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A standard ERG response, and a study of the B-wave changes of blurred retinal images

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Abstract

A standard ERG response, and a study of the B-wave changes of blurred retinal images

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A STANDARD ERG RESPONSE, AND A STUDY OF THE B-WAVE CHANGES OF BLURRED RETINAL IMAGES

A Thesis

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the Faculty of the College of Optometry

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In Partial Fulfillment

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Doctor of Optometry

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by

William Harry Reid

John Benjamin Rush

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APPROVED

Thesis Committee

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Advisor

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SECTION I

INTRODUCTION

A. GENERAL DISCUSSION OF ELECTRORETINOGRAPHY

The vertebrate eye has a resting potential in which the cornea is positive with respect to the retina.[1] A flash of light onto the eye produces a complex change in this potential. The recording and analysis of these changes in potential is the substance of electroretinography.

Electroretinography was first investigated by Holmgren in 1871.[2] He noticed that a flash of light directed into an eye caused a galvanometer attached to the retina to undergo a deflection. He called this, accurately as it later turned out, the "Retinal Current." Further work by Kuhne and Steiner[3] showed that the source might be located in the rod and cone cells but not in the ganglion cells.

By the early 1900's sufficiently sophisticated instruments had been

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[1]Ragnar Graint, Sensory Mechanisms of the Retina, London: Oxford University Press, 1947, p. 14.

[2]Jerry Hart Jacobson, Clinical Electroretinography, A monograph in the Bannerstone Division of American Lectures in Ophthalmology No. 46, Springfield, Ill.: Chas. E. Thomas, 1961, p. 4.

[3]Loc. cit.

developed to allow detailed analysis of the electroretinogram. Hartline in 1925[4] showed conclusively that the potential recorded from a corneal electrode was identical to that recorded from the surface of the exposed retina.

Ragnar Granit[5] in 1933 proposed the most widely accepted analysis of the typical ERG, based mainly upon his work with the cat retina. He postulated three processes occurring in the eye. Each of these processes individually contributes to the total resultant ERG. The basis of his work was from ERG's of ether-anesthetized cats. As the depth of anethesia increased the ERG underwent changes. He attributed these changes to the progressive failure of these processes. He labeled these processes PI, PII, and PIII. PI was the first process to be eliminated and PIII the last as the depth of anesthesia increased (Fig. 1). Riggs[6] has summarized these processes in Table 1. Earlier, Einthoven and Jolley, 1908[7], had divided the ERG into four labeled subdivisions (Fig. 1). The a- and d-waves were customarily associated with the onset and termination of illumination respectively, and in Granits analysis are due to PIII. The b-wave is the result of PII and is in some

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[4]Loc. cit.

[5]Granit, op. cit., p. 37.

[6]Lorin Riggs, Electrical Phenomena in Vision in Radiation Biology, Ed. A. Hollaender, New York, McGraw Hill Co., Vol.3, 1956, p. 589.

[7]Jacobson, op. cit., p. 6.

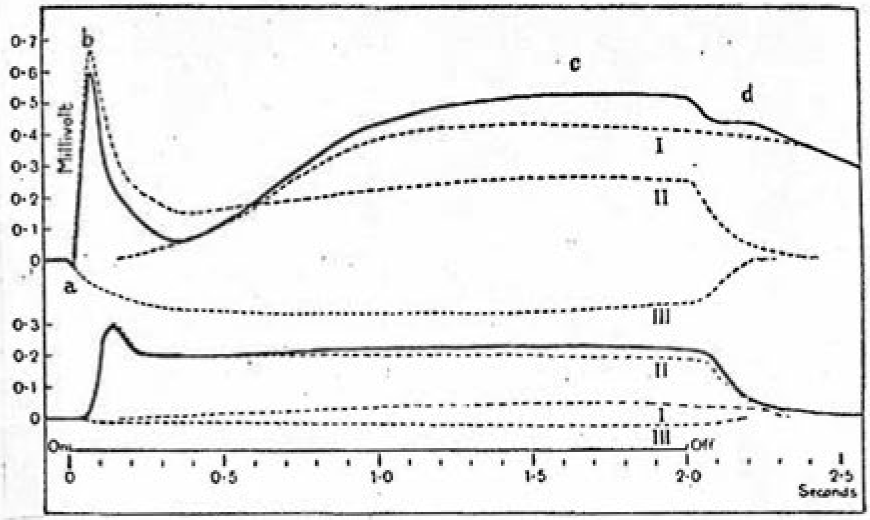

Fig. 1 Analysis of the electroretinogram at two intensities. Upper: 14 ml, lower: .14 ml The a-wave has been broadened slightly out of proportion to demonstrate its derivation more clearly. (Granit, 1933, J. Physiol., 77)

fashion related to optic nerve activity. Recent work, however, has cast some doubt on the association of the b-wave and optic nerve activity. Time studies by Lindsley[8] of the lateral geniculate activity and b-wave onset show that the lateral geniculate body responds before the b-wave is fully developed.

A more careful study of the retina of man shows some variations in wave form.[9] The a-wave and b-wave have been shown to consist of two waves each (Fig. 2). a_p and b_p are photopic portions of

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[8]D. Lindsley, "Discussion of Paper by L. Riggs," AMA Archives of Ophthalmology, Vol. 60 (Oct., 1958), p. 753.

[9]Jacobson, op. cit., p. 13 and 14.

TABLE I

Riggs[10] summary of the Characteristics of PI, PII, and PIII.

Property	Process		
	PI	PII	PIII
Latent time	Long	Medium	Short
Polarity	Positive	Positive	Negative
Electroretinogram wave accounted for	*c*-wave	*b*-wave	*a*- and *d*-waves
Effect on nerve impulses	"Sensitizes" PII	Excitatory	Inhibitory
Result of light adaptation	Not much change	Greatly reduced	Usually abolished
Probable site of origin	?	Bipolar cells?	Rod and cone cells
Effect of asphyxia	Moderately susceptible	Very susceptible	Highly resistant
Effect of ether	Abolished first (reversible)	Abolished second (reversible)	Abolished last (irreversible)
Intensity of light to stimulate	High	Low	High
Effect of alcohol	?	Enhances	Diminishes
Effect of adrenalin	Enhances and prolongs	Diminishes and prolongs	?
Effect of KCl	None	Abolishes	Enhances, then inhibits

the response. a_s and b_s are the scotopic portions. When the eye is light-adapted the a_p and b_p portion of the response dominate the

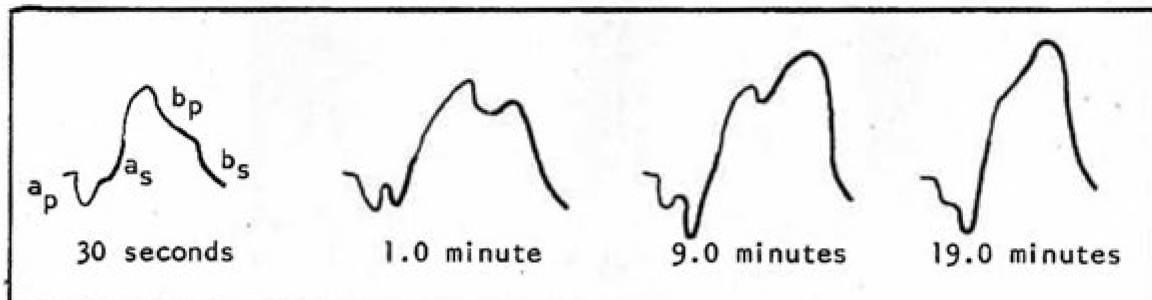

Fig. 2 a and b-wave changes under increasing dark adaptation time.[11]

ERG. As the eye progresses into dark adaptation a_s and b_s increase

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[10]Jacobson, op. cit., p.26.

[11]Jacobson, op. cit., p. 47.

until they completely dominate the a_p and b_p portion. Armington, Johnson, and Riggs[12], elaborating on this, have divided the response into its photopic and scotopic components (Fig. 3). There is a greater latency for the scotopic response (ii) than for the photopic response (i). A subsequent increase in the photopic response adds to the scotopic response producing a more rapid increase of the b-wave. The ensuing decrease in the amplitude of the photopic response slows the rate of increase in the b-wave.

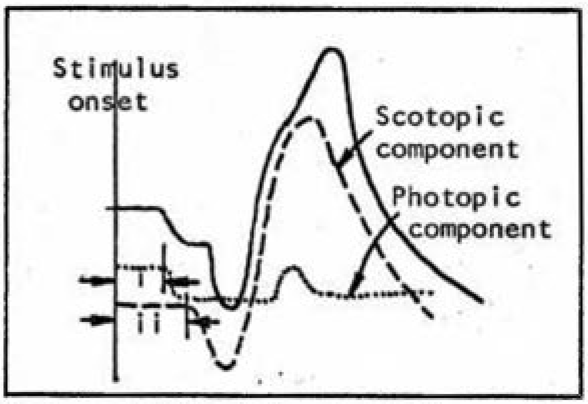

Fig. 3. Analysis of the dark adapted ERG into the photopic (dotted line) and scotopic (dashed line) components. Solid line constitues the sume of the two.

Upon complete dark adaptation, and subjected to an intense flash of light, the largest of b-wave amplitudes is obtained (Fig. 4). Figure 4 is an actual ERG recording made with the apparatus in this study. It was made prior to the study of blurred images, and the light stimulus was intense and uniformly diffuse. The retina and the stimulus are the two factors affecting the ERG and the stimulus is susceptible of greater variation. The ERG form has been shown to change as the stimulus changes in intensity, duration, spectral composition, area of retina illuminated, and rate of

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[12]Jacobson, op. cit., p. 18.

change of the stimulus intensity.[13] Increases in stimulus intensity increase the amplitude of the response. The increase in amplitude is roughly proportional to the logarithm of the stimulus intensity.[14] As the b-wave increases the a-wave amplitude also increases.[15] This introduces the problem of just how to measure the amplitude of the b-wave. The present practice is to measure from the trough of the a-wave to the peak of the b-wave.[16] This method assumes that the negative component remains constant for the interval that the b-wave is reaching its peak. A further complication is the fact that as intensity increases the implicit time decreases changing the temporal characteristics of the wave. The implicit time is the interval from onset of the stimulus to the peak of the wave is being considered (Fig. 5). For a given intensity, the implicit time is less for cones than rods.[17]

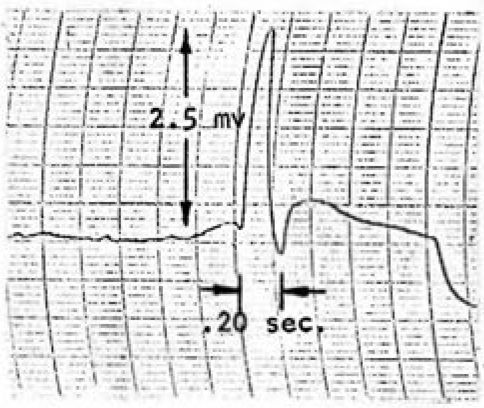

Fig. 4 Actual ERG with maximum dark adaptation and diffuse intense stimulus

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[13]Jacobson, op. cit., p. 14.

