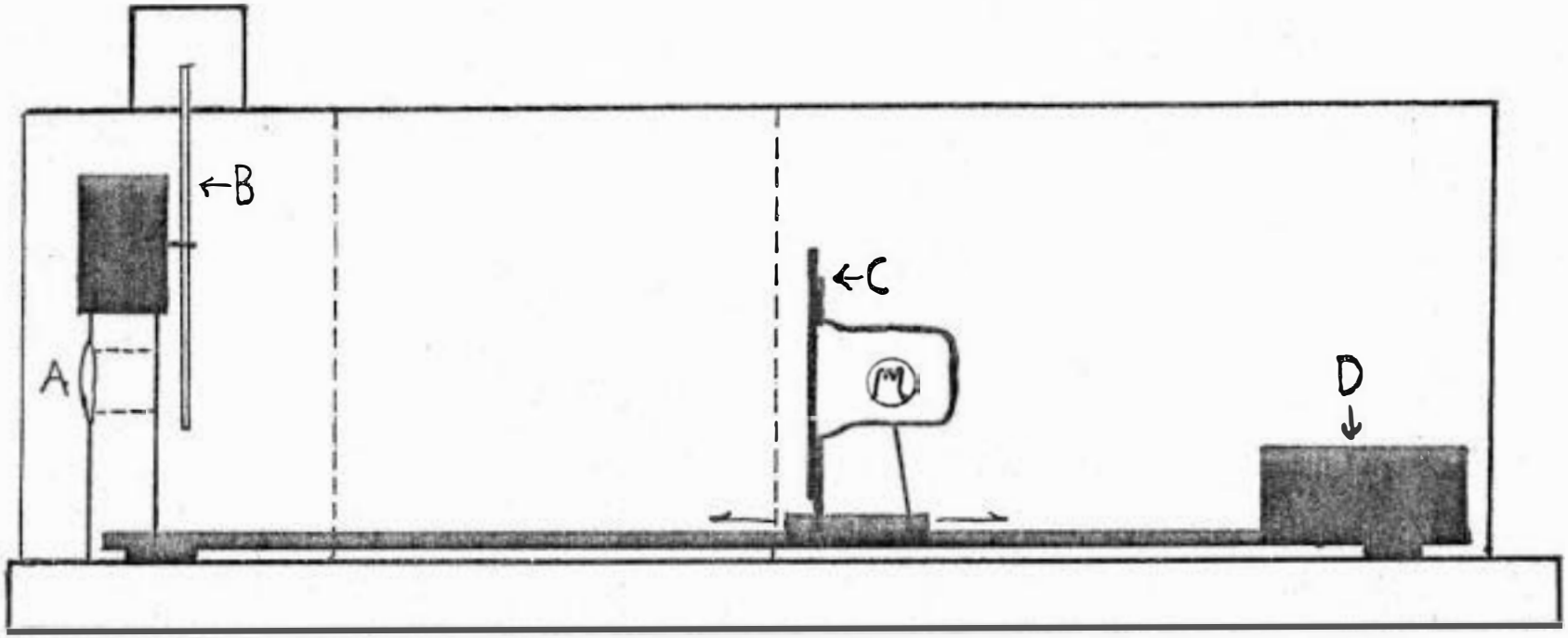
The Badal Optometer System

This system consists of an objective lens (see figure 1-a), a variable target (figure 1-c) and a computer monitored serve system for target localization. The objective lens power is approximately +7.00 Diopters and with a focal length of 0.1425 meters. This yields a 2.0306 centimeters per diopter calibration. The subject's entrance pupil must be coincident with the anterior focal point of the objective lens.

