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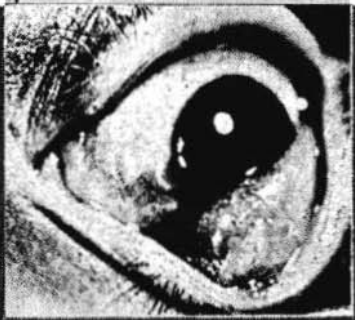

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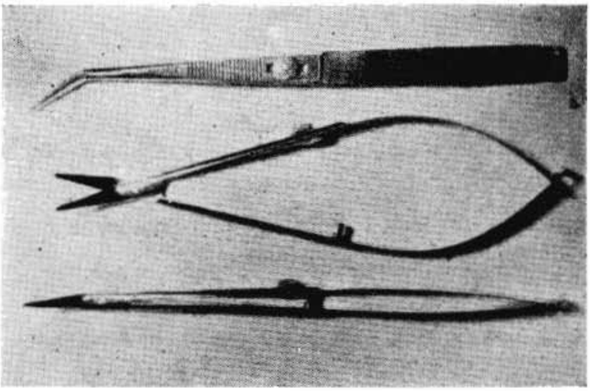

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A PROPOSITO DE UN CASO DE OSTEOPETROSIS

POR

ENRIQUE ARIZA HENAO, M. D.

Bogotá - Colombia

Por su rareza clínica y trascendencia oftalmológica, la osteopetrosis o enfermedad marmórea de los huesos justifica el interés que ha despertado a través de los estudios y recopilaciones existentes.

Descrito por Albers y Schönberg en 1904, el síndrome se caracteriza por marcadísimo aumento de la densidad de los huesos del esqueleto que incluye los de la base del cráneo, respetando su bóveda.

Histológicamente el proceso es una anomalía de osteogénesis, consistente en falla de los procesos reabsortivos lo que determina el progresivo espesamiento de la corteza ósea con estrechamiento del canal medular.

La falta de elasticidad resultante, es responsable de la gran fragilidad y predisposición a las fracturas en tales pacientes.

Su carácter hereditario y el desconocimiento íntimo de su etiología ha dado lugar a múltiples hipótesis que no satisfacen plenamente.

La afección es muy poco frecuente, hasta el punto de que hasta 1940 solamente se habían descrito y recopilado 118 casos (Vidgoff-Bracher); en nuestro país, no tenemos conocimiento de ningún caso reseñado.

Radiológicamente, el cráneo presenta en las placas antero-posteriores un signo patognomónico al que hemos denominado "*Imagen en antifaz*", por su singular parecido a tal prenda de disfraz (Fig. 1) y que se realiza a expensas del borramiento de las cavidades sinusales y de la predilección con que la enfermedad ataca el área en cuestión.

Cabe anotar que el proceso esclerosante puede extenderse a gran parte de los huesos que constituyen la bóveda, peculiaridad del caso que posteriormente describiremos (Fig. 2).

Según Pirie, la enfermedad puede hacerse radiológicamente aparente en el feto, pero acostumbra a evidenciarse en la primera infancia y continuar a lo largo de la vida.

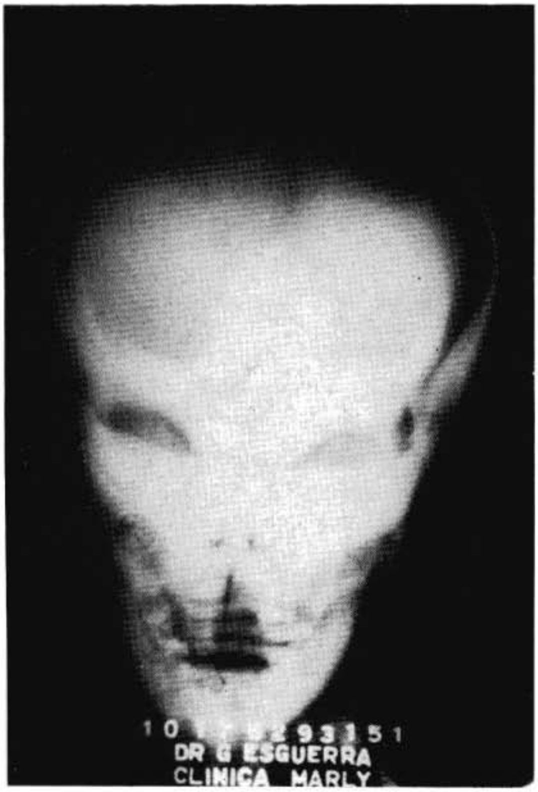

Fig. 1.– Radiografía anteroposterior del cráneo mostrando el signo radiológico que hemos denominado "signo del antifaz".

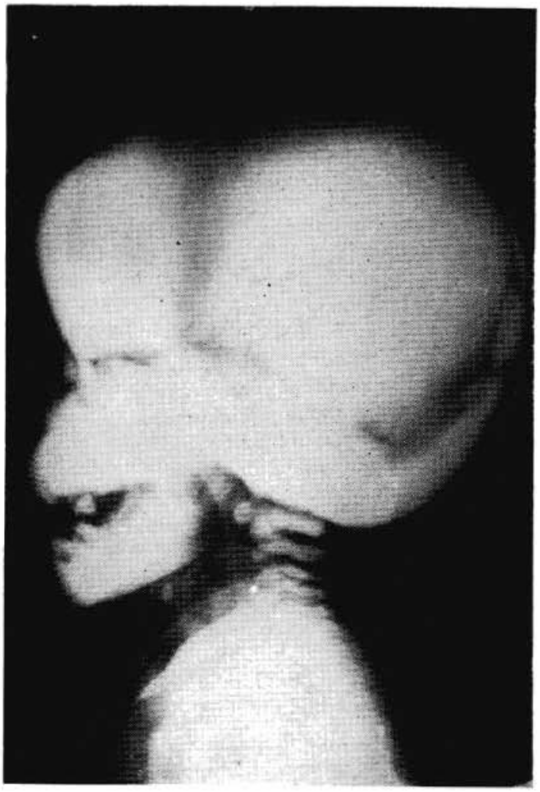

Fig. 2.—Radiografía lateral del cráneo que permite observar la extensión del proceso esclerosante a los huesos de la bóveda.

La osteopetrosis produce disminución de las cavidades orbitarias y estrechamiento de los conductos ópticos con proptosis y atrofia progresiva del II par que frecuentemente lleva a la ceguera.

En cuanto al pronóstico vital, debe señalarse la posibilidad de anemias mieloplásicas terminales, debidas a la desaparición progresiva de la medula ósea.

Existe una manifestación similar a la descrita, con parecidos signos radiológicos, pero asociada a la enfermedad de Hodgkin y que se diferencia de la osteopetrosis por originarse en el tejido linfoide, ser de aparición mucho más tardía y no reducir los conductos ópticos.

El carácter craneodisostósico de la enfermedad le otorga manifestaciones típicas de tales síndromes: exoftalmía, exotropía, defectuosa implantación dentaria y alteraciones nasales.

Fig. 3.—Radiografía de base de cráneo en la que se ve la gran invasión de la escama occipital, circunstancia poco frecuente.

Fig. 4.—Radiografía de pelvis y fémures en la que se aprecian indemnes las epífisis de los huesos largos, característica típica de la enfermedad, que explica la predilección de las fracturas por la unión epífiso-diafisiaria.

En algunos casos presenta sindactilia, síntoma común de la enfermedad de Laurence-Moon-Bield.

En otros, la forma de la frente y las alteraciones del puente nasal, junto con el aspecto de los dientes, acostumbra a confundirla con las manifestaciones hereditarias de la sífilis. El diagnóstico de certeza se basa siempre en los hallazgos radiográficos descritos.

Caso Clínico

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Niña de once meses de edad, a quien los padres han notado deficiencia visual y "falta de interés" por el medio que la rodea.

Los padres afirman que no existen antecedentes familiares de ceguera o disminución grave de la agudeza visual.

Paciente nació a término mediante cesárea y fue sometido a la incubadora durante 24 horas por "afección respiratoria". No hay antecedentes patológicos diferentes a los que motivan la consulta.

La niña tiene peso y tamaño dentro de límites normales.

Fig. 5.—Radiografía de la porción distal del antebrazo y de la mano mostrando el gran aumento de la densidad del radio y cúbito que llega hasta las propias epífisis.

Fig. 6.—Radiografía de pierna y pie con las mismas características de hiperdensidad diafisiaria.

Reflejos musculares satisfactorios.

Frente de tipo "olímpico".

Marcada alteración en la forma e implantación de los dientes.

Lagrimeo de ambos ojos.

A la palpación el saco lagrimal es ectásico y por compresión evacua contenido seroso.

Nistagmus horizontal muy aparente.

Medios de transparencia satisfactoria.

Atrofia simple parcial del II par de ambos ojos.

La radiografías craneales y esqueléticas hacen el diagnóstico de enfermedad marmórea de los huesos.

Resumen

Se presenta un caso avanzado de síndrome de Albers-Schönberg, que tiene como particularidad la gran invasión de los huesos de la bóveda craneal y la presencia de dacriocistitis resultante de la estenosis de los canales lagrimales a nivel de su trayecto óseo.

Se describe el "signo del antifaz", patognomónico de la enfermedad y siempre claramente visible en las radiografías antero-posteriores del cráneo.

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BIBLIOGRAFIA

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MAGDALENA CASTIÑEIRA JAIME (1962) Arch. Soc. Oftal-Amer., XXII, pág. 487.

Arch. Soc. amer. oftal. optom. (1962) - **4** - 137

A SERVOANALYSIS OF THE HUMAN ACCOMMODATIVE MECHANISM

BY

JOHN H. CARTER, O. D.

Philadelphia - Penn.

ACKNOWLEDGEMENTS:

This study was undertaken in the laboratories of the Division of Oftometry, Indiana University, Bloomington, Indiana. It was made possible in part by a National Science Foundation Grant, number G - 19302. The author is greatly indebted to Dr. M. J. Allen for his invaluable assistance in the execution of this study as well as for the use of a number of pieces of equipment of his original design.

ABSTRACT

The accommodative mechanism of the eye appears to function as a servomechanism, an error-actuated, self-regulating, feedback control device. Cybernetic approaches were applied to the ocular accommodative mechanism in an attempt to define various system parameters.

The most satisfactory model of the human accommodative mechanism seems to be a first order servo with a time delay of approximately 250 milliseconds and a dead zone. It has a time constant of approximately 275 milliseconds.

Satisfactory open-loop data could not be obtained since gain changed with volition. Repeatable closed-loop data were obtained and an attempt was made to formulate a transfer equation for the accommodative system, utilizing constants consistant with those derived from transient response data. Although an equation was derived yielding a satisfactory fit of the empirical frequency response curve, it defined a regenerative system and therefore had to be rejected.

When, under open-loop conditions, a negative accommodative stimulus was provided, the subject responded with positive accommodation. This suggests that the subject's eye was not able to recognize the polarity of the stimulus.

The influence of volition upon accommodative response and the inability of the subject to respond differentially to pre-focal and post-focal blur (in the absence of accommodative tracking) tend to throw considerable doubt upon the assumption that the accommodative mechanism is purely reflex.

INTRODUCTION

Accommodation is the dioptric adjustment of the eye to attain maximal sharpness of retinal imagery for an object of regard. The present investigation is based upon the premise that the accommodative mechanism functions as a servomechanism - an error actuated feedback control device. As such, it is subject to investigation using servoanalytic methods. Basically, these methods consist of quantitative investigation of the mechanism's transient response (response to a step input) and frequency response (response to a steady-state sinusoidal input).

Indeed, it was found that such methods of testing are applicable to the human accommodative mechanism, although the response of this mechanism does not appear to be fully automatic after the fashion of the pupil.

EQUIPMENT

General Instrumentation:

The present investigation utilized an infrared optometer to monitor accommodation, together with a number of pieces of auxiliary equipment. Figure 1 shows the master control section for equipment used in this study, together with a Tektronix Nº 502 dual-beam cathode ray oscilloscope and its associated Hewlett packard record camera.

The upper deck of the master control unit consists of a section which provides regulated and unregulated voltages to the remaining sections. The second section houses a Tensor Arbitrary Function Generator, Model 5846. In addition, it contains electronic filters and two 50 K precision potentiometers for voltage adjustment. The third section of the master control unit contains two precision resistance decades and gain and zerobalance controls for the Arbitrary Function Badal Optometer.

The fourth deck of the master control unit contains a precision voltage calibrator and a high-impedence voltmeter, used to monitor the action of the Arbitrary Function Badal Optometer target.

Three units for providing accommodative stimuli were utilized with the infrared optometer. The first of these was the Arbitrary Function Badal Optometer unit for the left eye, consisting of a high-speed rectilinear galvanometer which controls the position of a Snellen target with respect to a color-corrected ten diopter lens. It was used in the present study to provide sinusoidal dioptric signals.