[14]Granit, op. cit., p. 156.

[15]E. Johnson, The Character of the b-wave in the Human ERG, AMA Archives of Ophthalmology, Vol. 60, 1958, p. 565.

[16]Jacobson, op. cit., p. 14.

[17]Jacobson, op. cit., p. 15.

Johnson and Bartlett [18] found that stimulus durations lasting longer than 100 milliseconds produced identical ERG's in the dark adapted retina. Durations of less than 100 milliseconds produced diminished amplitudes if the intensity was not changed.

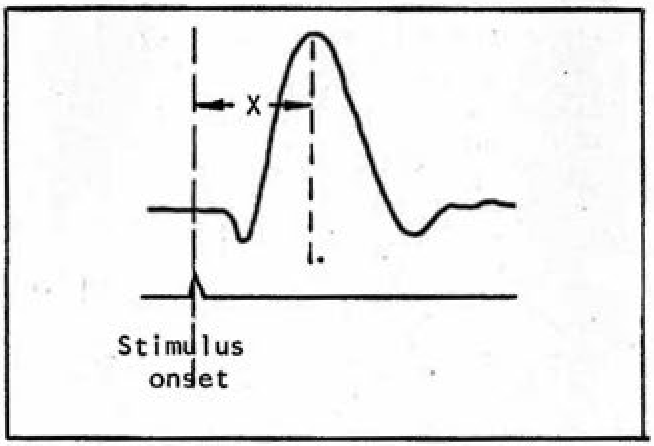

Fig. 5 Implicit time "x" from stimulus onset

Colored stimuli produce changes in the ERG (Fig. 6). Jacobson has listed the general shape of recordings which should be obtained with different colored stimuli.[19]

The size of area illuminated and location of the area on the retina are two related variables. A retinal area of approximately 20 mm^2 is required to produce a maximal ERG regardless of the intensity of the stimulus. Asher[20] was able to produce a typical ERG when the

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[18] E. Johnson and N. Bartlett, Effect of Stimulus Duration on Electrical Responses of the Human Retina, Journal of the Optical Society of America, Vol. 46, 1956, p. 167.

[19] Jacobson, op. cit., p. 72.

[20] Jacobson, op. cit., p. 18.

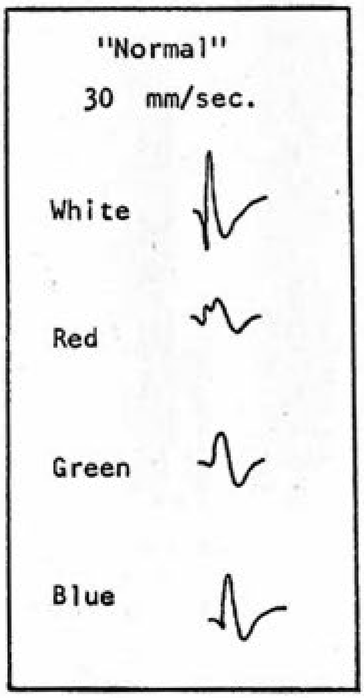

Fig. 6 ERG variations with wavelength changes[21]

stimulus was designed to lie only on the disc. The neural interconnections and scattering of light by the ocular media make it difficult to determine exactly how the retina responds to particular areas stimulated. Studies in critical fusion frequencies, however, do show a difference between peripheral and central retinal recordings.

Marg[22] studied the effect of stimulus size and retinal illumination on the human ERG. He found that as the area illuminated increases while luminance remains constant, the a-wave and the b'-wave (as measured from the peak of the b-wave to the beginning of the c-wave) increase in amplitude in a linear fashion, but the b-wave decreases rapidly after a brief increase.(Fig. 7). This point is significant to our study and will be discussed at length under the Discussion.

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[21] Jacobson, op. cit., p. 72.

[22] Loc. cit.

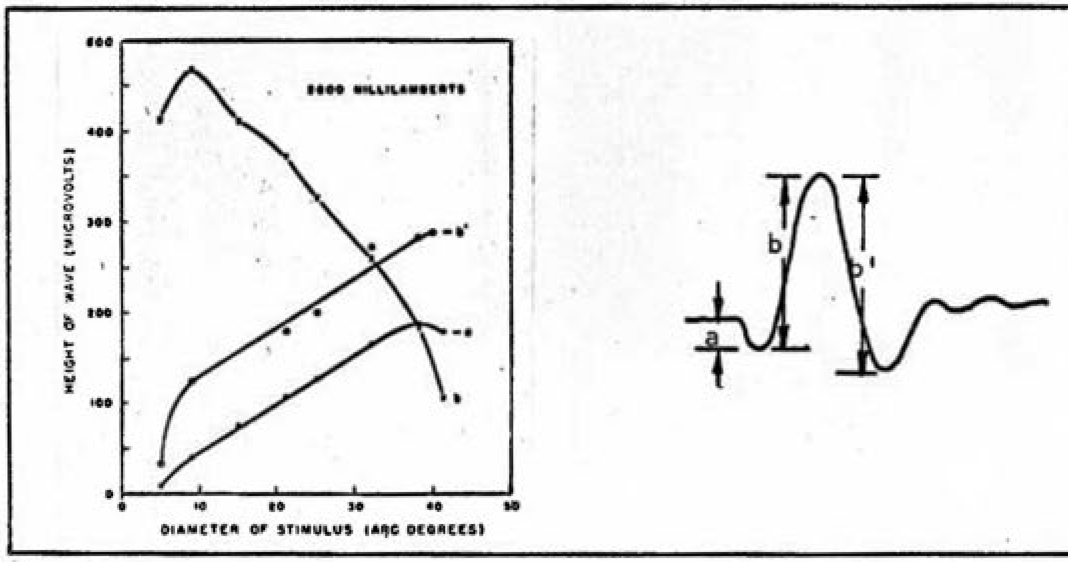

Fig. 7 Mean values of experimental sessions. Note that a- and b'-waves tend to be parallel linear functions. These two waves are plotted negatively in order to make a more compact graph.[23]

There are many other factors which may influence an ERG recording. Some of these are pupil size, interactions between the two eyes, degree of development of the retina, and the effect of blood circulation.[24] ERG changes due to blurring of the retinal image was an additional possibility and investigation of this possibility was the subject of the second area of this study.

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[23] E. Marg, The Effect of Stimulus Size and Retinal Illumination on the Human Electroretinogram, American Journal of Optometry and Archives of the American Academy of Optometry, Vol. 30, 1953, p. 417.

[24] Jacobson, op. cit., p. 29-34.

B. C. T. WHITE'S STUDIES ON THE EFFECTS OF CONTOUR SHARPNESS AND CHECK-SIZE ON VISUALLY EVOKED CORTICAL POTENTIALS

C. T. White delivered a lecture at Pacific University in October, 1968 in which he reported that visually evoked cortical potentials varied with refractive status of the subject.[25] Earlier work by Copenhaver and Perry, 1964; Lifshitz, 1966; and Sphelmann, 1965;[26] showed that the computer-averaged evoked cortical potential was different for diffuse illumination of the retina as opposed to sharply focused images. They had not done any work on the sensitivity of the evoked cortical potential to variations in sharpness of the retinal image. White and M. Russell Harter undertook to "...determine the degree of sensitivity of the averaged evoked cortical potential for: (a) the sharpness of focus of patterned visual stimuli, (b) the size of the elements of the pattern, and (c) the interaction between these variables."[27]

The method used was to dark adapt the subject for 5 minutes before starting the "run". The subject binocularly fixated the center of a translucent screen 60 cm away. In front of the surface was mounted the stimulus target. The targets were 20 x 25 cm

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[25] M. Russell Harter and C. T. White, Effects of Contour Sharpness and Check-Size on Visual Evoked Cortical Potentials, Vision Research, Vol. 8, 1968, p. 701.

[26] Loc. cit.

[27] Loc. cit.

Transparencies of a checkerboard pattern. The squares composing the checkerboard subtended visual angles of 12 minutes for the finest, 20 minutes for the moderate, and 46 minutes for the coarsest grid. The entire target subtended an angle of $20^\circ \times 15^\circ$. The target was then given a 10μ second flash from behind, at a frequency of 1/second using a strobe lamp situated one meter beyond the screen. A series of lenses (+6, +3, +1, 0, -1, -3, -6) were sequentially interposed between the subject and the target for purposes of improving or degrading the contour sharpness. The positive electrode was placed on the scalp 2.5 cm above the inion, and 2.5 cm to the right of the midline. The reference electrode was placed on the right ear lobe. The responses were then fed into a computer of average transients (CAT). One-hundred responses for each lens power were then stored and averaged by the computer and printed out as a single averaged response.

White found a significant change in the evoked potential at 90 to 100 milliseconds (called the "Point A"), and at 180 to 200 milliseconds (called the "Point B). As lens powers approached plano the A measure decreased and the B measure increased. This was true for all three stimulus targets but most noticeable for the 12 minute size. Although each subject had individual patterns they each showed similar changes at points A and B (Fig. 8). To take advantage of the similarity the data was calculated as a

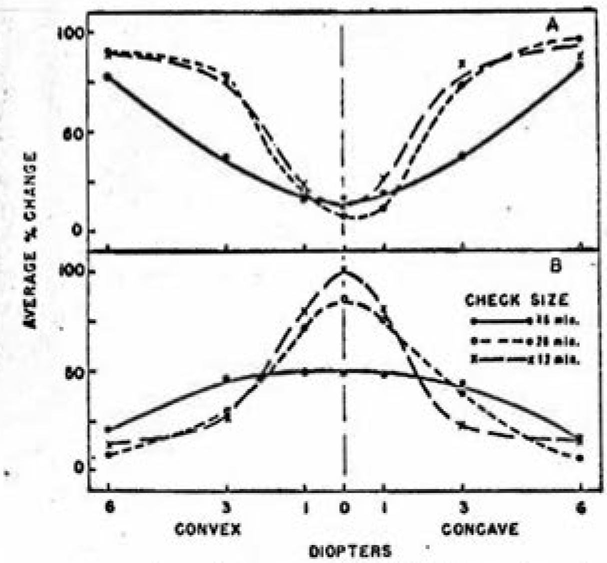

Fig. 8 Average percentage change in measures "A" (90–100 msec latency) and "B" (180–200 msec latency) of the evoked potentials as a function of the lenses used in viewing stimulus patterns and check-size within the patterns. These data were obtained from the evoked responses shown in Fig. 2. Each plotted point is a mean based on 12 averaged potentials (4 *Ss* and 3 replications).

percentage change in amplitude of the point considered.[29] Measure A seems more sensitive to changes in lens power than measure B. In other words, a change of ± 1 D produced greater changes in amplitude A than in B.

Two subjects with a high refractive error were then studied. Data were gathered while the subjects were wearing and not wearing their lens prescriptions (Fig. 9). Subject T.W. was a 3 Diopter Myope and the least change in A point amplitude occurred at 0 Diopter (plano) while wearing lenses of -3.0 diopters. Subject J.H., and 8 diopter myope likewise had minimal changes at plano

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[28] Harter and White, op. cit., p. 708.