The test target mounted in the optometer is an intensity modulated square wave grating, in which the detail subtends 5 minutes or 6 cy/degree. The grating is a combination of two vectographic slides containing long narrow polarized stripes. The stripes on the two slides are polarized 90 degrees from one another so that when the slides are superimposed, each stripe is polarized at 90 degrees from its surrounding stripe. When the combined gratings are transilluminated and viewed through a rotating polaroid, they appear out of phase by 180 degrees at a rate of 14 c/s. The contrast of the target never exceeds 50 percent. The target subtends an angle of 15 degrees when viewed through the optometer lens. This remains constant, independent of distance of the target from the Badal optometer lens. Visual acuity (normal and amblyopic) is tested with the same vectographic slides, projected into the rear projection system.

The computer is triggered by a photo cell that is synchronized with the stimulus to the subject thus being able to correlate with the input stimulus to the subject with the output (the VER).

STIMULUS PRESENTATION
VIA
BADAL TYPE OPTOMETER



A - LENS ASSEMBLY

B - ROTATING POLAROID DISC

C - BACK-ILLUMINATED TARGET

D - TARGET BLOCK DRIVE UNIT

The stimulus to accommodation varies with the distance between the test target and the objective lens. The stimulus is changed by a self-reversing servo-driven system (Velmex Uni-slide). The rate a stimulus change can be controlled by a rheostat control. This rate must be within the limits of the maximum rate of accommodation. Campbell and Westheimer found an average reaction time of 0.36 $\pm$ .09 seconds was present in a change of fixation from infinity to 50 cms. They also noted that a gross target took more time, as did targets of low illumination.

Far Point Testing of Visual Motor Functions

Test targets for the remaining visual functions can be presented by projecting them through circular polaroid onto the back of a lenticular rear projection screen from Edwards Scientific Company. The patient views the targets on the front surface of the screen through spectacles containing circular polaroid (clockwise before one eye and counterclockwise before the other eye). The circular polaroid will isolate haplopic images presented to the subject, even in the presence of head rotations.

The target used to measure direction of gaze in monocular and binocular fixation test is a bipartite slide. The halves of the slide are polarized 90 degrees from one another. The two field halves will flicker in antiphaze when viewed through a spinning circular polaroid. This phenomenom also occurs when viewed through a rotating plane polarized filter.

Circular polaroid consists of a plane (linear) polarizing filter and a quarter wave plate (retarder). The slow and fast axis of the retarder are 45 degrees to the axis of the polarizing filter. Light passing through the plane polarized filter emerges from the retarder as two wave fronts out of phase by 1/4 of a wave length. The combined wave fronts result in circularly polarized light, either clockwise or counterclockwise, depending on the orientation of the linear polaroid and retarder. The bipartite slide will appear to flicker in antiphase when viewed through a rotating circular polaroid. This is due to the fact that only the polarized portion of the slide (which temporarily parallels the orientation of the linear portion of the circular polaroid) is visible. If a patient wears spectacles containint a clockwise and a counterclockwise filter, only one

eye will perceive the flickering targets.

In order to measure eye position, targets are scanned across the visual field in search of the null position. Target position is controlled by reflecting the projected image from a mirror galvanometer (Beckman penmotor RB 504) onto the back surface of the rear projection screen. The angular rotation of the mirror is controlled by a wave form generator. The mirror rotates the target horizontally when measuring horizontal components of eye position, and vertically when measuring vertical components of eye position.

Fixation disparity is measured in two ways. The first method is identical to the method used to measure strabismus and phoria (direction of gaze). In the second method, haplopic images are presented to the two eyes. These images have disparities that alternate from "crossed" to "uncrossed" in a continuous cycle. The magnitude of the disparity is reduced with the mirror galvanometer until the VER reaches a minimum value. This value indicates a precise alignment of the haplopic targets with each eye's visual axis. This is known as the null position.

The garget separation for the null position on the rear projection screen equals the magnitude of the fixation disparity. Disparity reversals from "crossed" to "uncrossed" is achieved by rotating a retarding 1/4 wave plate before the haplopic targets. These targets are polarized 90 degrees to one another. As the retarder rotates, the phase relation between each plane polarized target and the 1/4 wave plate

varies, causing the transmitted light of each target to vary from clockwise to counterclockwise circular polarization. Any disparity in the haplopic targets projected through a rotating retarder will continuously reverse from "crossed" to "uncrossed" if a patient is wearing spectacles with clockwise and counterclockwise polaroid lenses.