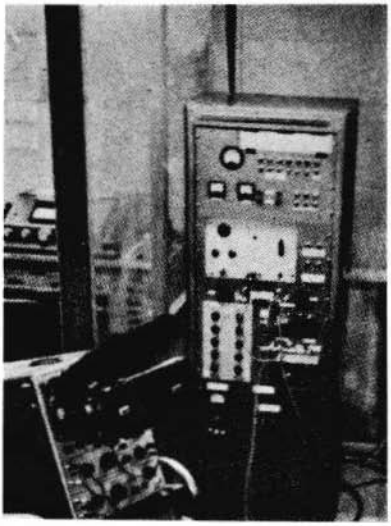

Fig. 1. Master control section for equipment utilized in the servoanalysis of the human accommodative mechanism.

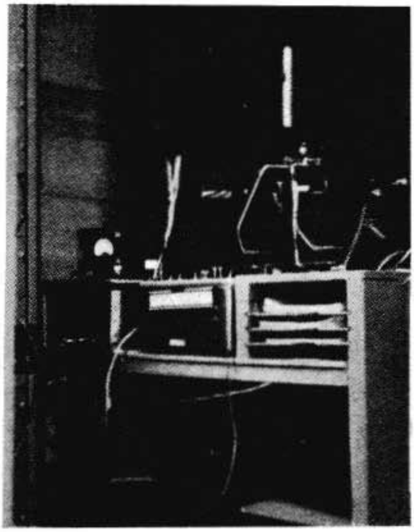

Fig. 2. The Allen infrared optometerhaploscope.

The second auxiliary unit employed was the Badal Step-function Optometer for the left eye. This unit was used for the analysis of the open-loop transient response of the accommodative mechanism.

The third stimulus unit employed was the Badal Step-function optometer for the right eye. This optometer was used in the investigation of the closed-loop transient response of the accommodative mechanism.

The Self-recording Infrared Optometer:

The self-recording optometer[1] used in this study was part of a haploscope designed for the Air Force by Allen [2]. In the present investigation, slight modification of the previously existing instrument was made to render it more suitable for obtaining frequency response information. Figure 2 shows the Allen haploscope-optometer combination and figure 3 shows the transient response of the infrared optometer. Figure 4 is a schematic eye calibration curve and figure 5 is a calibration curve for subject J. S., obtained by fixing the refractive power of the eye by means of cycloplegia and providing incremental changes in effective refractive state by means of trial lenses.

The Step-function Optometer for the Right Eye:

A Badal optometer system capable of presenting alternately two different dioptric stimuli to the right eye was used in studying the closed-loop transient response of the eye, as well as the response of the human accommodative mechanism to an optical rectangular input. Figure 6 is a photograph of the step-function optometer used for the right eye. A dicroic mirror deflects visible (but not infrared) radiation from the stimulus target into the subject's right eye.

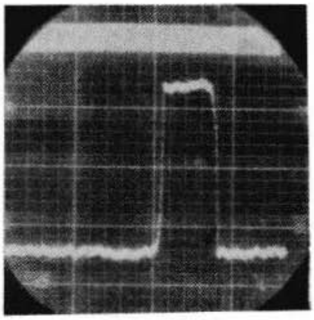

Fig. 3. Transient response of the Allen infrared optometer. 20 c.p.s. time mark.

The step-function optometer for the right eye contains two separate target systems. The upper systems has a ten diopter range and is used to project a Snellen target into the Badal Optometer below. A removable target in the lower system with a seven diopter range is used to suddenly introduce a stimulus at a different dioptric level. When this second target is brought within the tube of the lower optometer by means of a solenoid, a diffusing screen obscures the projected image from the upper system. The action time of the rotary solenoid controlling the removable target is 20 milliseconds.

When no current is allowed to flow through the rotary solenoid, the projected target is seen. When the solenoid is activated, the lower target moves into place.

Current to the solenoid can be swiched manually, or automatically by connecting the solenoid to a cam-actuate microswitch within the Tensor Generator. A simultaneous voltage presented to one channel of an oscilloscope provides a signal marker.

The Step-function Optometer for the Left Eye:

The left-eye Step-function optometer system provided optical step signals for investigation of the open-loop transient response of the human accommodative mechanism. Figure 7 is a photograph and figure 8 is a schematic diagram of this step-function optometer. In figure 8, C is a ten diopter achromatic lens situated ten centimeters before the entrance pupil of the eye. M is a beam splitter which transmits light originating from T1 and reflects light from T2. T1 and T2 are transilluminated by light from L, passing through diffusing plates, FG. Each target assembly is movable in the direction indicated in figure 8 by a double-headed arrow.

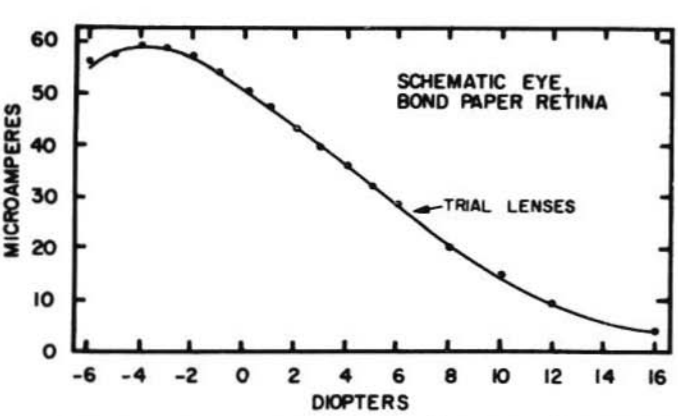

Fig. 4. Schematic-eye calibration of the Allen infrared optometer.

Operationally, T1 and T2 were positioned with respect to scales calibrated in diopters, and the stimulus value was changed between two desired dioptric levels by energizing one or the other light source. A low-level current was allowed to pass through the non-illuminated filament at all times, thereby keeping the filament sufficiently warm to be barely visible in an otherwise totally dark room. This, in association with a moderate overvoltage of the filament during its "on" phase, reduced the instrument rise time to approximately 18 milliseconds.

Voltage from across one bulb was fed by way of an attenuating potentiometer to one channel of the Tektronix Nº 502 oscilloscope, thereby providing a signal marker.

The Arbitrary-function Optometer:

The arbitrary-function optometer consists of a front-illuminated Snellen target, driven by an arm connected to the pen of a Massa* rectilinear galvanometer, type, M - 133, having a DC resistance of 1,000 ohms. Figure 9 shows the construction of the Arbitrary function optometer. A supporting structure, which could be clamped to the haploscope table in any desired position, held a laboratory jack. On top of the laboratory jack was affixed a brass plate, milled with a linear groove which in turn was mated to a corresponding projection on the base of the galvanometer carrier. The galvanometer could be moved along a line parallel to the orientation of the left haploscope arm.

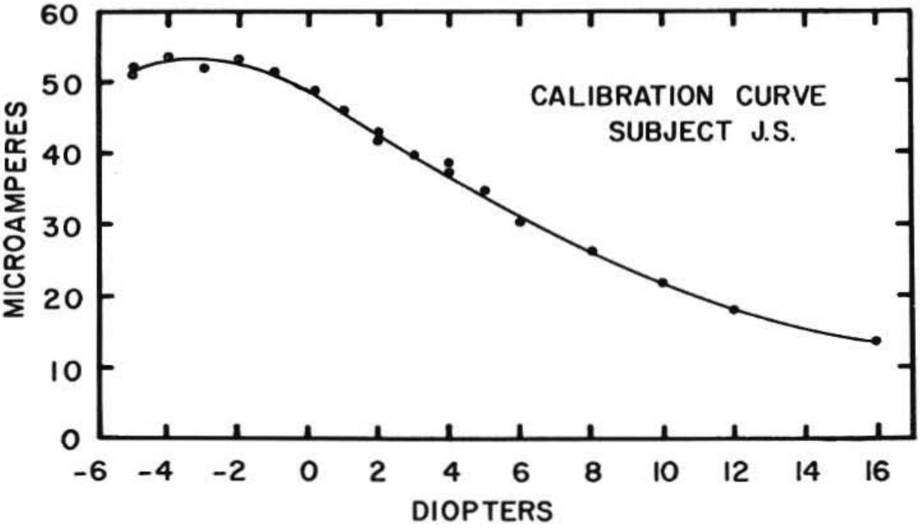

Fig. 5. The infrared optometer calibration curve for subject J. S. To derive this curve, the accommodation of S's right eye was paralyzed and the refractive status of that eye was altered by means of trial lenses.

A small aluminum plate was comented to the side of the galvanometer so that it projected parallel to the galvanometer pen. A hole drilled in the plate adjacent to the pen tip held a sleeve-bearing supporting in turn a thin rod which was attached to the tip of the galvanometer pen. A reduced Snellen chart was attached to a plate mounted upon the free end of the rod. The locus of the pen tip was aligned with the rod and with the optic axis of the left haploscope arm. An acro-

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* Massa Laboratories, Inc.
Hingham, Mass.

matic lens of ten diopters was used to complete the optometer, and a millimeter scale (used for calibration purposes) was attached to the lens mounting, parallel to the locus of the reduced Snellen chart. The gross (DC) accommodative stimulus level was obtained by movement of the galvanometer carrier across its specially constructed stage, while fine (DC) accommodative stimulus level adjustment was accomplished electrically.

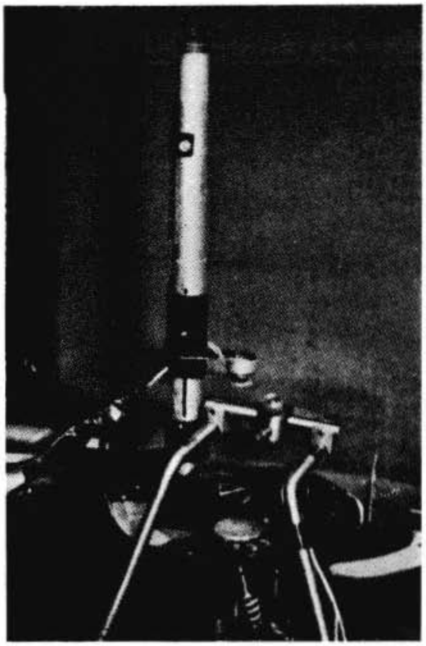

Fig. 6. Step-function optometer for the right eye.

Figure 10 shows the control circuit for the Arbitrary-function optometer. The Tensor* Arbitrary function generator, model 5846, supplies suppressed-carrier modulation of a 1½ KC sine wave. The output is (band-pass) filtered and then amplified by a Heathkit** hi-fidelity amplifier, model EA - 3. It is then fed by way of a step-up transformer into a full-wave bridge and thence to an integrating circuit. The resulting demodulated voltage is applied between the grids of a differential power amplifier with a cathode follower output. The AC accommodative stimulus level is set by means of a vernier gain control on the heathkit amplifier,

---

* **Tensor Electric Development Corp.**
Brooklyn, 33, N. Y.

** **Heath Company**
Benton Harbor, Michigan.

while the DC stimulus level adjustment (fine) is made by means of a vernier-controlled balance adjustment on the differential power amplifier.

Although the Tensor generator can be used to provide any desired function in the frequency range of 0.001 to 10.0 cps, it was used in the pressent investigation only for the purpose of providing sinusoidal and rectangular stimuli.
When used to supply a sine wave, it exhibits maximum harmonic distortion of 3%. Hum distortion is rated as down 45 db.

The output of the Arbitrary-function optometer control circuit was monitored continuously by a high impedence voltmeter, and by one channel of a (vernier-controlled) Tektronix Nº 502 dual beam cathode ray oscilloscope. This Latter arrangement permitted photographic recording of the stimulus to accommodation at a variable (calibrated) scale factor.

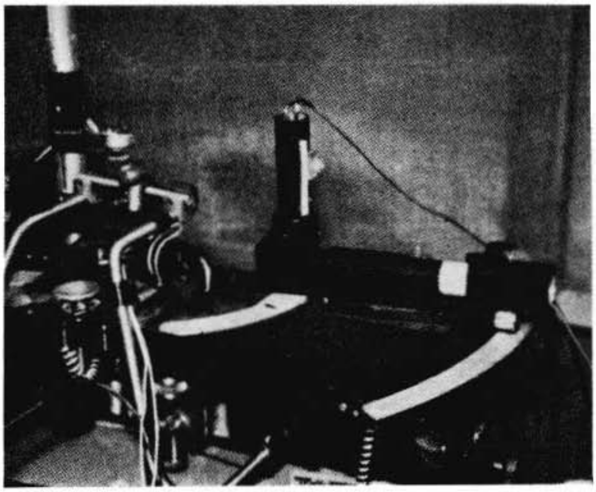

Fig. 7. Step-function optometer for the left eye.

EXPERIMENTAL SUBJECT

It was felt advisable to obtain extensive data with a single subject who could be well trained, rather than to obtain data on a larger number of less well trained subjects. The present study is concerned with general servo-characteristics of accommodation and individual variations were felt not to be important, although they undoubtedly exist.