[29] Loc. cit.

with his glasses on and maximal at -8.0 D without the lenses.

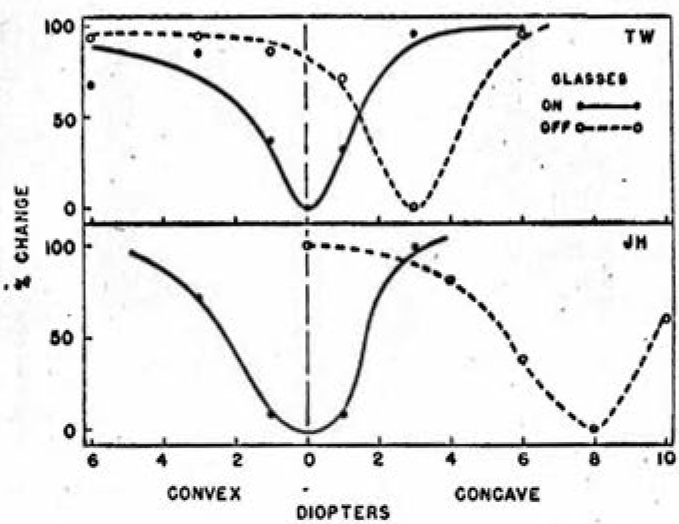

Fig. 9 Variations in component "A" (90-100 msec latency) as a function of viewing lenses and whether corrective glasses were worn for 2 *Ss* who required relatively large refractive corrections. When these *Ss* wore their glasses, their response functions resembled those of *Ss* requiring little or no correction.

In this manner White was able to determine the refractive error of subjects by recording the percent change in amplitude of the A position of the evoked cortical potential.

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[30] Harter and White, op. cit., p. 708.

C. PURPOSE OF THIS STUDY

The authors were interested in accumulating the necessary equipment, procedures, and experience required to record Electroretinograms. Dr. White's lecture provoked discussion between the authors regarding the specific location in the visual pathway of the source of the changes in cortical evoked potentials. If there is some activity in the retina that is controlled by the sharpness of the image perhaps an ERG experiment of proper design could identify it. It was to this end that the study was broadened to include an investigation of possible b-wave changes due to blurred retinal images.

SECTION II

APPARATUS

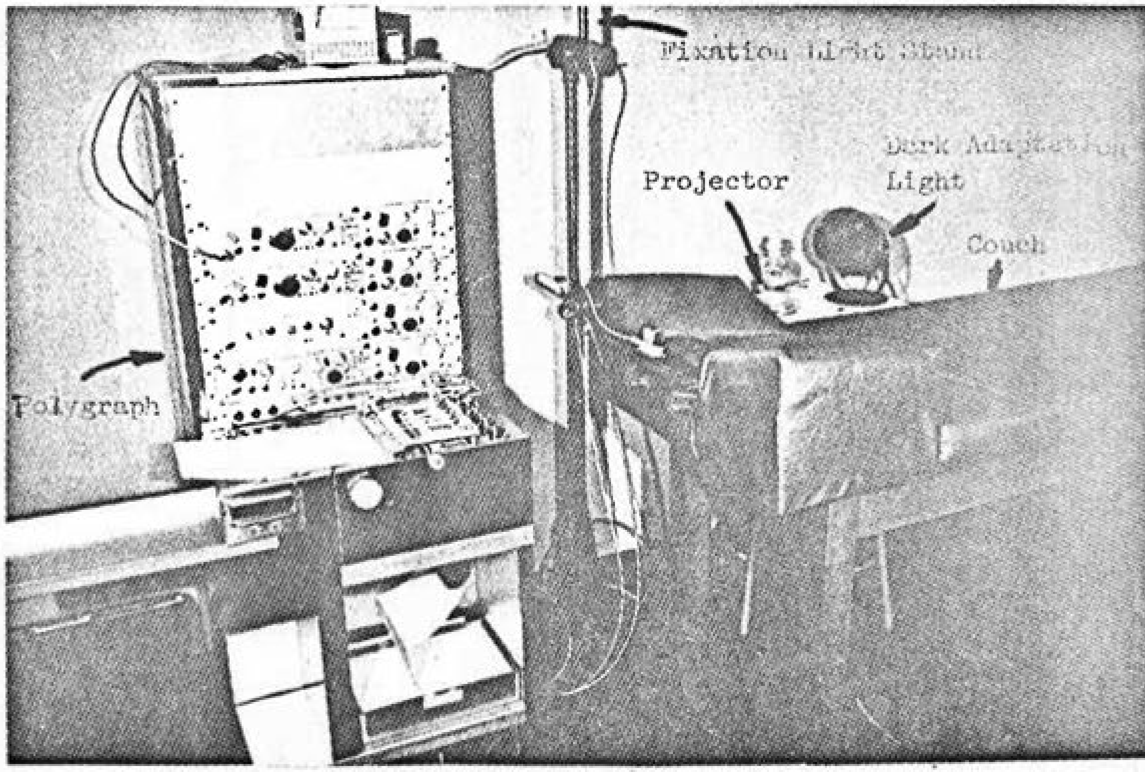


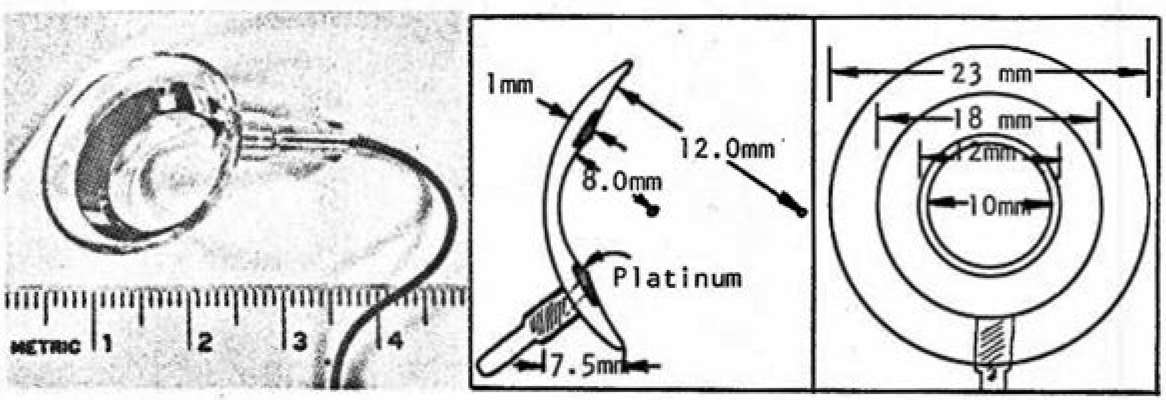
Fig. 10 General Electroretinographic Arrangement

A. RECORDING APPARATUS

The commercially available Model 7 Polygraph manufactured by Grass Instrument Company of Quincy, Massachusetts was used to record the ERG. The division of this model which was specifically utilized was the low level D.C. Pre-amplifier (Model 7p1 A) combined with the D.C. Driver Amplifier. Input was through the No. 2184, three pole input lead. The signal marker was used as a time base and also for indicating onset of light stimulation. Standard sensitivity is 50 mv/cm pen deflection for the combined amplifier and oscillograph. Frequency response of the combined amplifier and pen oscillograph is linear within ± 5% from D.C. to 45 cps and down 50% at 75 cps. The chart drive has 12 speeds from 2.5 mm/min. to 100 mm/sec. and speed is accurate to ± 1%.

B. RECORDING ELECTRODES

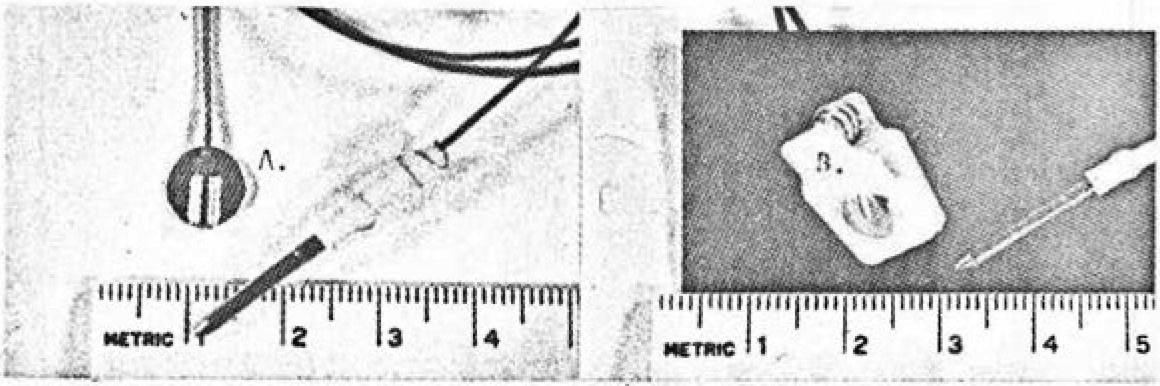
1. The primary recording electrode was designed by Dr. Thorne Shipley, Dept. of Ophthalmology, University of Miami School of Medicine. It was fabricated by Obrig Laboratories, Box 1899, Sarasota, Florida, to Dr. Shipley's specifications. The Contact Lens Electrode is the adult size being a 12.5 mm inside curve radius (Fig. 11).



Side View Front View
Fig. 11 Contact Lens Recording Electrode

2. The indifferent Electrode was a small gold disc measuring 8.0 mm in diameter (Fig. 12). It was located on the subject's face 1 cm lateral to the outer canthus. It was attached with a small piece

of tape and it made contact through standard EKG electrode paste (note Fig. 16). The length of the lead equaled that of the contact lense electrode to maximize common mode rejection of noise signals.