Haplopic targets, such as circular fields containing checkerboard patterns, are used to measure convergence and divergence amplitudes. The target for each eye has similar form to stimulate sensory fusion, and fine detail to stimulate and control accommodation. The haplopic presentation will be achieved with circular polaroid and the rear projection system. The projected targets are reflected onto the rear projection system by mirror galvanometers. Positions of the targets are controlled by voltage applied to the galvanometers. The targets are separated by the galvanometers to introduce a stimulus to convergence and divergence. The separation will increase until VER indicates that the targets are blurred or double, and at that time the separation will be reduced until the targets are seen clearly again.

Suppression tests are performed with a large field containing a checkerboard pattern and fixation mark presented to one eye, and a small flashing probe stimulus presented to the fovea of the tested eye. The size, intensity, and contrast of the test probe are varied in order to estimate the depth of central suppression. The haplopic images will be isolated with polaroid material

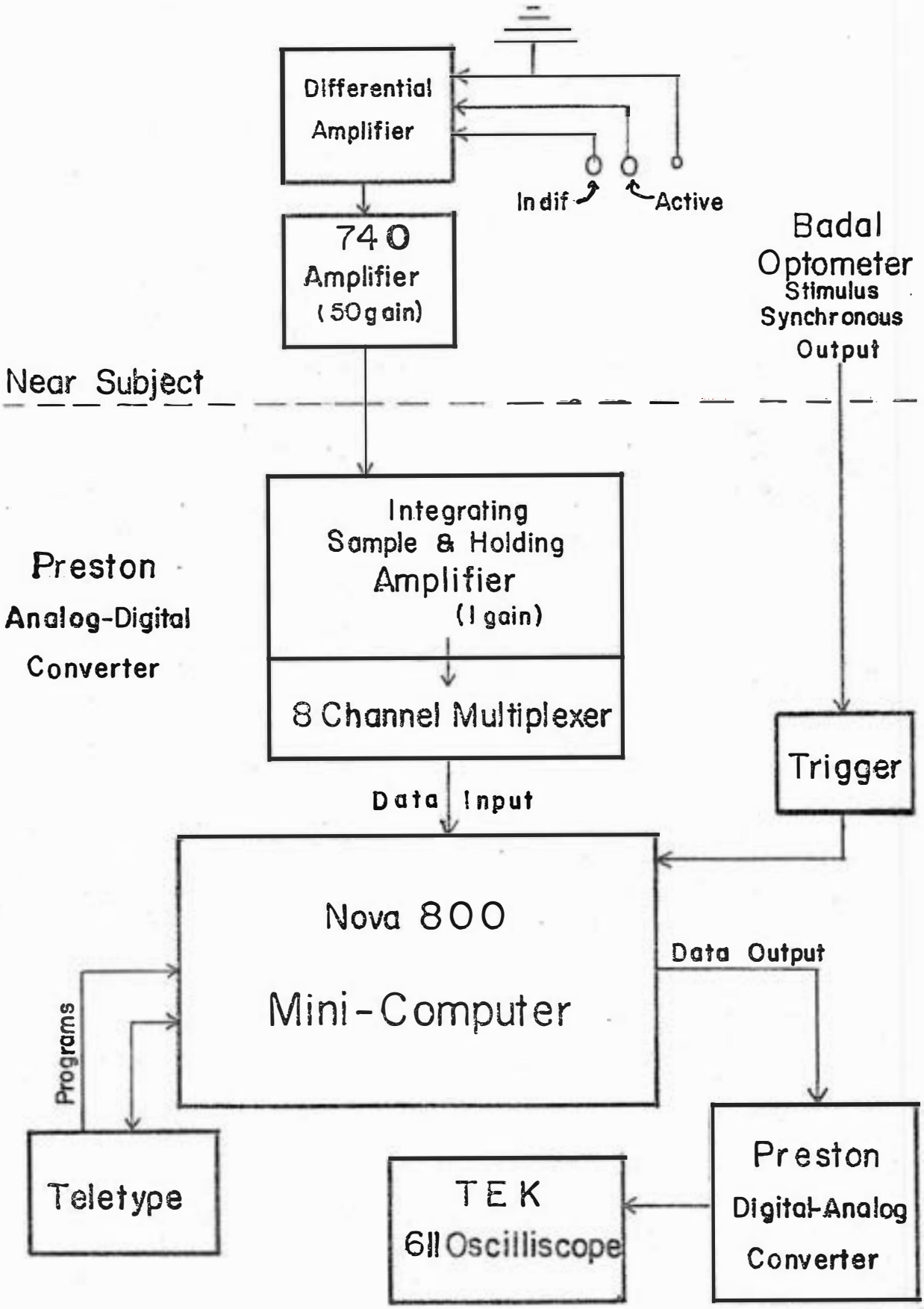
Haplopic targets for testing the quality of steriopsis will include the random dot (Julez) patterns and simple geometric shapes of unequal size. A range of disparities will be presented with slides of polarized random dot patterns. Varying disparity will be accomplished by a zoom lens system by altering the size of one ocular image. Disparities will be increased with either type of stimulus, until a noticeable increase in the binocular VER occurs. Test targets applied to stereopsis may also be used to test for aniseikonia.