The subject, J.S., a 22 year old caucasian male, satisfied the criteria established for this investigation. He had a corrected visual acuity in each eye of 20/20, with cycloplegic refractive findings of:

R -1.25 DS c -0.25 DC X 70
R -1.25 DS c -0.25 DC X 125

His ACA ratic (based upon blur points) was 3.6 to 1, and his amplitude of accommodation in each eye was ten diopters, measured by the technique of Donders.

Undoubtedly, human beings use all cues available, including psychic and various binocular cues, in the control of focus of the eye. When an individual is placed in a situation in which most of these cues are absent (Badal Optometer), and only retinal image blur and associated phenomena are present, he frequently is unable to control his accommodation efficiently and must learn to do so.

Prior to actual data taking, the subject was practised in responding to both step and steady-state accommodative stimuli. Three training sessions, each of roughly two hours duration, were undertaken with stimuli presented over a wide frecuency range, but at frequencies not exceding those at which the subject reported difficulty in tracking. It was felt that in the absence of such training, experimental results would be influenced by progressive changes occurring secondary to the learning process. It is true that this approach would be unnecessary if the accommodative mechanism were truly reflex in nature. However, as will be seen

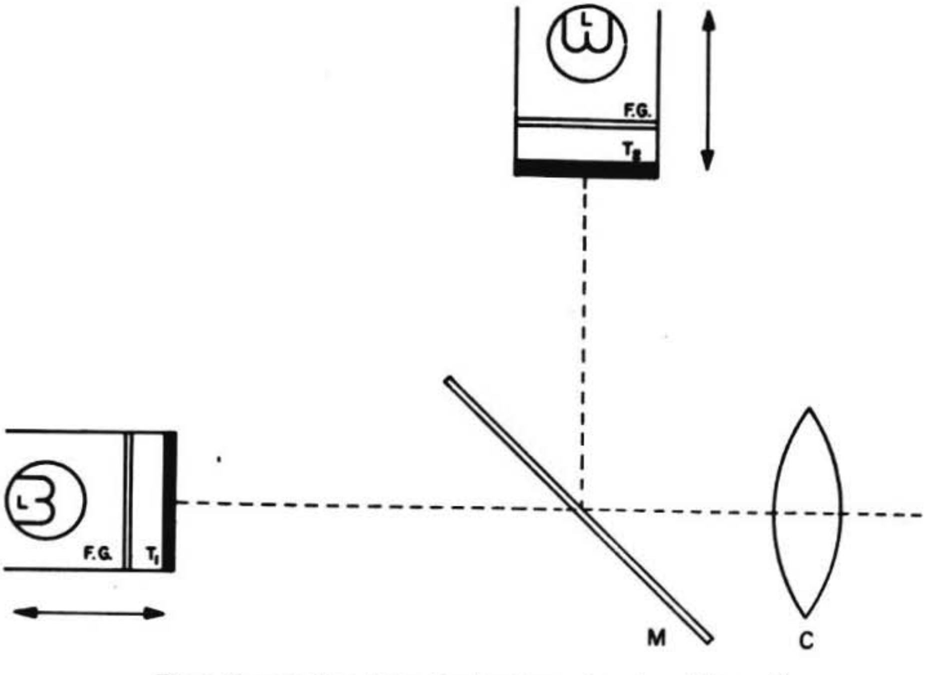

Fig. 8. Construction of the step-function optometer of figure 58.

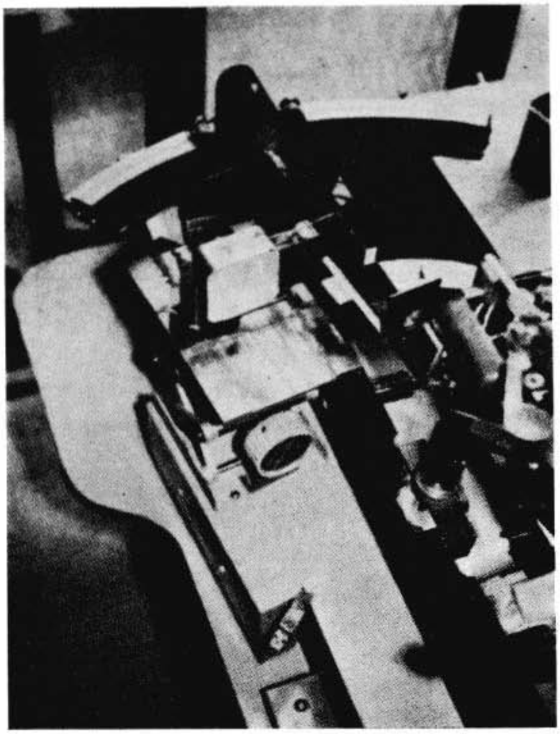

Fig. 9. The arbitrary-function Badal optometer. A brass plate, mounted upon a standard laboratory jack and milled with a linear groove, supports a complementary brass plate affixed to the rectilinear galvanometer. The Snellen target is coupled to the pen tip by means of a moly-coated balsa-wood shaft which is prevented from moving laterally by a close-fitting linear bearing. The bearing is mounted rigidly to a thin aluminum plate which is cemented to the galvanometer body. Although the instantaneous dioptric value is identified in terms of its electrical analog, it can be verified by noting the projection of the Snellen target upon a millimeter scale affixed to the left haploscope arm.

later, there is excellent reason to believe that the higher centers play a significant role in "reflex" accommodation.

METHOD

Open-loop Testing:

The conventional approach to the analysis of servomechanisms is to interrupt the servo-loop, introduce signals at a point adjacent to the break, and record responses on the opposite side of the point of discontinuity. The point of interruption of the serve-loop is unimportant, providing that no sub-loops exist in parallel with the major loop at the site of interruption. It was felt that the most convenient point at which to break the human accommodative serve-loop was at the controller.

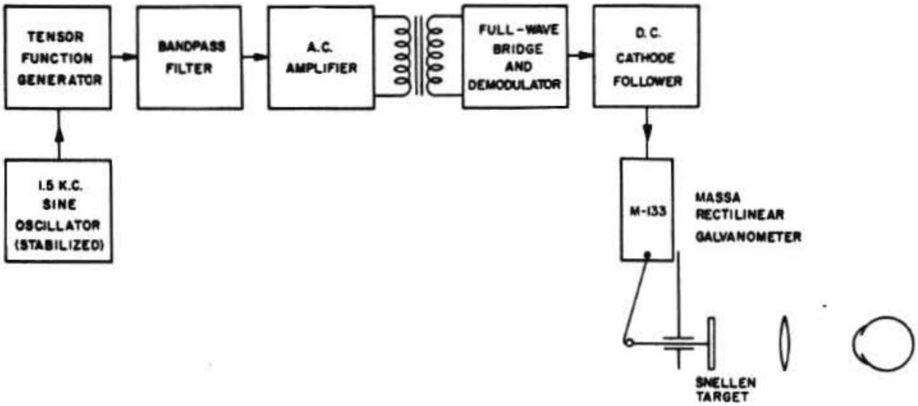

Fig. 10. Control circuit for the Badal arbitrary-function optometer.

With a normal accommodative mechanism, the amount of accommodation in the two eyes is the same. Hence, it was decided to break the servo-loop by atropinization of the left eye. This eye is then incapable of making corrective responses. However, an error-signal due to the blurred retinal imagery in that eye would ascend to the brain and initiate a signal for an accommodative response. Since no difference in efferent signal exists between the right and left eyes, the accommodation measured on the right eye is a correlate of the motor signal to the sinistraocular accommodative mechanism.

For open-loop data, the nature of the accommodative-convergence mechanism is an important consideration since accommodation causes the right eye to turn inward. The infrared optometer is sensitive to vignetting of its beam by the pupillary margin, being unable to distinguish between accommodative activity and decrement of light intensity secondary to absorption by the iris. The subject used in this study exhibits a comparatively low ACA ratio, and vignetting of the optometer beam resulting from an inturning of the right eye proved to be a problem only at the higher accommodative levels.

To obtain valid open-loop data, it is necessary that paralysis of the accommodative mechanism be sufficiently complete to prevent accommodative tracking. The subject was instructed to use 1% atropine sulfate in his left eye t.i.d. for two days preceding the investigation as well as twice during the morning of the day of investigation. Adequacy of cycloplegia was established since blurring of a Snellen target was perceived at equal (dioptric) distances, proximal and distal to the subject's far point.

Following atropinization of his left eye, the subject was placed in his dental bite attached to the infrared optometer. The instrument aligning lights were used

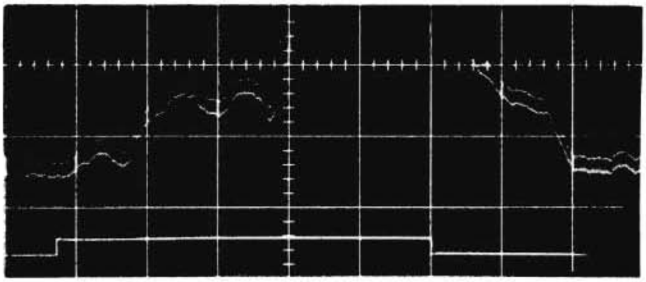

Fig. 11.

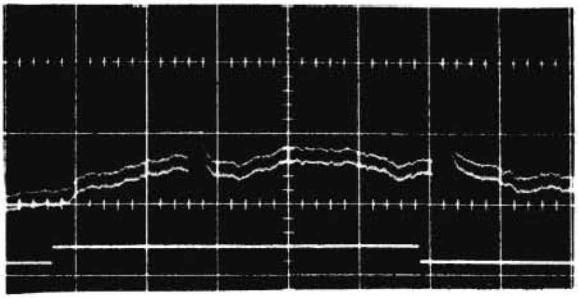

Fig. 12.

Figures 11 and 12 (above): Open-loop step response to a 0.25 D stimulus. In Fig. 11 the subject was instructed to attemp vigorously to clear the perceived blur while in Fig. 12 he was instructed to respond passively. A vertical distance equal to the height of the stimulus marker is 0.4D. The sweep rate is 2 sec./cm.

to align the subject's pupil with respect to the optometer beam. The left-eye Snellen target was placed at the phoria position where the subject saw it centered on the optometer source, made visible by removing the infrared filter. After alignment, all components of the infrared optometer and Badal target systems were secured and checks were made throughout the course of the investigation to insure that proper positioning prevailed.

It was originally intended that open-loop testing would consist of transient response and frequency response testing, and that frequency response testing would be executed over a range of frequencies between 0.01 and 10.0 cps. For reasons which will soon be apparent, investigation through the complete range of frequencies was not undertaken.

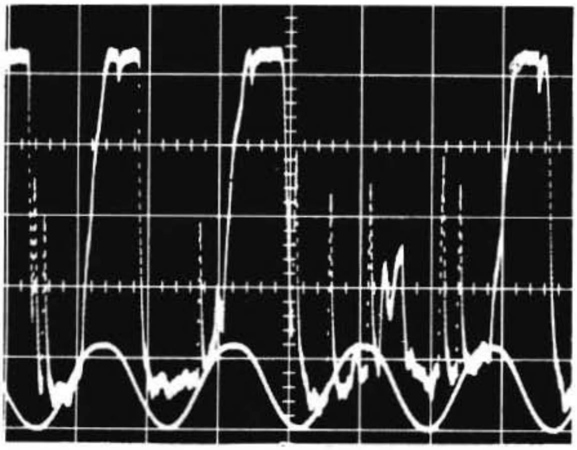

Fig. 13. Open-loop response to a 0.37 D sinusoidal stimulus having a frequency of 0.1 c.p.s. One major scale division equals 3.2 D on the response curve but pupillary vignetting a the higher levels ocurred rendering quantitative analysis inaccurate. In this figure, the subject was instructed to attempt vigorously to clear the perceived blur.

To obtain open-loop step function data, the step function optometer for the left eye was utilized. The vertical arm was adjusted to place the accommodative stimulus at the subject's far point and the horizontal arm was adjusted to place the accommodative stimulus 0.25 D. within his far point. The optometer could be hand-switched from distance setting to near setting, or switching could be accomplished automatically.

Figures 11 and 12 show S's open-loop response to a 0.25 D. accommodative stimulus. The occasional sharp peaks on these and subsequent records are blinks. The height of the stimulus marker is 0.4 D. Removal of the upper segment of the record in figure 11 resulted from the fact that vignetting of the optometer beam occurred, rendering the upper segment of the original record invalid. The breadth of the response line in thes and subsequent records is due to the presence of 60 cycle interference. In figure 11, the subject was instructed to attempt vigorously to clear the perceived blur, resulting when the stimulus target was switched from the far point to a level 0.25 D. within it. In figure 12, the subject was instructed to respond passively to perceived blur. From these figures, it is apparent that the magnitude of the open-loop response is determined, at least in part, by volition.

In figure 11, the positive accommodative response occurred following a dead time. Although the initial response was rapid, the accommodation soon commenced to waver about a drifting baseline until convergence of the right eye caused pupil vignetting and prevented further evaluation. The negative accommodative response followed a dead time, but did not demostrate appreciable instability since the relaxation stimulus was at the zero diopter level.