A. Indifferent Electrode B. Ear Lobe Ground Electrode

Fig. 12

3. The ground electrode was of the ear lobe clip type. The length of wire was not of importance here.

C. PROJECTION SYSTEM

The light source and projector was the Kodak Ektagraphic Model E slide projector. The light source was the standard projection lamp furnished with the projector. (500 watt, 120 volt, T - 12 bulb, C - 13 D filament). For this study the lamp was on for approximately 9 hours. After completion of the experiment the lamp was allowed to burn 2 hours as a check on spectral stability during the experiment. The particular lens utilized was the Kodak Ektanar 5 inch f/3.5. Anterior to the lens is fixed an Alphax tachistoscopic shutter. In this study it was set for 10 milliseconds with aperture

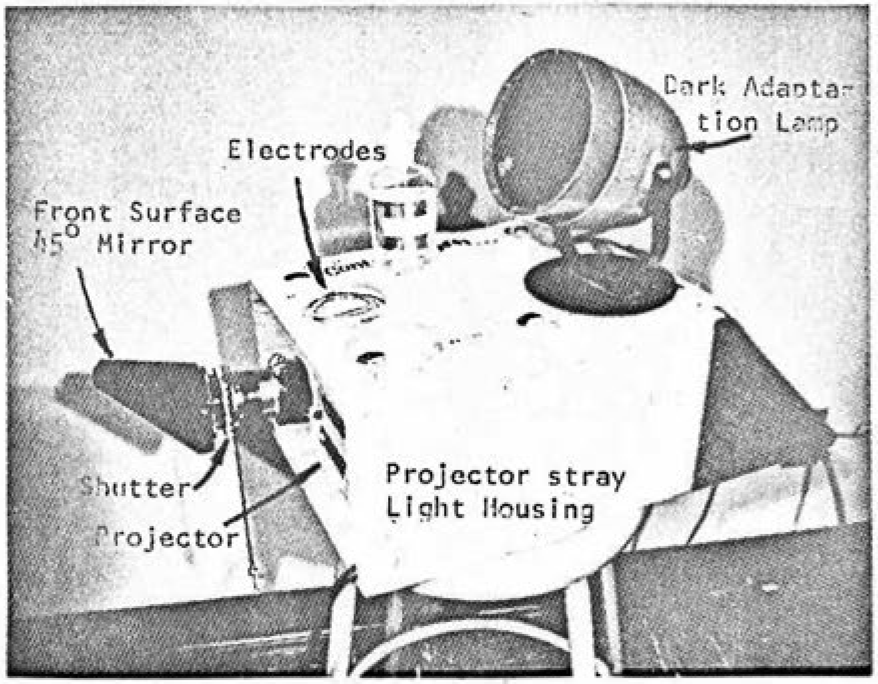


Fig. 13 PROJECTION ARRANGEMENT

of 35 mm. Anterior to the tachistoscopic shutter attachment is fixed a front surface reflecting mirror set at 45° angle to the projected light beam. This enables the projection of the target onto a screen mounted on the ceiling. The entire projector is housed in an open-end enclosure which allows maximum ventilation with minimum light escape. The room utilized was of deep gray walls and floor which aided in reducing reflected light. The projected targets were 35 mm slides of checker-board grid design. These were mounted between glass to prevent slide warpage which could result in an off focus target. The target slides were photographs of the original 10 x 12 inch transparencies used by C. T. White. Each square of the projected grid pattern was 2 cm wide, resulting in a 39 minute angle subtended at the eye (Fig. 14).

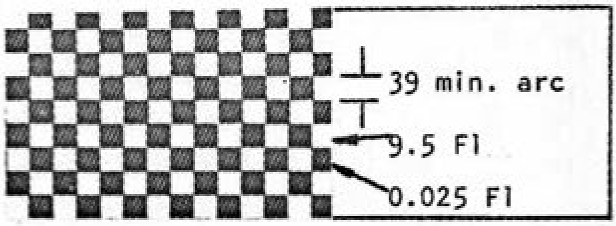


Fig. 14 Projected Stimulus

The distance from subject to screen was 175 cm. The maximum distance available was used as this was a far point study and a minimum demand on accommodation was desired. The overall target size was 44 x 64 cm. The brightness of the target was measured with a Luckiesh-Taylor Brightness meter. The dark squares were 0.025 foot-lamberts while the light squares were 9.5 foot-lamberts. A fixation target was utilized, consisting of a flashlight with two apertures to give a small square target with a Koenig bar. This was utilized to help stabilize the accommodative system for the proper distance (Fig. 15).

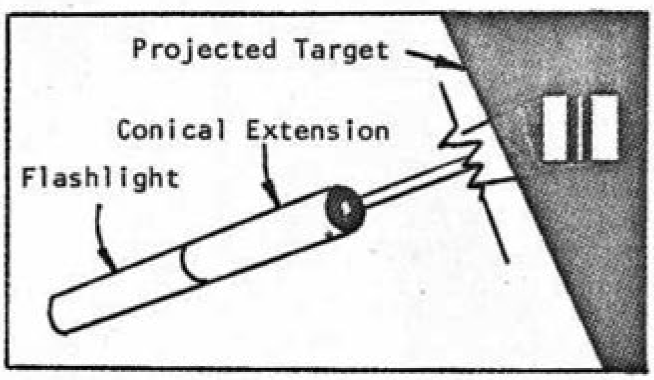


Fig. 15 FIXATION TARGET

A trial lens set and trial frame were used to mount the patients Rx and interpose additional lenses as needed. A small pen-light was utilized for illuminating and observing the panel and recording table of the polygraph. Illumination during dark adaptation was accomplished through the use of the Red Kodak Safelight Filter Wratten series 1. (over 620 nm).

D. SOLUTIONS AND INSTRUMENTS FOR OPHTHALMIC CARE

The following solutions were used in the care and handling of the contact lens electrode (Fig. 16). The soaking solution was the Barnes-Hind Sterile Soquette for contact lens storage. The lens was cleansed with Lobob laboratories CLC (bacteriostatic contact lens cleaner). Before insertion of the lens it was coated with

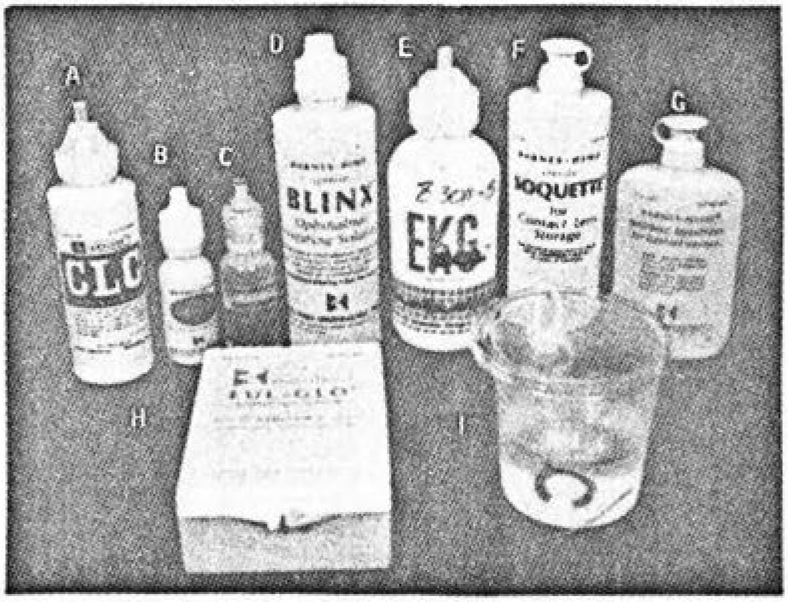
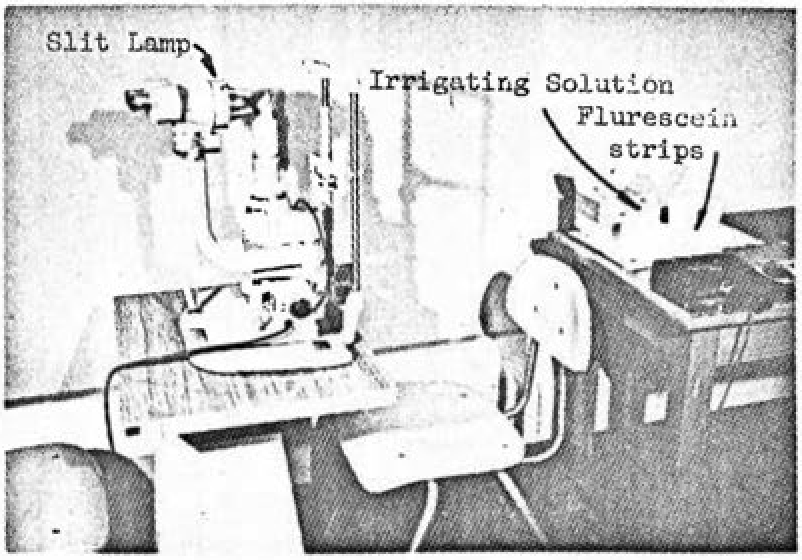


Fig. 16 Solutions for Ophthalmic care
a. Contact Lens Cleaner
b. Vascular Ophthalmic Decongestant
c. Local Anesthetic
d. Irrigating Solution
e. Electrode Paste
f. Contact Lens Soaking Solution
g. Contact Lens Wetting Solution
h. Fluorescein Strips
i. Container for Soaking Contact Lens

Barnes-Hind Wetting solution. Beck-Lee EKG Sol was used as electrode paste for the indifferent and ear lobe electrodes. The local anesthetic was 0.5% Proparacaine Hydrochloride (Opthaine by Squibb). Barnes-Hind Blinx Ophthalmic irrigating solution was used for wetting sterile fluorescein strips and irrigating the eye when needed. Before and after, the cornea was inspected with a Bausch and Lomb Slit lamp (Fig. 17).



The subject reclined on a couch designed to minimize head and body movement. The body portion was a 3 inch thick layer of foam rubber padding. The head portion was 5 inches thick and bounded on either

Fig. 17 Corneal Examination Arrangement

side by an incline of 7 to 10 inches. The entire couch was covered with heavy duty vinyl (Fig. 18).

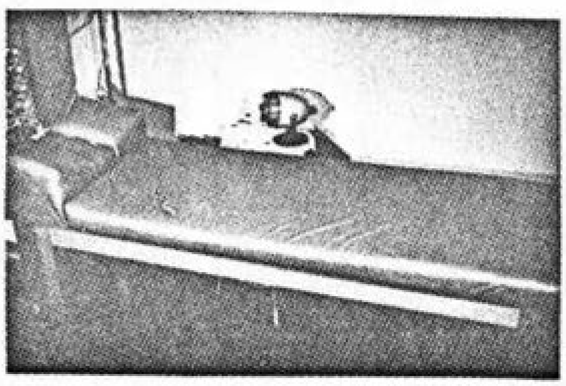


Fig. 18 Subject Couch

SECTION III

PROCEDURES

A. STANDARD PROCEDURE FOR OBTAINING ERG'S

The procedure itself is the primary consideration in ERG work. Each step must be carefully understood and performed exactingly. An understanding of the basic electronics involved as well as the structure and function of the eye are essential to anyone who enters into experimentation of this sort. One must have a grasp of general biological neuro-muscular processes, be able to recognize corneal damage, and be able to categorize possible subjects on the basis of their visual abilities, tolerances, possible retinal and other maladies. Once these areas have come into understanding, there is good reason for the researcher as well as the clinician to begin to take advantage of the electroretinographic concept.

The initial step in any new endeavor is always the most difficult. For this reason the authors have deemed it advantageous to explain briefly the procedures involved in obtaining the classical ERG. At first one must proceed very slowly and methodically. It is advisable that the researcher or clinician begin by first developing some proficiency in the use of a polygraph. An electrocardiogram is a fairly simple recording, and usually quite easy to obtain if there is an understanding of the controls of the polygraph. The instruction manual for the Grass Polygraph is suggested reading.