Computer and Data Analysis

The method and instrumentation of recording the VER is very basic. An active electrode is attached to the scalp 2.5 cm above the inion. An indifferent electrode attached to one ear lobe and a ground electrode attached to the other ear lobe. The stimulus is a sinusoidally modulated pattern of light and dark lines. The Badal Optometer provides a stimulus synchronous output which triggers the computer synchronous to the stimulus.

The electrical activity on the scalp is picked up by silver chloride electrodes and transferred via shielded cables to the differential amplifier. The differential amplifier is a Burr- Brown #3621 L/16 model with 110 dB CMR-60 cycle elimination, 1000 gain, and AC low frequency drift elimination. The differential amplifier takes the amplitude difference between the active and indifferent electrodes and amplifies the resultant. The resultant is then transferred to another amplifier before going to the Analog to Digital Converter.

The Analog-Digital Converter integrates and holds the sample data and converts the electrical data into "computer useful" digital information. The input data is sent to the Nova 800 mini-computer for analysis. The data is analyzed according to the specific programs which are read into the computer via the teletype. After the data input has been appropriately analyzed it is sent to the Digital-Analog Converter to change the "computer useful" data into electrical data which is displayed on a TEK 611 Oscilliscope. If this information is to be recorded, a


Differential Amplifier
Indif
Active
740 Amplifier (50 gain)
Badal Optometer Stimulus Synchronous Output
Near Subject
Integrating Sample & Holding Amplifier (1 gain)
Preston Analog-Digital Converter
8 Channel Multiplexer
Trigger
Data Input
Nova 800 Mini-Computer
Data Output
Programs
Teletype
TEK 611 Oscilliscope
Preston Digital-Analog Converter

polaroid camera attachment is used to take a picture of the oscilliscope screen.

In short, the method for obtaining a refractive error of the patient is done as follows. The Badal Optometer is used to present the stimulus lines at 90 degrees, 45 degrees, 180 degrees, and 135 degrees. The maximum response amplitude for each meridian is analyzed by the computer to obtain a sphere power, cylinder power, and cylinder axis for a refraction at the spectacle or corneal plane, whichever is desired. This is done monocularly. The patient then views the same pattern at far for motor and binocular analysis, but this time he is wearing the lens correction and is viewing with both eyes. The programs used in this sequence were the following: analysis of data for average response, variance and running trend.

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