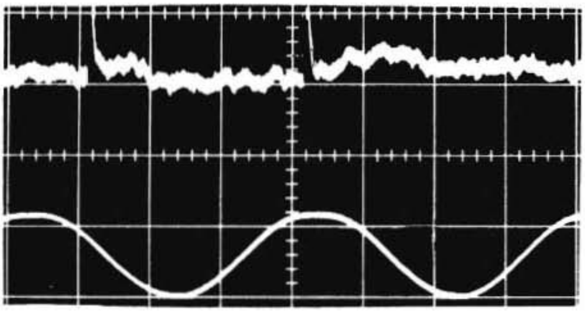

Fig. 14. Open-loop response to a 0.37 D sinusoidal stimulus having a frequency of 0.05 c.p.s. The subject was instructed to respond passively to the perceived blur. One major scale division represents 3.2 diopters on the response curve.

To obtain open-loop frequency response information, the left eye step function optometer was replaced by the arbitrary function optometer system. A procedure similar to that used in open-loop step function testing was utilized to co-align the right and left instrument axes.

By virtue of the variability of open-loop data, it is not possible to measure any systematic frequency dependent relationship between amplitude, phase, and frequency. For this reason, the open-loop data were not subjected to the same sort of analysis as closed-loop data. Open-loop frequency response data may, however, be analysed qualitatively.

On the open-loop frequency response records, one major scale división is equal to 3.2 diopters of accommodation. The stimulus to accommodation for open-loop steady state sinusoidal frequency response testing was 0.37 D., the target lying optically at the subject's far point when in its most distal position. In figure 13 the subject was instructed to attempt vigorously to clear the target when it blurred, whereas in figure 14 the subject was instructed to view the target passively. That these curves were obtained at two slightly different frequencies (see figure legend) is of little significance and the examples presented were selected largely on the basis of photographic quality.

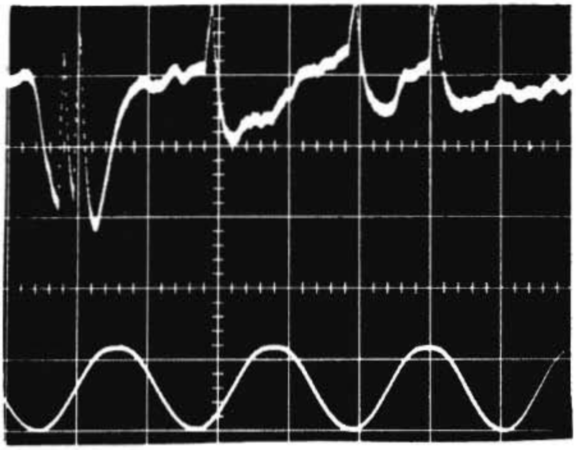

Fig. 15. Open-loop response to a 0.37 D sinusoidal stimulus having a frequency of 0.25 c.p.s. Note the presence of drift. One major scale division equals 3.2 D on the response curve.

In figure 15 it is apparent that the subject responded at a frequency corresponding to that of the accommodative stimulus, although considerable phase lag is in evidence. More important, the amplitude of response to a constant stimulus decreases progressively as a function of time throughout the course of the record. Further, the record demostrates long-term drift toward higher accommodative levels, similar to that seen on the open-loop step function curves.

Campbell and Westheimer [3] conducted a study in which they found that various cues such as chromatic aberration, spherical aberration, and astigmatism could be used to index the required direction of accommodative change. Subjects could utilize these cues after a brief training session in which other cues had been excluded. This suggests that accommodation may not be reflex in the strictest sense of the word, although subtle cues might be utilized under certain conditions to index the required direction and degree of accomomdative response. If certain characteristics of the ligth incident on the retina trigger accommodation reflexly, then a stimulus level beyond the subject's far point should elicit no response, inasmuch as the far point represents the level of maximum accommodative relaxation. If, on the other hand, the subject responds only to blur and is unable to ascertain the direction of blur in the absence of cortical activity, a positive accommodative response would be expected in association with a negative stimulus if accommodative tracking is prevented. To ascertain whether the subject would respond differentially to positive and negative blur, data were obtained without the subject being aware of any change in routine. The calibrated dial regulating the zero level of operation for the cathode follower stage in the arbitrary function

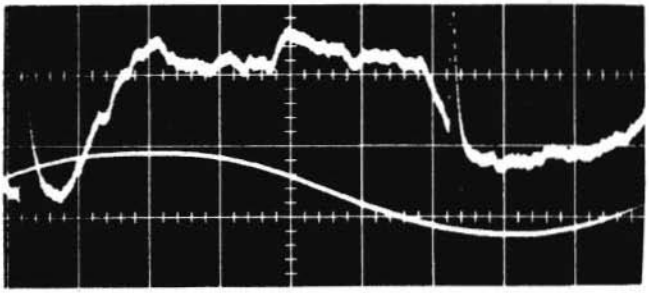

Fig. 16. Positive response to a 0.37 D "negative" accommodative stimulus. The subject was not advised as to the change in stimulus conditions. Polarity of signal input to the oscilloscope has been reversed. Sweep speed is 2 sec./cm.

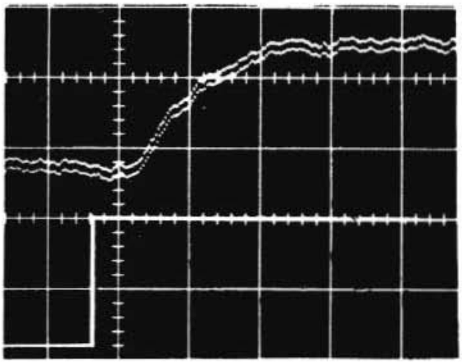

Fig. 17. Closed-loop accommodative response to a 2 D positive step-signal. Sweep speed is 0.5 sec./cm. The signal marker has been retouched.

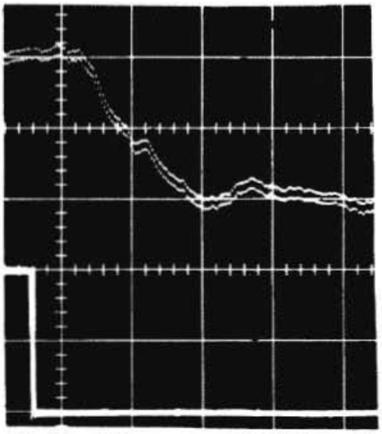

Fig. 18. Closed-loop accommodative response to a 2 D negative optical step-signal. Sweep speed is 0.5 sec./cm. The signal marker has been retouched for better reproduction.

optometer system was reset so that the target oscillated between the subject's far point and a point (optically) 0.37 D. beyond it, and the polarity of the signal input to the oscilloscope was reversed. Figure 16 is a photograph of the subject's response to this negative accommodative stimulus. It is apparent that the subject responded with positive accommodation.

One factor which could conceivably invalidate the above data with respect to the apparent inability of the subject to discern the directional value of the accommodative stimulus, is that normal oscillations of accommodation were absent during open-loop testing. This investigation does not establish whether such accommodati oscillations do or do not serve as an index of the direction of accommodative error. However, if they normally do play such a role, their abscence in this study would of necessity result in a lessened ability of the subject to appreciate

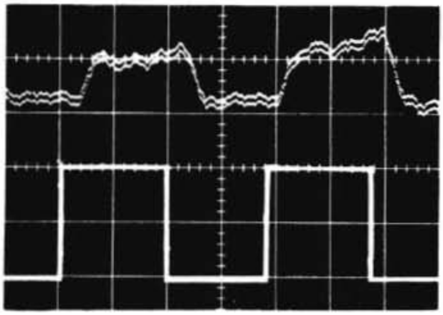

Fig. 19. 0.3 c.p.s.

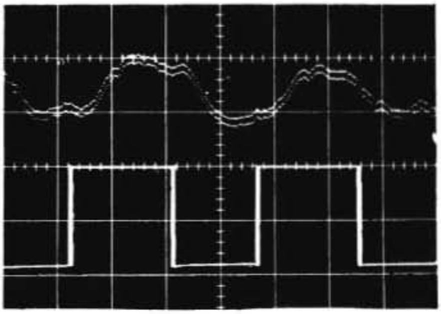

Fig. 20. 0.6 c.p.s.

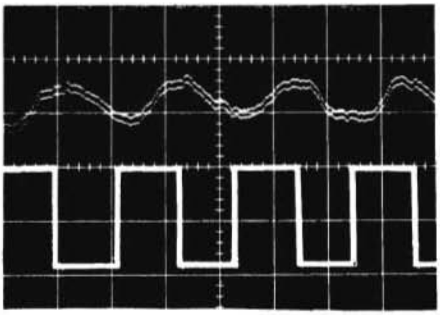

Fig. 21. 1.2 c.p.s.

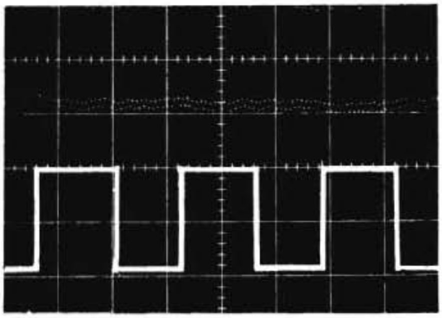

Fig. 22. 2.4 c.p.s.

Figs. 19, 20, 21, 22 (above). Closed-loop response of the eye to a one diopter rectangular stimulus. Note the degeneration of the rectangular waveform and attenuation with increased frequency. The signal markers on the above photographs have been retouched for better reproduction.

directional values. The work of Campbell and Westheimer, previously cited, as well as the fact that normal fluctuations of accommodation largely lie within a sensory dead zone would seem to make such a hypothesis improbable.

Closed-loop Transient Response Testing:

Closed-loop testing of the human accommodative mechanism was undertaken in the absence of cycloplegia. Mydriasis was utilized, however, in the right eye to minimize the possibility of vignetting of the infrared optometer beam, and in the left to minimize depth of focus. A signal amplitude of 1D. was utilized for both transient response analysis and steady-state frequency response analysis. The subject was instructed to respond vigorously to the accomodative stimulus at all times.

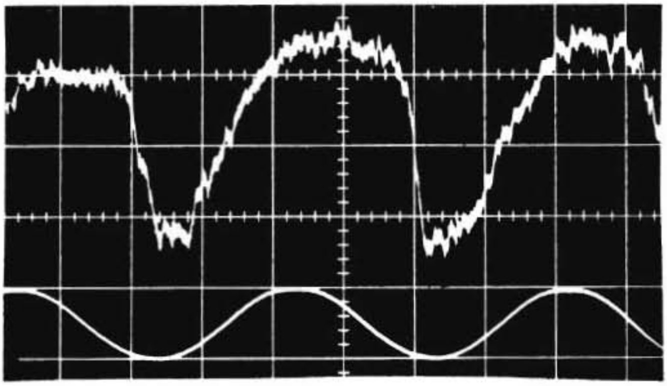

Fig. 23. Closed-loop response of the eye to a 1 D sinusoidal stimulus (0.05 c.p.s.). Note the deviation from sinusoidal form.

In closed-loop step response testing, the optometer system for the right eye was used since its alignment is more readily accomplished than in the case of the step-function optometer for the left eye. The solenoid action time of this optometer is 20 milliseconds. Since this value is negligible compared to the action time of the accommodative mechanism, corrections for optometer action time were not made.

Figure 17 is the accommodative response to a 2 D. positive optical step signal and figure 18 is the response to a 2 D. negative step input. The 1 D. records were unsuitable for publication due to the application of construction lines used to obtain quantitative information. The qualitative aspects of the response to a two diopter stimulus were similar to those for a 1 D. stimulus, save for the fluctuation noted midway along the linear section of the response curve of figure 18 which appeared only on this solitary photograph.

The initial response to a 1 D. optical step signal, either positive or negative, followed a time delay of up to 425 milliseconds but the corresponding value for repetitive data was 240 milliseconds for positive accommodation and 200 milliseconds for negative accommodation. Transient accommodative response appears to be approximately exponential and the time constant for positive accommodation was variously determined as 275 milliseconds (63% of full seale basis) and 325 milliseconds (initial slope basis) The corresponding values for negative accommodation were 250 and 346 milliseconds respectively.

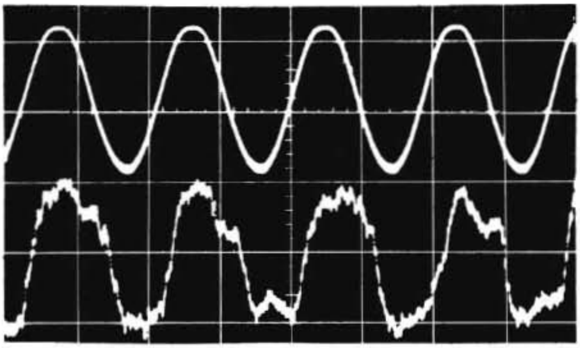

Fig. 24. Closed-loop response of the eye to a 1 D sinusoidal stimulus (0.1 c.p.s.).