Once the controls are understood, have the subject recline. Connect EKG electrodes in the following manner. One electrode with EKG paste goes around the right wrist. It is connected to the positive lead of the EKG pre-amplifier. A second wrist electrode connects to the left wrist, and to the negative connection pole. The third electrode connects to the right ankle and to the gound connection. As the sensitivity is increased evidence of a heart rate should become evident. The researcher or clinician should experiment with the controls and develop experience at manipulation of these knobs. Once there is a clear understanding of this he should move on to the Low-level D.C. Pre-amplifier and gain some knowledge and experience at these controls. Again the instruction manual is a suggested preparation for this. Finally when he feels confident he should attempt an actual ERG. This procedure has been outlined in the section marked "PROTOCOL". The first basic and typical ERG recordings may be obtained by omitting steps 14, 18, and 20 from the protocol as these were included for the next section which deals with a study on b-wave amplitudes and requires somewhat more experience. The first ERG recordings will be very erratic and the experimenter will immediately appreciate the need for a minimum of motion on the part of the subject. As he will be working at high levels of sensitivity almost any body or eye movement will cause a shift in baseline or momentary deflection in writing pen. However, as he develops control of the subject, he will begin to obtain more readable and consistent recordings.

The recording found in Figure 19 was among the first acceptable recordings of the present authors. This was accomplished, however, some time after obtaining many unreadable recordings.

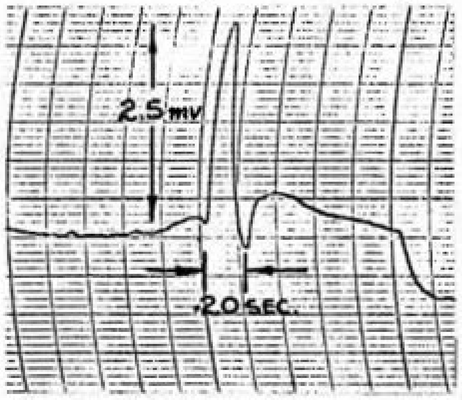


Fig. 19 Classical ERG

B. SPECIFIC PROCEDURES IN THE STUDY OF B-WAVE CHANGES

Once there was an ability to obtain an ERG recording in the classical sense, the authors began an investigation of possible b-wave changes from blurred retinal images. The Protocol and its elaboration were adhered to explicitly.

C. PROTOCOL

1. Polygraph preparation (Fig. 20)

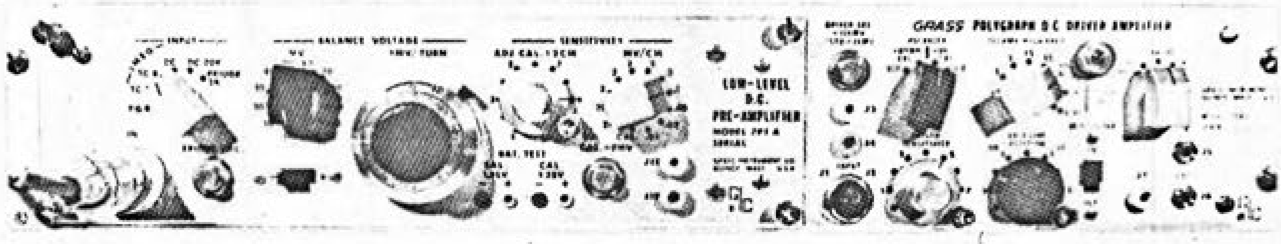


Fig. 20 Driver Amp. and Pre-amp controls

A. Ink pens
B. Power: "ON"
C. D.C. Driver Amp: "STANDBY"
D. Allow 5 minutes warm up
E. 60 cycle filter: "IN"
F. D.C. Driver Amp: "ON"
G. 1/2 Amp High Freq.: "75"
H. Polarity: "-UP CAL"
I. Calibrate Driver Sensitivity
J. Base Line Position adjustment
K. Low-Level D.C. Pre-Amp Sensitivity MV/CM: "CAL"
L. D.C. Driver Amp: "ON"
M. Calibrate sensitivity of Pre-Amp
N. Sensitivity MV/CM: ".1 mv/cm"
O. Input: "TC.8"
P. Paper Drive: "Chart and Pens"
Q. Paper Speed: "Central Position (OFF)"

2. Check projection system

3. Instill fluorescein stain and make slit lamp observations of cornea

4. Have subject recline

5. Prepare trial frame

6. Red Dark adaptation lamp "ON"

7. Room lights "OFF"

8. Dark adapt the subject for 20 minutes

9. At end of dark adaptation time connect the indifferent and ground electrodes

10. Instill 2 drops Ophtaine in both eyes

11. Preliminary instructions regarding eye movement

12. Fixation light: "ON"

13. Trial frame on with best visual acuity over dominant eye and occluded non-dominant eye

14. Red dark adaptation lamp "OFF"

15. Instructions to subject regarding recording procedure

16. Paper speed: "25 mm/sec"

17. D.C. Driver Amp Polarity: "-UP USE"

18. Preliminary recordings

19. Subjects response regarding clearness of target

20. Begin actual recordings:
    a. Plano lens on maximum acuity
    b. +5.00 diopter lens
    c. +8.00 diopter lens
    d. Plano lens

21. D.C. Driver Amp: "STANDBY"

22. Remove trial frame

23. Remove all electrodes

24. Instill Irrigating solution

25. Instill Fluorescein stain and make slit lamp observations for corneal damage

26. Instruct subject on care of eyes ("Do not rub eyes")

D. PROTOCOL ELABORATION

1. Regarding items 1a - 1j, 1l, 1p, 1q, of the protocol, for specifics refer to the Grass Instruments Instruction Manual "Model 7 Polygraph".
2. Regarding items 1k, 1m, 1n, 1o, refer to Grass Instruments Instruction Manual "Model 7 Pre-amplifiers".
3. The checking of the projection system was accomplished by moving the projector and/or the angled mirror so as to center the checkerboard target onto the projection screen. The fixation target is then centered on the screen.
4. "Prepare Trial Frame"; The subjects best refraction as determined by trial lenses was inserted into a trial frame. The eye which was not tested was occluded with a trial frame occluder. Two trial lenses (+5.00 D and +8.00 D) were held ready for insertion over the measuring eye as the experiment progressed.
5. The insertion of the contact lens electrode was accomplished by having the dark adaptation light near the face to provide illumination. The subject was asked to look down while the upper lid was raised and held against the skull at the level of the eyebrow. The upper portion of the lens was inserted under the upper lid. Then the lower lid was held firmly against the cheek and the subject was asked to look towards the ceiling. The lower edge of the lens was then inserted. Care was taken to be sure it was riding centrally and that

there was adequate freedom in following small angles of eye movement.

6. "Preliminary instructions regarding eye movement"; To minimize the chance of corneal trauma the subject was directed as follows: "When the lens is placed on the eye look only at the fixation target. Do not try to look around the room."

7. "Instructions to subject regarding recording procedure"; These were done as follows: "Relax as completely as you can, and blink at will. On the command 'Ready', do not blink until approximately one second after the flash."

8. "Subjects response regarding clearness of target"; Several preliminary recordings were made and the subject was asked, "Can you see the fixation target?", and "Was the checkerboard sharp and clear?".

9. Recording Procedure: All of the electrodes were connected to the polygraph. The trial lens was placed on the subject with the best prescription. The polygraph was turned "ON" and calibrated. The signal marker and timer were also turned "ON". The chart speed was set as 25 mm/sec. The operator held the "Remote Down" signal marker in the left hand and also used this hand to adjust "Base Line Position". In the right hand he grasped the shutter release cable on the tachistoscope. The subject was given the command "Ready". At this point he was to stop blinking and maintain fixation on the fixation target. The operator then pressed the shutter release cable and the signal marker "Remote Down" at the same time. The time between

the stimulus to the onset of the response varies with stimulus intensity as was cited earlier in the introduction. The most accurate estimate under the particular parameters outlined here, was 10 milliseconds latent period from onset of stimulus. Several preliminary recordings were made so that the baseline could be adjusted and the subject become familiar with the routine. When satisfactory responses were elicited the gathering of data to be used was begun. It was found that frequent alteration of baseline was necessary as it drifted beyond the limits of the paper.

The lenses correcting the refractive error were always left in and are referred to hereafter as "PLANO" implying that these lenses were the zero point for subsequent additions. The interval between flashes varied from 2 to 5 seconds. This was consistent with Burians [31] observations that the subject would remain dark adapted and no change would occur in the response as long as the interval was over two seconds. We found that a shorter interval was desirable to minimize small eye movements and attempts at re-fixation which caused erratic shifts in the baseline. On each subject fifteen to twenty-five flashes and their associated recordings were made through plano and the most consistent recordings were selected

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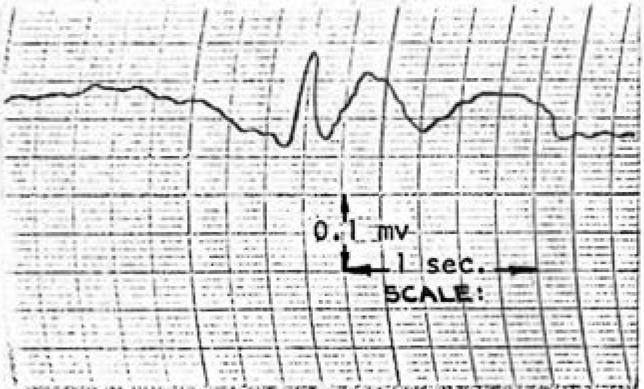
[31] J. Armington and F. Thiede, Selective Adaptation of Components of the Human ERG, Journal of the Optometric Society of America, Vol. 44, 1954, p. 779.

for averaging. The recording procedure was repeated with addition of +5.00 D, +8.00 D and in 3 instances a repeat determination with plano to have a check on the stability of response. The electrodes were then removed and a slit lamp examination of the cornea was performed.

IV. RESULTS

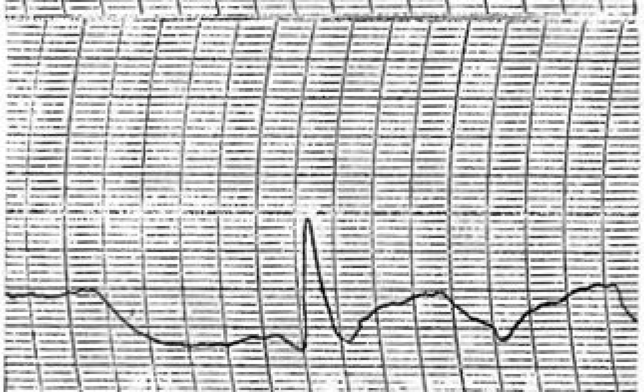
A. ACTUAL REPRESENTATIVE RECORDINGS FOR EACH SUBJECT



1.

2.

3.



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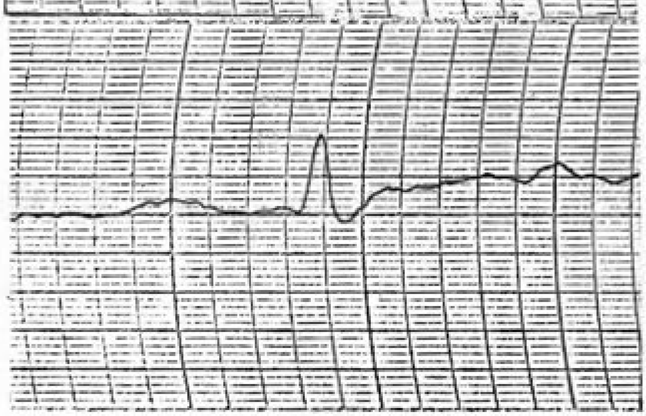
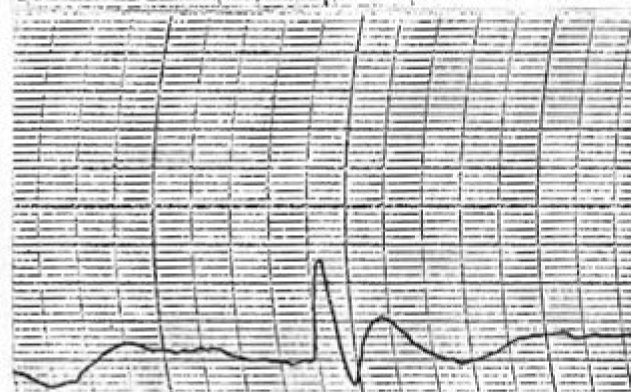


5.

6.

7.



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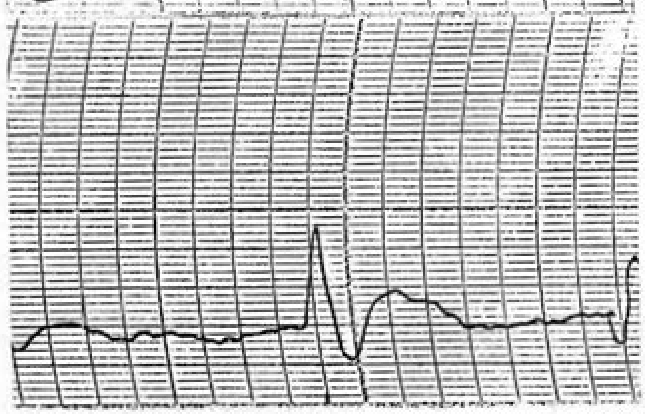


9.

IV. RESULTS

B. DATA

Responses	Plano b	Plano b'	+5.00 D b	+5.00 D b'	+8.00 D b	+8.00 D b'	Plano b	Plano b'
			SUBJECT # 1					
1.	5.5*	15.0	9.5	15.0	9.0	13.5		
2.	6.5	13.0	8.0	13.5	7.5	14.5		
3.	7.0	10.0	9.0	14.0	7.5	14.5		
4.	6.5	15.0	10.0	11.0	10.5	15.5		
5.	9.0	14.0	6.0	13.0	9.5	14.0		
6.	6.0	14.0	7.0	14.0	11.5	11.5		
7.	8.0	14.0	5.5	14.5				
8.	7.0	12.0	7.0	13.5				
9.	8.5	10.0	6.5	13.0				
	$\bar{x}_b$ = 7.1111		$\bar{x}_b$ = 7.6111		$\bar{x}_b$ = 9.2500			
	$\bar{x}_{b'}$ = 13.000		$\bar{x}_{b'}$ = 13.500		$\bar{x}_{b'}$ = 13.917			
			SUBJECT # 2					
1.	13.0	8.0	12.5	10.5	14.0	12.0		
2.	11.0	12.5	11.0	10.0	13.5	10.5		
3.	12.5	10.0	9.0	11.5	11.0	12.5		
4.	12.5	9.0	11.0	10.0	16.0	12.0		
5.	11.0	14.0	11.5	10.0	11.0	11.5		
6.	11.5	8.0	11.5	11.0	12.5	13.5		
7.	10.5		12.0	11.0	11.0	11.5		
8.	10.5	11.0	10.0	8.5	13.0	8.5		
9.	8.5	8.5	12.0	10.0	14.5	8.5		
10.	9.0	7.0	9.5	12.0	10.0	12.0		
11.			9.5	10.0				
12.			10.0	7.5				
	$\bar{x}_b$ = 10.9500		$\bar{x}_b$ = 10.7916		$\bar{x}_b$ = 12.6500			
	$\bar{x}_{b'}$ = 9.7777		$\bar{x}_{b'}$ = 10.1666		$\bar{x}_{b'}$ = 11.2500			
			SUBJECT # 3					
1.	12.0	9.0	8.5	12.5	15.5	16.5		
2.	6.0	10.0	14.0	15.5	14.5	32.0		
3.	9.0	9.5	10.5	17.0	11.0	13.5		
4.	9.0	16.0	12.0	12.0	9.0	26.0		
5.	5.0	14.0	11.0	15.0	8.0	23.0		
6.	9.0	11.0	10.0	18.0	9.0	25.0		
7.	9.0	14.5	9.0	21.5				
8.	8.5	8.5	12.0	20.0				
9.	11.0	22.0	10.0	22.0				
10.	7.5	13.0	9.0	18.0				
11.			10.5	18.5				
12.			9.5	21.0				
	$\bar{x}_b$ = 8.6000		$\bar{x}_b$ = 10.5000		$\bar{x}_b$ = 11.1666			
	$\bar{x}_{b'}$ = 12.750		$\bar{x}_{b'}$ = 17.5833		$\bar{x}_{b'}$ = 22.6666			

* All values are measured in millimeters and may be converted to millivolts by multiplying by .01 .

SUBJECT # 4

Responses	Plano b	Plano b'	+5.00 D b	+5.00 D b'	+8.00 D b	+8.00 D b'	Plano b	Plano b'
1.	22.5	11.5	17.5	16.5	38.0	32.0	11.0	17.0
2.	20.0	15.0	20.0	25.0	21.0	15.0	16.5	19.5
3.	18.0	10.0	20.0	23.0	18.5	19.5	14.0	13.0
4.	18.0	10.0	21.0	24.0	13.0	17.0	17.0	22.5
5.	23.0	14.0	23.0	23.0	19.0	16.0	16.5	15.5
6.	17.5	13.5	26.0	27.0	20.0	25.0	12.0	13.0
7.	20.5	16.0	23.5	21.5	15.0	11.0	14.0	14.0
8.	18.5		19.5	21.5	12.0	17.0	15.0	19.0
9.	15.0	14.5	17.0	12.0	17.0	16.5	18.0	13.5
10.			17.0	20.0				

	Plano	+5.00 D	+8.00 D	Plano
	$\bar{x}_b$ = 19.2220	$\bar{x}_b$ = 20.9000	$\bar{x}_b$ = 19.2780	$\bar{x}_b$ = 14.8888
	$\bar{x}_{b'}$ = 13.6025	$\bar{x}_{b'}$ = 21.3500	$\bar{x}_{b'}$ = 18.7777	$\bar{x}_{b'}$ = 16.3333

$\bar{x}_b$ = 17.0000

$\bar{x}_{b'}$ = 14.7941

SUBJECT # 5

Responses	Plano b	Plano b'	+5.00 D b	+5.00 D b'	+8.00 D b	+8.00 D b'	Plano b	Plano b'
1.	6.0	8.0	9.0	8.0	7.5	9.5		
2.	5.0	7.5	7.0	9.0	9.0	11.0		
3.	6.5	11.5	7.0	9.0	8.0	11.5		
4.	6.5	10.0	8.0	7.5	8.0	10.0		
5.	6.0	10.0	5.5	10.5	10.5	16.5		
6.	6.0	13.0	7.0	10.0	9.0	14.0		
7.	8.5	13.5	5.5	9.5	10.0	11.5		
8.	6.5	8.5	6.5	10.0	8.0	16.0		
9.	7.0	9.0			8.0	15.0		
10.	6.0	9.0	5.0	12.5	9.0	13.0		
11.	6.0	12.0	6.0	9.0	9.5	14.0		
12.	7.5	15.0	6.0	13.0	8.0	14.0		
13.	6.5	8.5	5.0	13.0	9.5	14.0		
14.			6.0	11.0	8.0	15.0		
15..			5.0	11.0	8.0	15.5		
16.			7.0	7.5				
17.			6.0	11.0				
18.			5.5	11.5				
19.			7.5	7.5				
20.			7.0	8.0				

	Plano	+5.00 D	+8.00 D
	$\bar{x}_b$ = 6.6153	$\bar{x}_b$ = 6.3947	$\bar{x}_b$ = 8.6666
	$\bar{x}_{b'}$ = 10.423	$\bar{x}_{b'}$ = 10.2576	$\bar{x}_{b'}$ = 13.366

Responses	Plano b	Plano b'	+5.00 D b	+5.00 D b'	+8.00 D b	+8.00 D b'	Plano b	Plano b'
SUBJECT # 6								
1.	2.0	5.0	3.5	6.5	4.0	6.0	3.0	4.0
2.	2.5	5.0	3.0	5.0	4.5	6.0	2.0	6.5
3.	2.0	4.5	3.0	5.0	5.0	6.5	2.0	4.0
4.	1.5	4.0	3.0	5.5	4.5	5.5	1.5	4.0
5.	2.5	6.0	3.0	4.5	5.0	5.0	2.5	4.0
6.	2.5	5.0	3.5	5.5	4.5	9.0	2.5	3.5
7.	3.0	3.5	2.5	4.5	3.0	5.5	2.5	5.0
8.	2.0	4.0	2.5	4.5	3.0	6.0	2.0	3.5
9.	2.5	4.0	2.5	4.5	3.0	5.0		
10.	2.0	4.0			4.0	5.5		
11.	3.0	3.0			3.5	5.5		
12.	3.0	3.0						
13.	3.0	4.0						
14.	1.0	3.0						
15.	4.0	4.0						
16.	3.0	4.0						
17.	2.5	5.5						
18.	1.5	4.5						
19.	3.5	4.5						
20.	2.0	5.0						
	$\bar{x}_b = 2.4500$		$\bar{x}_b = 2.9444$		$\bar{x}_b = 4.0000$		$\bar{x}_b = 2.2500$	
	$\bar{x}_{b'} = 4.2750$		$\bar{x}_{b'} = 5.0555$		$\bar{x}_{b'} = 5.9545$		$\bar{x}_{b'} = 4.3125$	

$\bar{x}_b = 2.3928$

$\bar{x}_{b'} = 4.2857$

Responses	Plano b	Plano b'	+5.00 D b	+5.00 D b'	+8.00 D b	+8.00 D b'
SUBJECT # 7						
1.	14.0	5.0	20.0	7.5	19.0	10.5
2.	10.0	7.0	15.0	10.0	20.0	10.0
3.	15.0	8.0	13.5	10.0	12.0	9.5
4.	12.0	11.0	8.5	9.0	17.0	19.0
5.	5.0	10.0	12.5	9.5	14.5	6.0
6.	6.0	7.0	13.0	13.5	14.5	9.5
7.	9.0	5.0	9.5	10.0	12.0	10.5
8.	13.0	7.0	13.5	10.5	12.0	10.0
9.	11.0	22.0	14.0	14.0	13.5	10.0
10.	5.0	7.0	15.0	12.0	14.0	9.0
11.			13.5	15.0		
12.			14.0	15.0		
13.			16.0	12.0		
14.			16.0	18.0		
15.			14.0	12.5		
	$\bar{x}_b = 10.0000$		$\bar{x}_b = 13.0000$		$\bar{x}_b = 14.8500$	
	$\bar{x}_{b'} = 8.9000$		$\bar{x}_{b'} = 11.9000$		$\bar{x}_{b'} = 10.4000$	