If maximum velocity is defined in terms of the steepest slope on the accommodative response curve, the maximum velocity for a 1 D. positive swing was 3.08 D./sec. while the corresponding value for a unit negative excursion was 2.89 D/sec.

If average velocity is defined in terms of the elapsed time between two successive zero-derivative points on the response curve, the average velocity for positive accommodation was 1.01 D./sec. while that for negative accommodation was 2.24 D./sec. The low average velocity for positive accommodation is attributable to the time required to accommodate for the last 10% of the stimulus.

A frequently encountered, but not invariable, peculiarity of the accommodative relaxation curve is noted in figure 18. Based upon a 1 D. negative step stimulus, the accommodation achieves maximum relaxation in 0.446 seconds, then increases to a relative maximum positive level of 0.2 D., attaining this value after roughly

275 milliseconds. The accommodation then drifts slowly toward a state of more complete relaxation.

In attempting to interpret this phenomenon, two points are noteworthy. First, the 0.2 D. value is of the same order of magnitude as the ocular depth of focus. Second, the time interval between attainment of the initial relaxad state and the relative maximum is of the same order of magnitude as the system dead time. Thus, the subject appears to first relax his accommodation to the distal limit of the depth of focus range, this then providing a stimulus for positive accommodation which does not commence until the signal has returned from the brain. When the proximal limit of the depth of focus is reached, the accommodation drifts slowly within a sensory dead zone until a suitable resting level is attained, this level lying in proximity to the distal limit (the lazy lag of accommodation). Such a hypothesis could be better evaluated if the study were repeated employing a null-seeking infrared optometer, capable of more accurately defining the instantaneous DC accommodative level.

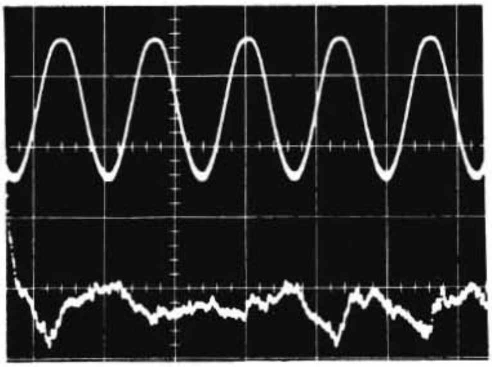

Fig. 25. Closed-loop response of the eye to a 1 D sinusoidal stimulus (0.4 c.p.s.). Note that one entire cycle was skipped.

Closed-loop Response to a Rectangular Input:

It was desired to ascertain the nature of the closed-loop response of the eye to a rectangular accommodative stimulus. It was felt that, due to the presence of system dead time, lag of response behind stimulus should occur, and that at the higher frequencies the response should loose its rectangular form and degenerate into an approximately sinusoidal waveform. Indeed, both of these effects were realized (see figures 19 - 22).

To test the closed-loop response of the eye to a dioptric rectangular wave, the right eye step-function optometer system (employing red-free light), and the accommodation recording system were positioned before the subject. A cam-actuated microswitch provided in the Tensor Generator allowed the dioptric stimulus to alternate between two preset levels.

Figure 19 shows the response of the eye to a one diopter stimulus presented at 0.3 cps. It is noted that of the two cycles completely represented in this figure, the response on one was greater than the response on the other. The degree of difference noted on this photograph was greater than in the case of other pothographs taken under like conditions. The tendency for accommodation to reach an inflection point at near, and the coast slowly toward a higher dioptric level, was encountered for inputs pelow the frequency at which rounding commenced, perhaps representing drift within a sensory dead zone. Figure 20 was taken under similar conditions to figure 19 except for change in signal frequency (0.6 cps). Marked rounding is in evidence.

In figure 21, (1.2 cps.), rounding is more complete and significant attenuation is present. Rounding occurs since the direction of the stimulus alters before the initial accommodative response attains its maximal value. Note the approximately sinusoidal characteristic of the response. Figure 22 was taken under like conditions, save for frequency (2.4 cps). Here, the response is barely distinguishable from noise.

Closed-loop Frequency Response:

In closed-loop frequency response testing, the arbitrary function optometer system was aligned with respect to S's left eye and the accommodative stimulus was allowed to vary in sinusoidal fashion between the limits of 0.75 D. and 1.75 D. within S's far point. The 0.75.D bias was allowed to offset possible effects of instrument myopia.

As in the case of closed-loop transient response testing, the subject was instructed to exert maximum effort at all times. Multiple photographs of stimulus vs. response were made at each frequency setting and phase and amplitude measurements were made from these photographs.

Closed-loop frequency response data revealed a large non-minimum phase shift secondary to system dead time. Figures 23 and 24 are raw data recorded at 0.05 cps. and 0.1 cps. respectively. It will be observed that, at the lower frequency, considerable distortion is in evidence, perhaps secondary to dead-zone effects. The subject expressed considerable difficulty in responding at very low frequencies, and it is interesting to note that at the higher frequencies whole cycles were occasionally skipped (see figure 25).

At any given signal frequency, not all cycles yielded identical amplitudes, nor is phase shift identical for each cycle. Such variation is most pronounced in the case of very high and very low frequencies. This presents some difficulty in interpreting data, since frequency response analysis depends upon a knowlege of the precise value of relative amplitude and phase angle at each frequency. Although the initial approach was to measure the relative amplitude and phase shift for each cycle and to average all of these values, it was found that the data could be plotted more successfully if a procedure were followed in which all obviously anomalous data were rejected and the remainder were averaged.

Figure 26 a is a plot of amplitude ratio against frequency. The line shown on this figure has been constructed to show an attenuation slope of 20 db. per fre-

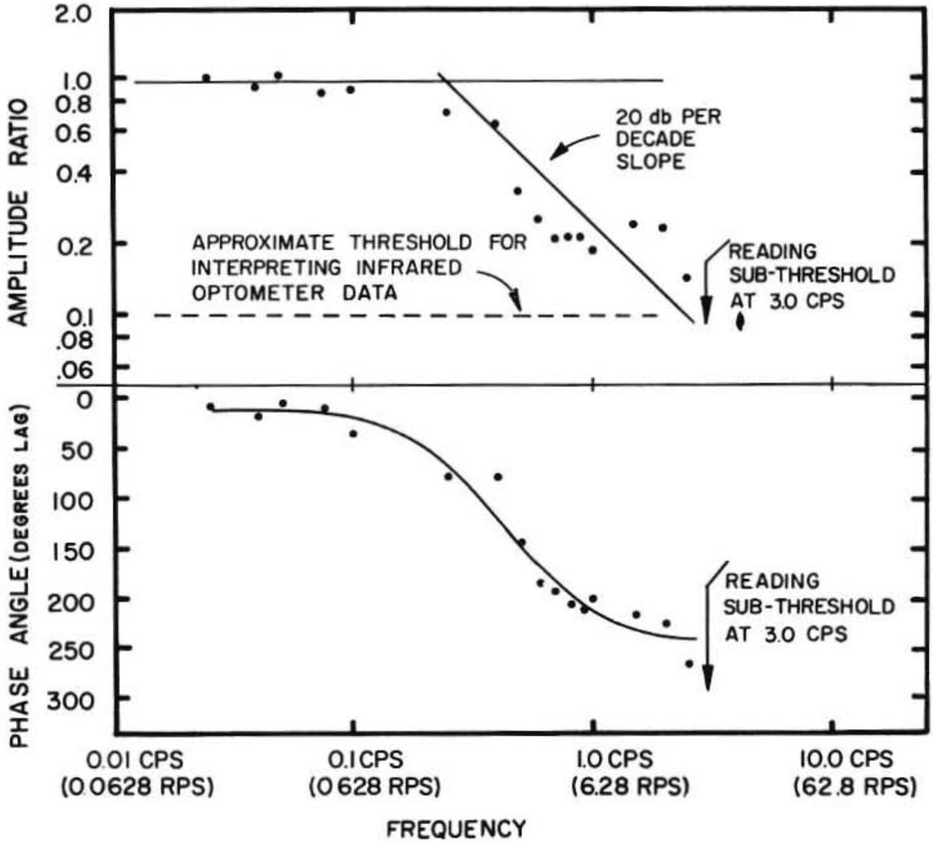

Fig. 26a (above).
Fig. 26b (below).
Closed-loop attenuation characteristic (26a) and closed-loop phase shift characteristic (26b).

quency decade, since this slope (typical of a first-order system) fits the data better than that for a higher order system. Figure 26 b is a plot of phase shift against frequency. The phase shift is largely non-minimum since the maximum possible lag for a linear first order system, free from dead time, is 90°.

In figure 27, the amplitude and phase responses were combined on a complex plane plot in which the radius vector indicates the amplitude ratio at a given frequency while polar angle defines the phase angle. A cmooth curve was drawn which appeared to fit the experimental data. Some of the test frequencies are noted along the curve.

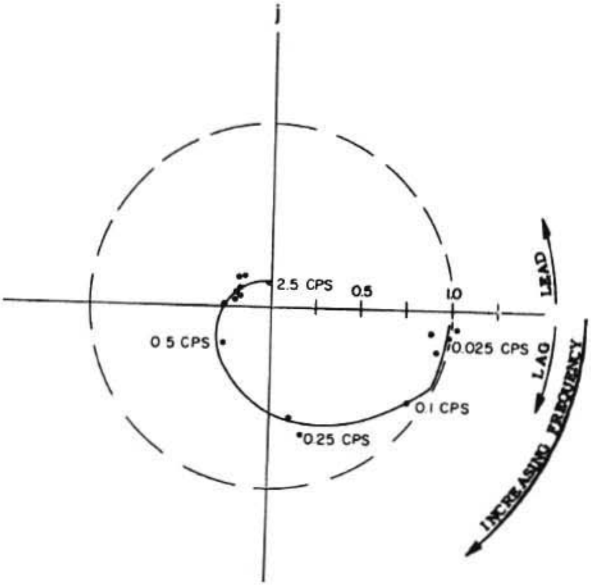

Fig. 27. A complex plane representation of the empirical frequency response of the human accommodative mechanism. The radius vector defines the amplitude ratio at a given frequency while phase lag is defined by the polar angle.

DISCUSSION

The premise upon which the present investigation has been based is that the accommodative mechanism of the eye functions as a servomechanism, an error-actuated feedback control device. It appears that this original assumption was at least partially justified since numerous parameters relating to the mode of action of the accomodative mechanism can be defined in servoanalytic terms. On the other hand, the accommodative mechanism scarcely exhibits all of the automatic properties ascribed to the pupillary mechanism by Stark.[4]

The first suggestion of a strong volitional element in accommodation appeared when the loop was broken by atropinization of S's left eye. It was found that the open-loop gain was very high or very low depending upon the attitude of the subject. This effect was observable with both both step and sinusoidal dioptric inputs.

Further evidence that the accommodative mechanism is not fully automatic appeared when, under open-loop conditions, the subject responded to a negative dioptric stimulus with a positive accommodative response. This suggests that the required direction of change of accommodative posture is not coded in terms of the physical characteristics of light incident on the retina. However, it has been shown that a subject can learn to utilize chromatic aberration, spherical aberration, and astigmatism to provide directional cues when placed in an artificial environment such as a Badal optometer. Undoubtedly, under normal environmental conditions,

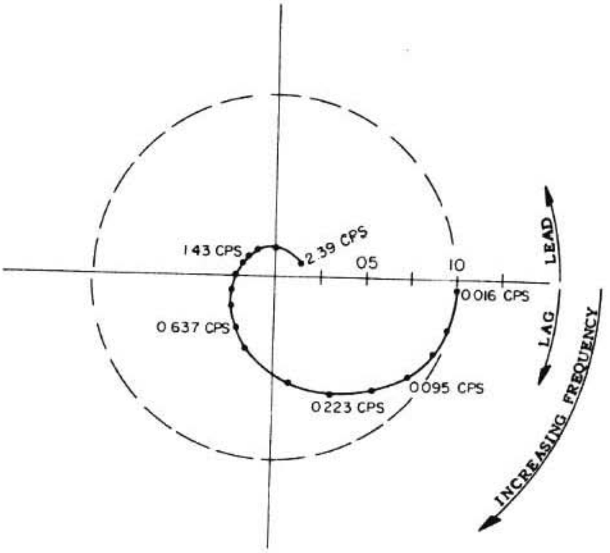

Fig. 28. A complex plane representation of the frequency response of anhypothetical system operating according to the formula:

$$G(w) \frac{0.6\,e^{-j\,(0.3w)}}{1-0.4(\cos 0.3w)+j(0.27w+0.4\sin 0.3w)}$$

little difficulty attends sensing the required direction of accommodative change since many cues to relative distance are present (eg. monocular and binocular parallax, superposition, direction of convergence change, relative size, etc.)

The availability of open-loop data greatly facilitates servoanalysis since it permits ready idenitfication of certain system parameters, simplifies mathematical analysis, and permits the prediction of closed-loop stability. It is possible, however, to evaluate the performance characteristics of a given servomechanism in the absence of valid open-loop data.

The closed-loop frequency response characteristics measured for subject, J. S., were presented in figures 26 and 27. Under the assumption that the accommodative mechanism can be treated as a first order servo embracing dead time, the general open-loop equation was formulated as follows:

$$(1) \qquad g(w) = \frac{k\, e^{-j\,w\,T1}}{1 + j\,w\,T_2}$$

where:

$g(w)$ is the open-loop system gain
k is a gain constant
T_1 is the system dead time
T_2 is the system time constant

The closed-loop response is related to the open-loop response by means of the formula:

$$(2) \qquad G(w) = \frac{g}{1 + g\ H}$$

where:

$G(w)$ is the closed-loop gain
g is the open-loop gain
H is the system feedback factor.

Formula (1) was inserted into formula (2) to provide a general equation for the closed-loop response of the eye. H, the feedback factor, was assumed to be a constant defining the attenuation produced by dead zone. It corresponde to a depth of focus of roughly $\pm\ ^1/_6$ D. Values of T_1 and T_2 were selected to be consistent with experimentally derived values and to permit $G(w)$ to define a curve similar to that of figure 27. A value of k was selected which provided unity gain at zero frequency.

Figure 28 is a complex plane plot constructed according to the resultant formula. Although the general form of the curves in figures 27 and 28 are similar, moderate divergence of frecuencies for corresponding sets of point is in evidence.

The equation upon which figure 28 is based is as follows:

$$G(w) = \frac{0.6\,e\,{-j}(0.3\,w)}{1 - 0.4(\cos 0.3\,w) \quad j(0.27w \quad 0.4 \sin 0.3\,w}$$

Where: -0.4 represents the product of k and H.

Since kH is negative, the equation above defines a system which is regenerative and, as such, would not be error — correcting. Similarly, the open-loop gain of a regenerative system is less than the closed-loop gain. We have previously seen that the open-loop gain of the human accommodative system exceeds the closed-loop gain when the subject makes a vigorous attempt to clear a perceived blur.

From the above, it is apparent that the cited formula cannot represent the actual transfer function for the human accommodative mechanism. Hence, it is of interest to speculate concerning possible means of obtaining an equation for a degenerative system which is compatible with the empirical frequency response of the human accommodative mechanism.

Conventional servo formulae presuppose that the gain constant, k, does not vary. However, it has been seen that the open-loop gain varies markedly depending largely upon expended effort. If we can assume that the subject "tries harder" in one frequency range than another, it is possible that k may be frequency dependent. The manner in which k, varying as a function of frequency, would influence the closed-loop system gain would not be simple, inasmuch as it appears in the denominator of the closed-loop transfer function as well as in its numerator. Likewise, it might be possible that the accommodative system is higher than first order. Unfortunately, changes in gain with frequency would alter the attenuation slope while the utilization of a second time constant would increase the theoretical slope to 40 db. per decade. Neither of these effects are readily reconciled with the attenuation curve of figure 26. Attempts were not made during the present investigation to utilize equations having more than a single time constant.

One further possibility exists since it is known that a satisfactory fit of the experimental curve can be obtained if the numerical value of the system time constant is increased. A value of 1.5 seconds yields a reasonably satisfactory fit, but this value seems unlikely since it exceeds the experimentally derived value by a factor of five to six times.

Figure 29 is a block diagram of the human accommodative servomechanism showing its relationship to the experimental conditions of the present investigation. Sources of time delay are not noted explicitly on the diagram but are understood to exist throughout the system in the form of nerve conduction and synaptic delays, as well as neuro-muscular lags and delays associated with the muscle-lens dynamics. Under the conditions of open-loop testing, the accommodative servo-loop was interrupted at X1 by atropinization of the left eye, while no light was available to the right eye by virtue of the absence of visible radiation in the infrared optometer system. This had the effect of breaking the servo-loop at X2. Optical readout was taken at R.

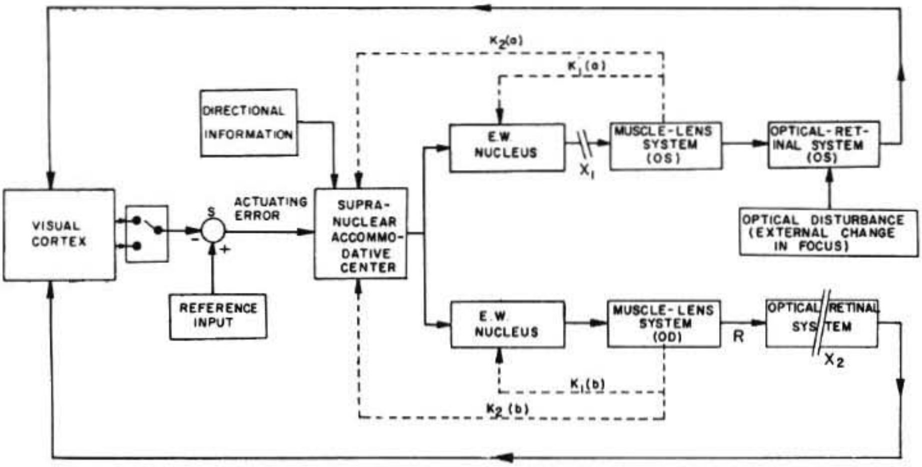

Fig. 29. A block diagram of the human accommodative servomechanism as related to the conditions of the present investigation.

In the brain, some parameter of the cortical "image" relating to perceptual clarity is accepted for one or the other eye and compared at summing junction, S, with a reference input. The precise nature of the reference input is unknown. Perhaps the output of the retinal derivative fibers is involved since this relates to the contrast gradient at the image border.

We may assume that gain is acquired in the forward loop while the action of the feedback loop is passive. It may be further assumed that the forward path "inverts" the signal so as to make the system degenerative. Consider the forward path to contain a single operational amplifier and a time delay, and the feedback path to contain only a time delay. It is likely that the time constant of the accommodative system is related to the muscle-lens dynamics, although its precise site is of little importance to the present problem.

Although both the supra-nuclear accommodative center and the E. W. nuclei may be thought of as contributing gain, it is likely that volitional control exists only in the supra-nuclear center. An alternative to supposing that gain varies with volition in a "reflex" system is to imagine that a true reflex system (with constant gain) exists, which can be overridden by impulses originating at a center for voluntary accommodation. The more reasonable assumption, however, would seem to be the former and it is likely that the cortical "image" is in some manner evaluated with respect to clarity and, should a corrective accommodative act be necessary, directional cues are provided from an external source.

Although not anatomically established, the possibility of kinesthetic feedback from the ciliary muscle or associated structures must be considered in the analysis of the accommodative mechanism. Such auxiliary loops, should they exist, could be either regenerative or degenerative. In the former case, they would serve to increase gain while in the later they would tend to reduce gain while expanding the flat portion of the frequency response curve.

The dotted lines in figure 29 indicate possible sites of proprioceptive loops. Under the conditions of "open-loop" testing, loop K1 (a) and/or loop K2 (a) would be deactivated, wile loop K1 (b) and/or loop K2 (b) would be unaffected. Such internal loops could shift the frequency break point and alter the forward gain of the system. Since, however, the constants from such sub-systems would be lumped with those from the remainder of the mechanism, presence or absence of such auxiliary loops could not be inferred.

SUMMARY AND CONCLUSIONS

The purpose of the present investigation has been to analyze the accommodative mechanism as a feedback control device. Accommodative responses to both sinusoidal and step stimuli were recorded by means of an infrared optometer. The responses were, in each case, compared with the stimuli and the data were subjected to servoanalytic techniques.

The more significant findings of the present investigation follow:

1. The closed-loop transient response of the human accommodative mechanism occurs following a time delay and is approximately exponential. With non-repetitive signals, the time delay is approximately 425 milliseconds for both positive accommodation and accommodative relaxation. With repetitive signals, the time

delay averagel 240 milliseconds for positive accommodation and 200 milliseconds for accommodative relaxation.

2. The time constant of the accommodative mechanism was estimated according to two criteria. The results follow:

Positive Accommodation:

63% of full-scale basis: 275 milliseconds
Initial slope basis: 325 milliseconds

Accommodative Relaxation:

63% of full-scale basis: 250 milliseconds
Initial slope basis: 346 milliseconds

3. The closed-loop frequency response data could be fit reasonably well by an attenuation curve having a constant slope of 20 db. per frequency decade. Such a slope typifies a first order system. Phase analysis reveals a very large non-minimum component which is related to system dead time.

4. The accommodative servo-loop was opened by atropinization of S's left eye. A negative accommodative stimulus (i.e. a pre-focal blur) was provided for that eye. The right eye of the subject responded in the manner which would be expected for a post-focal blur. This suggests that directional cues are probably not provided by physical characteristics of the stimulating light. As such, it is likely that a subject, under normal environmental conditions, learns to utilize numerous (including psychic) cues to indicate the required direction of accommodative change.

5. Open-loop gain appeared high under the condition that the subject was instructed to attempt vigorously to clear any perceived blur. Under the condition that the subject was instructed to respond passively, open-loop gain was low. An alternative to assuming that changes in gain can be induced voluntarily in a "reflex" mechanism is the assumption that a reflex mechanism exists which can be overridden by impulses originating at a "voluntary control center".

6. Under the assumption that the human accommodative mechanism is a first order servo embracing dead time and dead zone, an attempt was made to formulate the system transfer equation. When a formula was constructed which provided a satisfactory fit of the empirical frequency response data (using constants compatible with ex experimentally derived values), it was found that the resulting equation defined a regenerative system. Since such a system would not be error-correcting, the equation must be rejected.

7. While it is apparent that volition plays an essential role in accommodation, under normal environmental conditions accommodation seems to be automatic (in the sense that control is not at a conscious level). Many persons placed in an environment in which few of the normal cues to distance are present (eg. Badal Optometer) must learn to respond to different cues than those to which they are accustomed. This accounts for the difficulty often encountered in measuring accommodative changes in the eye of an untrained subject who is attempting to respond to accommodative stimuli presented in a Badal system.

8. Further research is indicated, utilizing a greater number of subjects, to derive a realistic transfer equation for the human accommodative mechanism. A major obstacle in the present investigation has been the fact that the attenuation curve shows a slope characteristic of a first order system, while attenuation commences at a very low frequency. This suggests the presence of a regenerative system (not possible since it would not be error-correcting), or a system having a time constant too long to be reconciled with experimentally derived values. Perhaps voluntary factors enter strongly into frequency response data, or perhaps the mechanism of accommodation is too complex to be accounted for on the basis of a model which is a first order servo containing a single loop and embracing time delay and dead zone.

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PATIENT INTERROGATION

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The practitioner of any healing art is guided in his examinations by the statements of the patient. The value of these statements will often be determined by the type of questions asked. The purpose of this paper is to aid the practitioner in his interrogation of the patient so that the responses received will be of the greatest value. Let us state at the very beginning that we are not attempting to set up a list of questions which would be suitable for all patiens, all practitioners and all situations.

There is good reason for our not being able to recommend a fixed, all-knowing routine for patient interrogations. In view of the innumerable possibilities which may confront the practitioner in his daily contact with patients, any attempt to line up an all-inclusive, fool-proof method of questioning would prove futile. If we but stop to consider the tremendous store of knowledge and experience needed for questioning a patient inteligently and pertinently, we must conclude that devising a complete and through routine of patient questioning is an almost impossible task. Yet, both inside and outside our field of endeavor, the seeming weakness of some practitioners in searching out and recording an adequate and relevant patient history moves the author to attempt to give at least some direction in history taking and recording and to offer some suggestions in the type of thinking which should motivate the questioner.

To those experienced practitioners who may think it presumptuous on the part of the author to undertake this weighty subject, let us assure them that we humbly agree with their point of view. Nevertheless, the author feels that his interest in the subject, his own background and length of experience make him somewhat more qualified to offer the material which follows.

We like to think that primary reason for practicing our profession is to aid those seeking our counsel and help. Ideally, if our patients are to receive the best possible care, every step undertaken should be carried out adequately and every necessary test should be performed in the effort to correct any and all defects presented. This brings us to the beginning of the examination or, more correctly, to the beginning of our patient contact, i.e., meeting the patient.

There is no question but that the manner with which the doctor and patient greet each other and the manner in which they continue to communicate throughout subsequent visits will produce certain definite, mental impressions on one another. The very start of the relationship may spell the success or failure of handling a case. The initial phase of contact should start the conveying of a feeling of confidence. This is important because the confidence established in the mind of the patient in the short interval between the initial greeting and the beginning of interrogation will often determine the kind of responses that will be given to the questions asked.

Perhaps, some clarification is needed for the term, *patient interrogation,* as used here. To the writer, this term embraces meeting the patient, taking his pre-history, and eliciting all subjective ocular symptoms and complaints as well as any pertinent systemic symptoms which may exist in the present or have existed in the past. While taking the pre-history, the doctor will have suprficially psychoanalyzed and evaluated the patient. The patient's ability to comprehend and respond has registered and the doctor's insight into the patient's relative intellectual capacity has been exercised. Any further questioning will now depend upon the doctor's evaluation of the patient's comprehension and answering ability.