Responses	Plano F	Plano B	+5.00 D F	+5.00 D B	+8.00 D F	+8.00 D B	Plano F	Plano B
				SUBJECT # 8				
1.	12.0	12.5	9.0	9.0	15.5	9.5	8.5	8.0
2.	10.0	9.0	9.0	13.5	12.5	8.5	10.0	9.0
3.	9.0	14.0	8.5	11.0	12.0	22.0	10.0	10.5
4.	9.0	9.5	9.0	9.0	11.0	14.5	9.0	10.0
5.	9.5	8.0	10.5	11.5	12.5	22.0	9.0	9.0
6.	8.0	8.5	8.0	13.5	12.0	20.0	10.0	10.0
7.	8.5	9.0	8.5	10.0	11.0	13.5	10.0	9.0
8.	8.0	8.5	8.5	12.5	10.0	12.5	9.5	15.5
9.	9.0	7.5	8.0	10.0	10.5	10.5	9.0	10.5
10.	9.0	8.5	12.0	14.0	10.0	8.5	10.0	14.0
11.	8.0	8.0	9.0	7.0	12.5	15.5	9.0	9.5
12.	8.0	8.0	7.0	11.0	11.5	10.0	9.0	9.0
13.	8.5	8.0	9.0	13.5	10.5	13.5	10.5	13.0
14.	9.0	8.0	10.5	14.5	10.5	11.5	8.0	8.0
15.	8.0	7.0	8.0	13.5	10.0	14.0	10.0	9.0
16.	9.0	9.0	9.0	14.0	9.0	14.0	11.0	10.0
17.	6.5	8.5	9.5	14.0	12.5	12.5	11.0	10.0
18.	8.0	9.5	9.5	9.0	10.5	17.0	10.0	13.0
19.			9.0	11.0	10.0	9.0	9.0	9.0
20.			11.0	10.0	12.0	20.0	9.5	15.5
21.			8.0	9.0	10.0	11.0	9.0	8.0
22.			8.0	16.0	11.0	16.0		
23.			9.0	15.0	10.5	14.5		
24.			8.5	15.0	12.0	15.0		
25.			10.0	12.5				

Plano	+5.00 D	+8.00 D	Plano
$\bar{x}_b = 8.7222$	$\bar{x}_b = 9.0400$	$\bar{x}_b = 11.2291$	$\bar{x}_b = 9.5714$
$\bar{x}_{b'} = 8.9444$	$\bar{x}_{b'} = 11.960$	$\bar{x}_{b'} = 13.9583$	$\bar{x}_{b'} = 10.4523$

$\bar{x}_b = 8.9499$

$\bar{x}_{b'} = 9.5124$

Responses	Plano		+5.00 D		+8.00 D		Plano	
	b	b'	b	b'	b	b'	b	b'

SUBJECT # 9

1.	12.0	12.0	16.5	13.0	22.5	14.0	6.0	7.5
2.	11.0	13.0	13.5	15.0	11.0	15.0	10.5	9.0
3.	7.5	15.0	12.5	13.0	11.5	10.0	10.5	6.5
4.	9.5	9.0	12.5	11.5	11.5	17.0	8.0	11.0
5.	10.0	11.0	11.5	12.5	11.5	12.5	8.0	5.0
6.	10.5	9.0	10.0	10.0	11.0	10.5	8.0	---
7.	8.0	8.0	8.5	10.0	8.0	8.0	9.0	7.0
8.	7.0	13.0	11.5	11.5	8.0	16.5	7.0	---
9.	11.0	20.0	8.5	---	9.0	9.0	13.5	9.0
10.	11.5	18.5	12.0	9.0	9.0	8.0	10.0	10.0
11.	10.0	12.0	14.0	20.0	8.0	8.0	9.0	17.0
12.	9.5	8.5	12.5	15.5	10.5	20.5	10.0	14.0
13.	9.0	10.0	10.5	14.0	8.0	17.0	9.0	9.0
14.	11.0	7.0	9.5	12.5	8.0	18.0	8.0	9.0
15.	10.0	11.0	11.0	22.5			8.0	11.0
16.	10.0	13.0	11.0	25.0			9.0	8.0
17.	10.5	25.0	9.0	14.0				
18.	13.0	8.0	9.0	12.0				
19.	9.0	5.0	11.0	11.0				
20.	10.0	10.0						
21.	9.0	12.0						
22.	10.0	8.0						
23.	10.0	7.0						
24.	7.0	9.0						
25.	7.0	8.0						
26.	10.0	11.0						
27.	6.0	10.0						

Plano	+5.00 D	+8.00 D	Plano
$\bar{x}_b$ = 9.5555	$\bar{x}_b$ = 10.8500	$\bar{x}_b$ = 10.5000	$\bar{x}_b$ = 9.0000
$\bar{x}_{b'}$ = 11.2777	$\bar{x}_{b'}$ = 14.6500	$\bar{x}_{b'}$ = 13.4642	$\bar{x}_{b'}$ = 9.5000

$\bar{x}_b$ = 9.3488

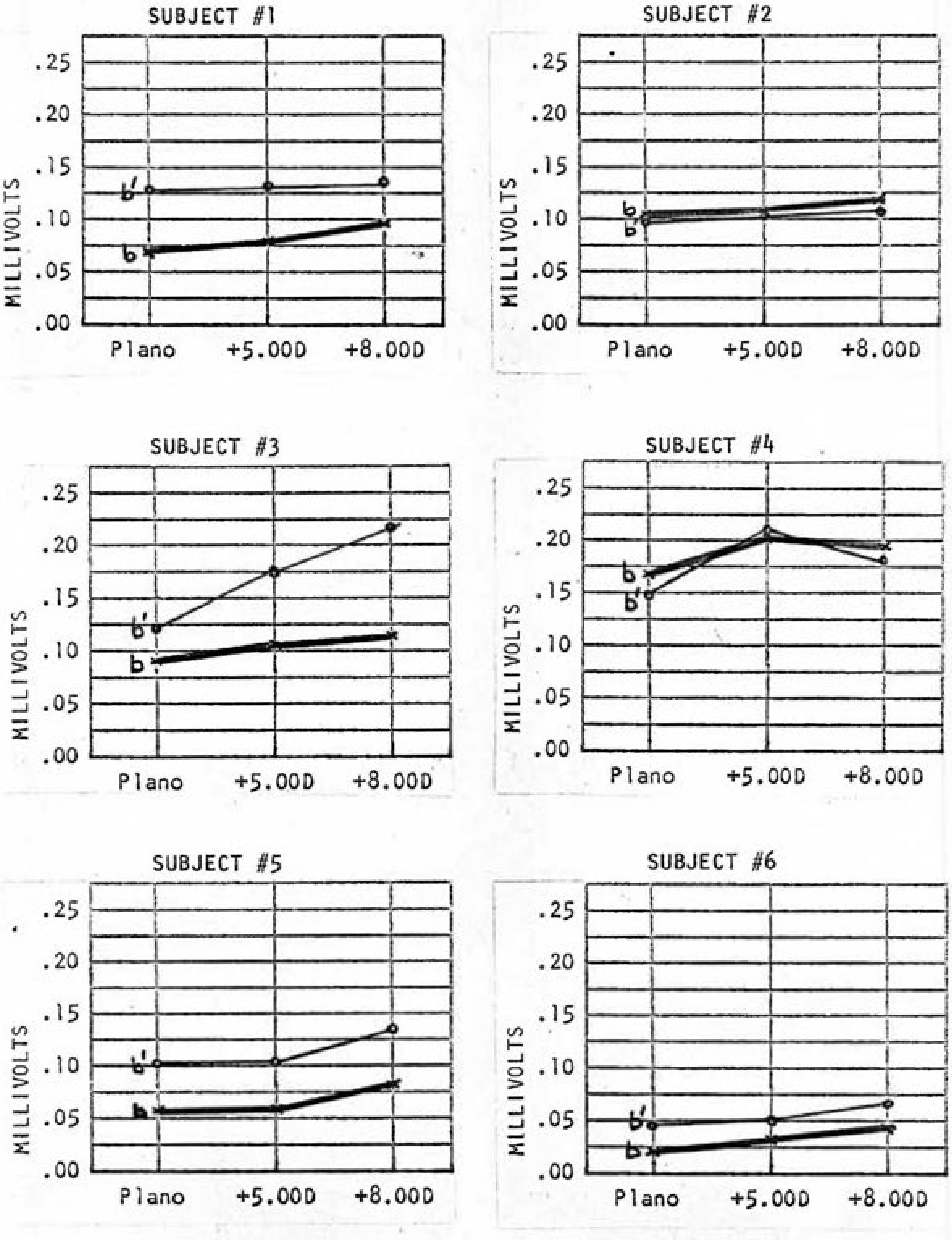
$\bar{x}_{b'}$ = 9.7325

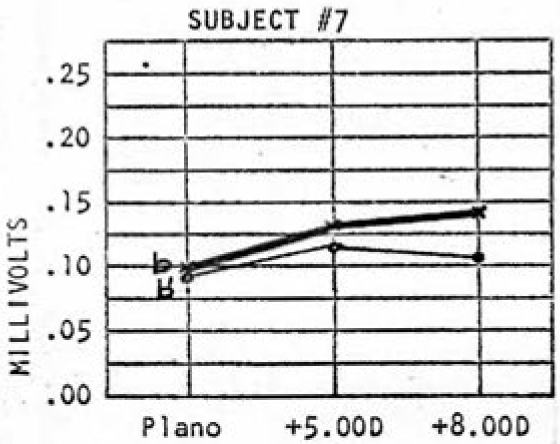
$\bar{X}_{\bar{x}_b}$	8.9964	10.1757	11.2878
$\bar{X}_{x_{b'}}$	10.3528	12.9358	13.7505

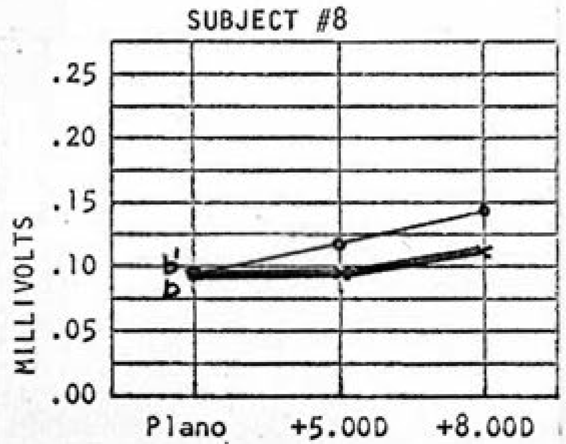
Mean values of all of the b and b' waves for all nine subjects.