The pre-history is followed by the taking of the actual history. History is defined as a recording of the past. Many doctors prefer to record significant past actions and reactions under history and to list significant symptoms under another heading. The author prefers to include, under the heading of history, all significant actions and reactions of the past, subjective symptoms of the present, and aims of prevention for the future. History taking naturally continues during subsequent testing and all salient remarks are recorded.

The aim of our interrogation should be twofold: first, to try to resolve the patient's complaints and symptoms into a "chief complaint", which many times is not so easy to do as it might appear; and second, to proceed there from to apply all our art and all our knowledge to the end of rendering the patient comfortable and satisfied. May we repeat our thesis for emphasis? We interrogate the patient and elicit his significant complaints so that we may evaluate his condition and thus apply all the knowledge and procedures we have available to give him the relief he seeks.

For all history taking, we should formulate a list of stock questions and use these as basis for interrogation. We should make this list as complete as possible and use it in its entirety, omitting only the questions which obviously do not apply to the particular patient. Gradually, as we become more adept in history taking, we may make use of variations, additions, substitutions and deletions to pin-point pertinent symptoms and complaints.

As the interrogation progresses, the direction the examination will take becomes formulated in our mind. Here, the old adage, "Experience is the best teacher", was never truer. Let us take a look at the suggested outline below and examine it carefully. The symptoms and complaints listed are everyday disturbances which bring patients into our offices seeking relief. Often, on the one hand, a single symptom may be indicative of a variety of conditions; while, on the other hand, a combination of symptoms (syndrome) may indicate only a single defect.

OUTLINE

During interrogation the following preliminary data are obtained from the patient:

Pre-History:

Name:
Address:
Date of Birth:
Sex:
Source of Referral:
Date:
Telephone Number:
Occupation:
Avocation:
Name of Family Doctor:

The taking of preliminary data is followed by an interrogation which requires the best answers the patient is able to supply. The doctor must be patient and must search out the correct answers by persistent questioning and careful, attentive listening.

Oculary History:

1. The first questions here may be, "What is troubling you? Why are you having your eyes examined?" These might be termed the leading questions.

2. These questions are followed by: "Did you ever have your eyes examined before?" Obviously, there is no outstandinng clue to show that the patient has had previous eye care. If the patient has had his eyes examined before, we might expect him to be somewhat familiar with the examination routine and to display

a lesser degree of anxiety when he describes his symptoms than would someone who has never had an eye examination.

3. If the patient is wearing a correction, we may ask him. "How long have you been wearing your glasses?" If the patient is not wearing glasses but gives a history of having had his eyes examined previously, the practitioner should find out as accurately as possible whether treatment was instituted at the time, the nature of any treatment, and whether or not glasses were prescribed.

4. If the patient is wearing glasses, a determination of his visual acuity both with and without the glasses in place may tell the complete story of the type of correction he is wearing. Often, the obvious, physical aspects of the lenses will be sufficient to give the desired information.

5. Ordinary physical symptoms, such as smartling, burning, itching, aching and the sensation of pain, all seem to have different meanings to differen people. It is helpful to have the patient disclose the area of disturbance. For example, *itching* may result from an allergic dermatitis, or it may be related to a low grade blepharitis or to a conjunctivitis, or to both of the conditions. *Smarting* and *burning* present acute sensations, the former usually being less severe than the latter. *Smarting* may arise from the presence of smoke and fumes in the atmosphere, while a *burning* sensation arises when some foreing matter is accidently flown or rubbed onto the conjunctiva. The complaint of *aching* might lead us to think of an accommodative spasm, an acute conjunctivitis, or possibly of *glaucoma simplex*. The existence of pain should alert us at once. *Pain* denotes a sharp discomfort and leads us to look for such causes as an imbedded foreign body, a *keratitis*, an *iritis*, an *acute glaucoma*, *dacryoadenitis* or *cystitis*.

6. The complaint of *photophobia* is an all-present type of symptom. It may accompany any one or more of the preceding symptoms and be combined with other complaints, of which fatigue is a common membre.

7. Excessive *tearing* is a common complaint. It has various indications. When it is present, the direction of our thinking, as in the case of many of the symptoms above, must depend on a consideration of the presence of associated and accompanying complaints.

8. There are many types of *headaches*. The complaint of *headaches* may or may not indicate a need for a refractive correction or an associated treatment. It is important to ascertain the usual time of onset of the headaches, their frequency, the type of work done by the patient and the lighting conditions associated with his work and other activities. Any of these data may offer important clues. Parietal headaches and morning headaches are rarely the results of ocular distress,

although all other types of headaches may be caused by stresses and disturbances accompanying visual effort.

9. The doctor should find out about any past injuries. We should ask, "Did you ever have any injury or accident to your eyes?" If the answer is in the affirmative, we must then ask, "How, when, where?".

10. After we are satisfied that we have a clear understanding of the patient's reasons for seeking our services, we may then state concisely and simply to the patient his chief complaint. The reaction to our statement will tell us what the patient really desires.

Systemic History:

This part of the examination may begin with, "How is your general health?" This is a routine question. Any additional questions and answers will depend on the patient's well-being and on any objective symptoms which may be disclosed during the examination. Such symptoms may apply to ear, nose or throat conditions; to vascular, endocrine, liver, pancreatic, nephritic or intercranial upsets; and to hereditary or congenital defects.

Addenda to History:

Any significant variations from the normal of either an ocular or systemic nature noted during the course of the examination should be followed up by the practitioner. This will require additional questioning and the recording of more data.

Subjective symptoms may have different interpretations at different age levels. As far as possible, the significance of specific symptoms must be evaluated in terms of possible ocular causative factors which have brought the patient to seek our services. The probability of our deductions will be determined as the examination progresses.

As we are all aware, there are an infinite number of questions which may be directed to the patient during an examination. The analysis of one patient's symptoms may be accomplished with facility during the initial questioning period, while the diagnosis of another patient's complaints may be obtained only after a prolonged period of diligent searching. The knowledge and experience of the practitioner will guide him in deciding whether a given questioning period should be of long or short duration. The basis for the amount of interrogation, of course, will depend on the variety of symptoms, apparent seriousness of the complaints and the ability of the practitioner to understand their meanings and evaluate their possible causes. Usually, there exists one main complaint for which the patient is seeking a remedy. Other disturbances may be either secondary symptoms or complaints which are insignificant compared with the symptom of chief concern. Usually, the greater the severity of the primary complaint, the less will be the need of immediate attention for secondary difficulties. We must be careful not to confuse associated symptoms of the primary complaint with secondary symptoms which may arise from other difficulties of minor importance. Naturally, the greater the doctor's experience, the more pointed and direct will be his questioning. When the complaints do not add up to a clear-cut picture, or the picture seems to present a focus outside the scope of our practice, then a consultation is indicated.

Let us follow the outline just presented and see what type of questions we would employ.

Pre-History:

The patient's geographical location and his living standards may present special problems. We must, therefore, try to be aware of any possible disturbing conditions existing in the area where the patient lives. The age of the patient is important as this should alert us to conditions which may be caused by the factor of time. We should also always keep in mind the occupational hazards to which the patient may be exposed.

The history should begin with the definite complaint of the patient. It should include onset, frequency, duration, etc. However, if the complaint is vague, it is recommended that the questioning start with the ocular history outline suggested here.

A knowledge of symptoms is, of course, mandatory for an understanding of the reasons which motivate the patient to seek attention. The comprehension of cause and effect is helpful in enabling the doctor to correlate the information he obtains. The more definite and informative the responses of the patient, the more readily can the doctor arrive at a tentative diagnosis.

It is not uncommon for a patient's complaints to be of such a nature that the impressions presented will cause practitioners of different specialties to arrive at different decisions. It, therefore, behooves us to utilize the knowledge of differential diagnosis sufficiently to decide on the underlying condition and to decide on whether the patient belong withain our scope of practice, wheter a consultation is desirable, or whether the patient is in need of the services of more than one type of practitioner. It is not neccessary to state here how rewarding it is to be able to make a proper differential deduction or to be able to channel the patient for special and proper care when that is his need.

Case histories as usually encountered may be grouped into the following categories. It will be observed that each category becomes progressively more challenging.

1. *Simple Defects:* A patietn with a mild degree of myopia will present poor distance vision and good near vision without his correction. The presbyope requires help at the near point. The hyperope shows various degrees of visual acuity, according to age and other factors.

2. *Mildly Involved Defects:* Patients in this clasification may show astigmatic errors, mild muscle defects and combinations of several problems. Their symptoms may be vertigo, headaches, neurasthenia, hysteria, etc.

3. *Defects with complications:* These patients present problems involving stereopsis, diplopia, gross muscle imbalances, antimetropia, aniseikonia, aphakia, etc.

4. *Hereditary and Congenital Defects:* The problems presented by these patients include cataracts, retinitis pigmentosa, colobomas, etc.

5. *Acquired Defects:* Patients in this category may display trauma, organic distrubances and secondary ocular involvements related to systemic disturbances.

We are all familiar with cases of simple refraction in which relatived the same error is found in a number of different individuals, each one of whom requires a different approach because each one presents a different set of symptoms. The psychological understanding of the behavior of these patients and the application of our comprehension and knowledge to them may spell the difference between treated patient and *satisfactorily* treated patients. In contra-distinction to these cases, there are some which present semingly more involved errors but require far less pampering and attention. For example, a high astigmatic error may be easier to correct satisfactorily than a low one. Congenital and hereditary defects may require relatively severe courses of treatment and are many times amenable only to the use of subnormal vision aids. Acquired defects usually speak for themselves and are readily identified.

The vastness of the field with which we are concerned makes itself apparent in many ways. For example, when a patient complains of dizziness, for which there are listed at least fifteen causes, we must make an astute deduction to determine whether or not the vertigo may be allayed or subdued by any treatment within our field. The cause may be a single defect or it may be a combination of factors. This type of approach in our thinking must be applied to many symptoms encountered in our practice, such as headaches, neurasthenia and hysteria. For enlightment on the causes underlying these complaints, we must draw upon our knowledge of abnormal psychology, pathology, physiological optics, and refraction in its fullest sense. We must be ready to recognize the existence of many systemic diseases which present both subjective and objective ocular symptoms and be able to decide on the type of referral needed. In the case of those defects which are rather severe and show an advanced or irreversible change in ocular function, we must present a report, preferably written, to a (near) member of the family or to the patient's physician.

There are patients who volunteer full, unrelated, historical episodes. Often, this type of individual is very anxious about his eyes and is trying to be most helpful. He may hope to uncover for us the clue which will give him best vision. On occasion, a lonely person may use this approach to prolong his visit. A sympathic ear on our part will help both these types of persons. Of course, we record only relevant data. When time is lacking, we may assume a more dominant attitude and begin asking questions of a more pointed nature. However, it must be admitted that a tolerant and sympathic attitude may be very beneficial to the patient in obtaining the feeling of security which he seeks.

All too rare is the patient who submits himself periodically for ocular investigation as a means of finding out his ocular status. This approach should be encouraged, as a wide-spread habit of periodic eye examinations would benefit the public enormously. This type of patient offer a real challange to the practitioner, since he presents no obvious symptoms.

We must understand and appreciate the psychosomatic aspects of our patients if we are to care for them properly. When we observe a variety of complaints reported by different patients, all with more or less the same defect, and when we find one patient with the same defect as the others and no complaints at all, we are led to wonder. The reason seems obvious. The reaction of the individual to his physical shortcomings depends on his personality. The psychoneurotic, the individual with an anxiety complex, and the neurasthenic, all present symptoms of their discomforts in varying degrees, depending on their emotional states; while phlegmatic and depressed individuals withstand the same difficulties with little or no complaint. To all these considerations must be added an awareness of the working conditions of the patient and the conditions under which he uses his eyes. We must remember that a combination of factors may precipitate symptoms and complaints. We can see that psychosomatic factors play a large part in our practices. It behooves us to try to understand our patients better so that we may prescribe for them with a fuller comprehension.

The author cannot agree with the school of thought which teaches that most symptoms or complaints are present not because of the existence of physical defects, but in addition to them. We believe that the defect precipitates discomforts which are magnified when the ocular apparatus can no longer endure the demands made upon it and than these discomforts are made more noticeable by other contributing factors, such as poor lighting effects and a weakness of emotional stability.

Summary: The true art of prescribing involves the application of the multiple findings of an adequate examination to the salient complaints and symptoms of the patient. To this must be added a thorough evaluation of the findings from a satisfactory history with the personality of the patient included in the final analysis.

Conclusion:

When we can evaluate the probable direction of the examination and prescription from an interrogatory session with the patient, we may conclude that an adequate, informative and enlightened history has been recorded.