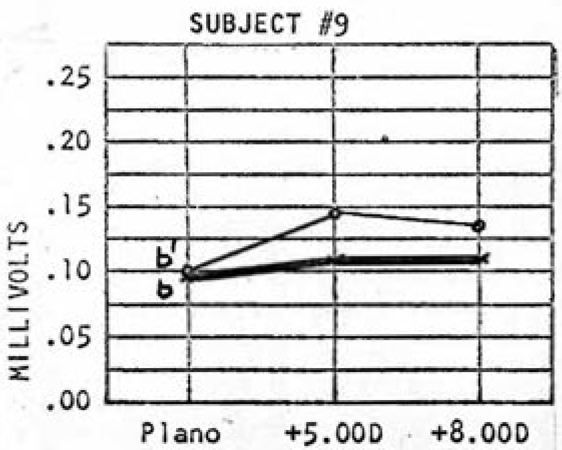
Fig.

Individual relationships resulting from lens changes, converted into millivolts.




SUBJECT #7
.25
.20
.15
.10
.05
.00
MILLIVOLTS
b'
b
Plano
+5.00D
+8.00D


SUBJECT #8
.25
.20
.15
.10
.05
.00
MILLIVOLTS
b'
b
Plano
+5.00D
+8.00D


SUBJECT #9
.25
.20
.15
.10
.05
.00
MILLIVOLTS
b'
b
Plano
+5.00D
+8.00D

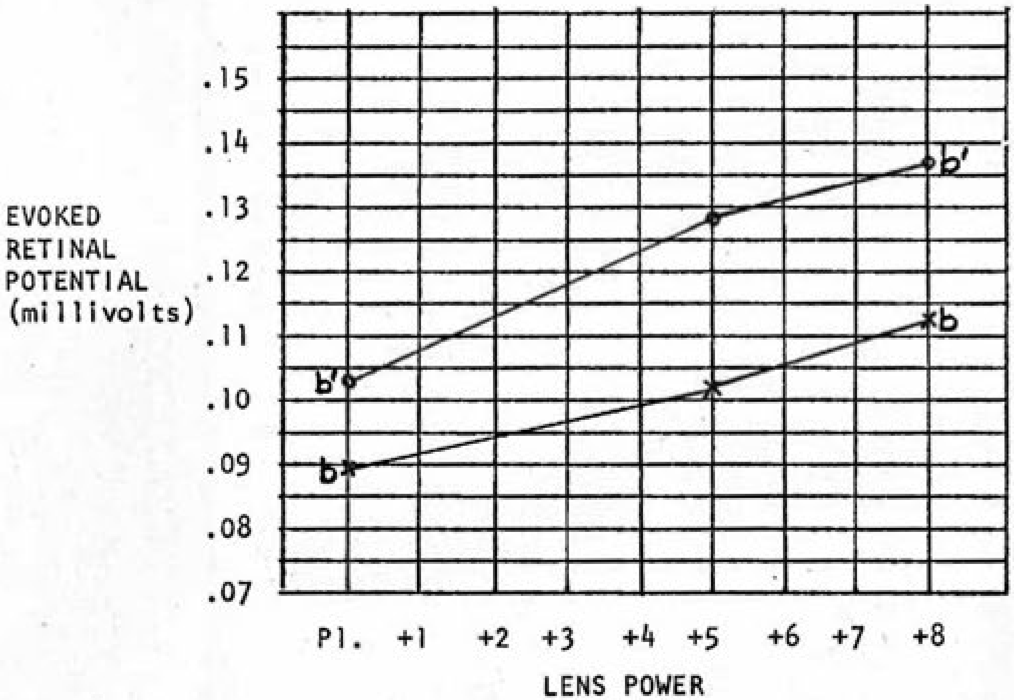


Fig. The average of the b and b' wave amplitudes due to lens power changes for the total nine subjects.

C. ANALYSIS

Data were collected on fifteen male subjects aged 23 to 31, of whom nine were included in this study. The first six subjects' data were excluded as the authors were then directing their efforts toward mastering the techniques involved.

The amplitude of the b-wave was measured in the standard clinical manner as noted previously. The b'-wave amplitude was also measured using Marg's method. Consistent responses obtained at each lens strength were averaged for both b and b'. Temporal chacteristics were measured and found to show negligible changes from lens to lens and subject to subject. The duration of the b-wave was estimated by randomly selecting two hundred responses from all the subjects. The mean duration was .21 seconds with a sigma of .02 seconds.

The students t-test utilizing the mean differences was used to compare the b- and b'-wave amplitudes for the various lens strengths (Table 2).

TABLE 2
P Values Calculated With Students t-test for 3 lens Strengths and b- and b'-wave Amplitudes

	Plano to +5.00 D	+5.00 D to +8.00 D	Plano to +8.00 D
p for b-wave amplitude	between .05 and .10	between .10 and .20	between .010 and .025
p for b'-wave amplitude	between .10 and .20	above .50	between .05 and .10
$\bar{d}$ ± S.E.* for b-wave amplitude	1.8502 ± .8863	.7738 ±.5378	2.6171 ± .9464
$\bar{d}$ ± S. E. for b'-wave amplitude	1.692 ± 1.1062	.4099 ± .6325	2.1452 ± .9824

*Mean difference ± standard error

V. DISCUSSION

This study has shown that when a +5.00 D or +8.00 D lens was placed before a refractively corrected eye, an increase occurred in the amplitude of the b-wave of the ERG. The authors could find no evidence that a study of this kind, using similar stimuli and/or methods had been reported.

A possible explanation for this increase in the amplitude of the b-wave assumes that the amplitude of the b-wave is a function of the total number of retinal receptors discharging. The refractively corrected eye places a sharply defined checkerboard image on the retina and the total area of the retina receiving the stimulus is at a minimum. As plus lenses are added the retinal image becomes less sharply defined and light originally confined to the bright areas invades the formerly dark areas. as the lens power increases to eight diopters, the subjects reported a uniformly diffuse blur.

Both Granit[32] and Jacobson[33] have shown that an increase in the amplitude of the b-wave is proportional to the logarithm of the stimulus intensity for intermediate intensities (Fig. 21). At

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[32] Granit, op. cit., p. 149.

[33] Jacobson, op. cit., p. 14.

lower intensities, the b-wave response is proportional to the fourth root of the stimulus intensity. At very high intensities the logarithmic curve flattens and little increase or even a decrease of the response is noted beyond a certain high level of stimulation. For this reason our stimulus is of intermediate intensity or luminance as noted in the apparatus section. For the condition of sharp focus the bright areas of the retinal image are

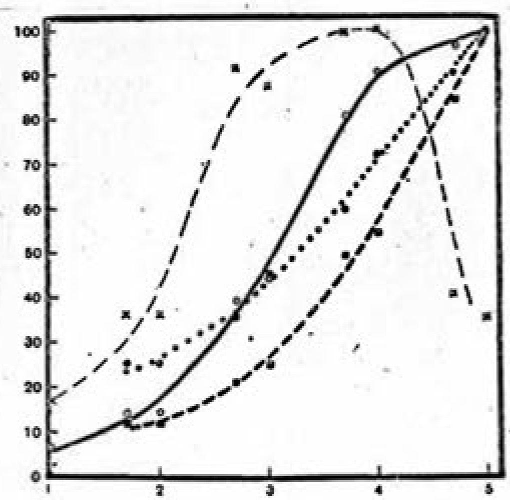

FIGURE 23 Effects of increasing the intensity of the stimulus on the electrical reactions of the cat retina. o-o size of *b*-wave; --- rate of rise of *b*-wave; .... reciprocal of latent period; x---x size of *c*-wave. Abscissae: log I. Ordinates: response as percentage of the maximum. (Granit, 1932, Report Physiol. Opt. Soc. Discussion on Vision, London)

responding to a stimulus of high luminance (9.5 fl). The dark areas do not respond due to a stimulus of low luminance (.025 fl). When the +8.0 D lens is used, the luminance of the formerly bright areas is reduced which produces a corresponding reduction in the contribution to the b-wave response from those areas. However, since this is a logarithmic function the reduction in b-wave amplitude will be relatively slight. The formerly dark areas will experience a luminance increase of the same magnitude as the formerly bright areas luminance was decreased. Again, since this is a log function, the resulting contribution to b-wave amplitude for these areas will be relatively large. The net effect will be an increase in recorded b-wave amplitude.

Marg[34] (Fig. 7) observed that as the area of retina illuminated increased there was a corresponding increase of the b'-wave. Our study confirms this point, since we believe that in going from plano to +8.00 D, we effectively increased the area of the retina illuminated. The t-test for plano to +8.00 D for the b'-wave gives a p of between .10 and .05.

Marg also reported that as the area of the retinal image increased the b-wave showed a brief increase in amplitude and then a rapid decrease. This is in apparent conflict with our observation of an increase in b-wave in going from plano to +8.00 D. This problem is resolved by considering the manner in which the retinal images increased in area. Marg's retinal areas increased by increasing in overall dimensions thereby involving more of the peripheral retina. Our target retained its overall dimensions and maintained the same peripheral to central relationship.

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[34] Marg, op. cit., p. 418.

Barlow[35] using microelectrode techniques on the frog retina found that the central receptive field was surrounded by an inhibitory periphery. Thus, extending illumination to this periphery while maintaining that of the center constant led to a reduction in activity of the center. As Marg's stimulus increased in size more peripheral areas of the retina were stimulated which presumably caused a decrease in the b-wave amplitude by inhibiting the central fields. Since our overall size remained constant we were able to minimize this peripheral-central interaction.

Harter and White found that visually evoked cortical potentials varied as a function of the sharpness of the retinal image. We speculated that the differences in cortical potentials might be traced to the retinal end of the visual pathway and may be found through analysis of the ERG. Our intent was to determine what, if any, contribution to the evoked cortical potential could be traced to the retina. We found that the b-wave amplitude did change with changes in retinal image quality. It is our conclusion that the ERG is sensitive to retinal image quality and that the ERG does have some connection with the cortical evoked potential.

A possible study that could be performed is to use the same stimulus variables and simultaneously record the ERG and cortical evoked

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[35]Ragnar Granit, Receptors and Sensory Perception, Yale University Press, New Haven, 1955, p. 74.

potentials. A more direct relationship would then be more evident.

VI. SUMMARY AND CONCLUSION

This study accomplished two results: (a) first there was the development of facilities at Pacific University College of Optometry for obtaining valid ERG recordings; (b) secondly the apparatus was utilized to study the possible b-wave changes from blurring of the retinal image. ERG's for nine male subjects were recorded while they fixated on a checker-board target. Lenses equal to the subjects refractive error, (R.E. + plus 5.00 D) and (R.E. + plus 8.00 D) were interposed before the eye at the spectacle plane. The results showed that: (1) amplitude of the b-wave increased with increase in plus lens power, and (2) the amplitude of the b'-wave also increased with an increase in plus lens power. The results suggest that there is a retinal mechanism operating that discriminates between sharp and blurred retinal images.

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