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THE OPTOMETRIC EDUCATION PROGRAM IN THE UNITED STATES

BY

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A meaningful description of optometric education in the United States probably is accomplished best by outlining the total academic training beginning with elementary schooling. The outline would vary slightly from region to region, but for practical purposes the total sequence fulfills the following time schedule:

I.	Elementary School	8 yrs.
II.	High School	4 yrs.
III.	Liberal Arts and Sciences	2 yrs.
IV.	Optometry	3-4 yrs.

No. I, the elementary school training, normally begins at six year of age. A year or so of "Kindergarten" may procede this as an option before six years of age, but "Kindergarten" normally includes none of the conventional academic subjects. The eight years of elementary school are normally required of all children by law, and the courses are normally the same for all children, including reading, writing, arithmetic, spelling, history, geography, music, literature, etc. In a very few communities the children are permitted some elective courses at the seventh and eighth grade levels.

In No. II, high school, the student is permitted a few optional courses, depending on whether he does or does not anticipate attending a college or university. The student planning to study optometry would choose a college-preparatory program to include 16 high school units (four per year). A college preparatory course would typically include at least two units of mathematics, two of a science, four of English composition and literature, two of a foreign language, two of a social science, usually history, and four additional elective or optional courses, usually selected from the above categories according to his interests. A student not following a college preparatory program would still be eligible to attend a college or university, but would have some course deficiencies to make up as extra work.

Each student takes his high school courses in the school facilities of his own community.

No. III, the liberal arts and sciences courses, may be taken in many of about 1,700 institutions of higher education in the nation, or in another country of desired. Admission to some is more competitive than for others, but, generally speaking, every high school graduate has the opportunity to enroll in a college or university somewhere. Students in the upper third of their high school classes normally can anticipate satisfactory progress at the college level.

College (or university) courses are usually tallied in either of two types of "units" or "credits", the semester hour"* or the "quarter hour". A normal academic year approximates 30 semester hours or 45 quarter hours, either to be converted into the other by the simple ratio of 2 to 3. Hence two years of liberal arts and sciences will total 60 semester hours or 90 quarter hours. These credits may be earned entirely at one institution or they may be accumulated by attendance at two or more in succession, or even a part-time basis. In preparation for the study of optometry the student must include credits in certain courses, as are specified by the optometry school or collage of his choice. Typically these requirements include 8-10 semesters hours in general physics, 8-10 in general chemistry, 8-10 in biology, 6-10 in mathematic (through analytical geometry, and, in some cases, calculus), and various amounts of English composition, foreign language, psychology, social sciences, and the humanities. Students who have not met the specified pre-optometry requirements or who have high school deficiencies to make up may require more than two years. On the average the optometry student will have taken three years of liberal arts and science work, for various reasons.

In each course the student receives a grade as well as credit. His grades have as much bearing on his admission to optometry as his credits. Thus a student with 60 semester hours of "B" or "A" work is much more certain to be admitted to optometry than is one with a grade level of "C". Grade levels of "D" and "F" (failure) are not admissible.

No. IV, the professional program in optometry, is available at any of the ten schools of optometry in the United States. One of the schools requires a full-time (nine months per year) attendance of four years. All of the others require three, except that two have a fourth year option for an additional degree or diploma.

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* A "semester credit hour" monas one hour of lecture per week for one semester, or the weighted equivalent in practical laboratory work.

The optometry curricula differ somewhat in the 10 schools, but all include substantial coverage of the following subjects: Geometric and physical optics, physiological and psychological optics, ophthalmic (mechanical) optics, clinical and theoretical optometry, general and ocular pathology, general and ocular anatomy, occupational vision, illumination, the professional orientation courses in jurisprudence, practice management, socio-economic, aspects of optometry, and history of optometry, and variously special courses in statistics, psychology, physiology, bac teriology, heredity, pharmacology, etc. The professional curriculum may be described aptly as one designed to prepare the student to become a "general practitioner in the field of vision", not to be construed as one who will engage in medical or surgical work.

The clinical optometry courses include all phases of optometry practice, such as refraction, orthoptics, visual training, contact lenses, subnormal vision, visual screening, opthalmic dispensing, testing for color vision, stereopsis, visual fields, aniseikonia, etc. Typically the clinical training includes work with regular patients, wherein the student prescribes, designs, orders, and dispenses eyewear, contac lenses, etc., and participates in all aspects of the clinic operation essentially as he would in a private practice, but under faculty supervision. Ophthalmic (mechanical optics, include lens and frame fabrication and design as well as the study of the physical and optical properties of eyewear. Ocular pathology has its emphasis on the detection of ocular anormalies needing medical attention.

Virtually all of the courses except the professional orientation courses include practical laboratory exercises.

Five of the ten optometry schools are in universities, in which instances the pre-optometry liberal arts and sciences (No. III) and the optometry (No. IV) may be taken at a single institution. Even in these schools, however, a large share of the optometry students will have taken their pre-optometry elsewhere.

Following completion of one of the professional optometry programs, the student is eligible to take a state licensing board examination in the state in which he plans to practice. A few students take examinations in several states.

Several of the university optometry schools offer advanced work in physiological optics leading to the Master of Science (M.S.) and/or the Doctor of Philosophy (Ph.D.) degrees. Such training is considered particularly valuable for those planning to do research in vision or teaching in optometry schools.

Indiana University, Division of Optometry.

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PROGRAMA DE EDUCACION OPTOMETRICA EN LOS ESTADOS UNIDOS

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Para hacer una descripción detallada de la educación Optométrica en los Estados Unidos de la mejor manera posible, se van a enumerar los estudios académicos comenzando por los elementales. Esta descripción es algo diferente en algunas regiones, pero de todos modos la secuencia completa llena los siguientes horarios:

1º Escuela Elemental	8 años.
2º Bachillerato Inferior	4 años.
3º Materias liberales y Ciencias ... ... (Universidad Pre-Optometría)	2 años.
4º Optometría	3 a 4 años.

Nº 1. — Los cursos elementales comienzan normalmente a la edad de 6 años. Un año de "Kindergarten" adicional antes de los 6 años se hace opcionalmente, pero normalmente este Kindergarten no incluye ninguna de las materias académicas convencionales. Los 8 años de escuelas elementales son decretadas por ley para todos los niños, y los cursos son todos iguales, incluyendo lectura, escritura, aritmética, ortografía, historia, geografía, música y literatura, etc. En algunas regiones es permitido a los niños tomar cursos especiales especialmente en el 7º u 8º grado.

Nº 2. — En el Bachillerato Inferior, se permite al estudiante algunos cursos especiales, pero depende de si va a asistir a alguna Facultad o Universidad. El estudiante que va a estudiar Optometría prefiere un programa de preparación a Facultad que incluye 16 cursos de Bachillerato (4 por año). Un curso preparatorio a Facultad, por lo general incluye 2 cursos de Matemáticas, 2 de Ciencias, 4 de Inglés avanzado y Literatura, 2 de un idioma extranjero, 2 de ciencias sociales, por lo general Historia, y 4 adicionales de elección o cursos opcionales, que por lo general se eligen en las categorías antes indicadas y de acuerdo con el propio interés. Un estudiante que no siga el programa preparatorio de Facultad también puede atender una Facultad o Universidad, pero tendrá algunos cursos adicionales que llenar como extra. Cada estudiante toma los cursos de Bachillerato Inferior en los colegios de su comunidad en particular.

Nº 3. — Los cursos de materias liberales y Ciencias, pueden ser tomados en una de las 1.700 instituciones de educación superior en la nación, o en cualquier otro país, si así se desea. La admisión en algunas, es más difícil que en otras, por lo general, cualquier estudiante, que termina el Bachillerato Inferior, puede ingresar a una Facultad o Universidad donde quiera. Los estudiantes clasificados en el tercio más alto de los cursos de bachillerato, por lo general terminan con éxito los estudios de Facultad.

Los cursos de Facultad o Universidad son tenidos en cuenta como unidades o créditos, la "hora-semestre" significa una hora de clase semanal en un semestre, o su equivalente en trabajo de laboratorio, o la hora de cuarto de año. Un año académico normal tiene alrededor de 30 "horas-semestre" o 45 "horas de cuarto de año" las que pueden convertir entre sí en la proporción de 2 a 3. De aquí que dos años de materias liberales y ciencias totalizan 60 "horas-semestre" o 90 "horas de cuarto de semestre". Los créditos se pueden conseguir completamente en una institución o pueden ser acumulados atendiendo a 2 o más en su orden, o aún como "parte de tiempo". Cuando el estudiante se prepara para estudiar Optometría debe incluir créditos en ciertos cursos, de acuerdo con los requerimientos de la Facultad de Optometría que haya escogido. Por lo general estas exigencias incluyen de 8-10 "horas-semestre" en física, 8 a 10 en química, 8 a 10 en biología, 6 a 10 en matemáticas (Geometría Analítica y en algunos casos Cálculo), composiciones en inglés, idioma extranjero, psicología, ciencias sociales y humanidades. Los estudiantes que no han completado estos cursos de Pre-Optometría, o que tienen deficiencias de Bachillerato, pueden gastar más de 2 años. Por lo general un estudiante de Optometría toma 3 años de cursos liberales y ciencias, por varias razones. En cada curso el estudiante recibe un grado así como un crédito. Sus grados tienen tanto que ver en la admisión como sus créditos. Así un estudiante con 6 "horas-semestre" con calificaciones de A o B, es admitido más fácilmente que uno que esté en nivel de C. Las calificaciones D y F no son admitidas.

Nº 4. — El programa profesional en Optometría, se obtiene en cualquiera de las 10 Facultades de Optometría de los Estados Unidos. Una de las Facultades requiere tiempo completo (nueve meses por año) de asistencia durante 4 años. El resto requieren 3, con excepción de dos que tienen un año opcional (4º) para conseguir un Grado Adicional o Diploma. El curso de Optometría es ligeramente diferente en las 10 Facultades, pero todas incluyen substancialmente las siguientes materias: Geometría y Física Optica, Fisiología y Psicología Optica, Optica Oftálmica (Mecánica), Optometría Clínica y Teórica, Patología General y Ocular, Anatomía General y Ocular, Visión de Oficio, Iluminación, Cursos de Orientación Profesional en Jurisprudencia, Manejo Práctico, Aspectos Socio-Económicos en Optometría, Historia de la Optometría, Cursos Especiales en Estadística, Psicología, Fisiología, Bacteriología, Farmacología y Genética. El curso profesional se describe como preparación al estudiante, para llegar a ser un "Especialista General en el Campo de la Visión", y no como uno que hace "Trabajo Médico y Quirúrgico".

Los cursos clínicos de Optometría incluyen todas las fases de Optometría Práctica, con Refracción, Ortóptica, Entrenamiento Visual, Lentes de Contacto, Visión Subnormal, Pruebas Visuales, Adaptación de Anteojos, Pruebas de Visión de Color, Estereopsis o Visión Estereoscópica, Campos Visuales, Aniseikonia, etc. Por lo general el entrenamiento clínico incluye trabajo con pacientes generales, donde el estudiante prescribe, diseña, ordena, adapta anteojos, lentes de contacto, etc., y participa en todos los aspectos de la operación clínica esencialmente como si lo hiciese en su Consultorio privado, pero supervigilado por los profesores. Optica Oftálmica (Mecánica), incluye fabricación de lentes y monturas de anteojos, así como el estudio de los propiedades físicas y ópticas de los anteojos. La patología ocular tiene énfasis especial en el descubrimiento de anomalías oculares que necesitan atención médica.

Por lo general todos los cursos, con excepción de Orientación Profesional, incluyen Prácticas de Laboratorio.

Cinco de las 10 Facultades de Optometría están localizadas en Universidades Generales, en cuyos casos, los cursos liberales y las Ciencias (Nº 111 y la Optometría (Nº IV), se pueden tomar dentro de la misma Institución. Aun en estas Facultades, sin embargo, una gran parte de los estudiantes de Optometría han hecho sus cursos de Pre-Optometría en otras partes.

Una vez completado el curso profesional, el estudiante se halla capacitado para presentar los Exámenes de Licenciamiento del Estado en donde va a ejercer. Algunos estudiantes presentan exámenes en varios Estados.

Algunas de las Universidades Optométricas ofrecen cursos avanzados en Fisiología Optica que confiere el título de "Master of Science" (M.S.) y o el de Doctor en Filosofía (Ph. D.) dichos cursos son de un gran valor para aquellos especialistas que desean participar en Investigación de la Visión, o enseñar en las Facultades de Optometría.

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FLASHRATE DISCRIMINABILITY OF HUMAN SUBJECTS AT THRESHOLD INTENSITY LEVELS

BY

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ABSTRACT

A study was conducted to determine the ability of human subjects to correctly identify three different flashrates at the differential stimulus threshold of detection. The subject viewed a 40 degree diffusely illuminated surround with a two minute aperture through which the stimulus white light was passed. The five surround luminance levels of white light used were 2700, 100, 1.0, 0,01, and 0.001 ft. lamberts. The observers were instructed to use only foveal vision.

Flashrates of 40, 80, and 160 flashes per minute were randomly presented as stimuli to the five observers. A total of 900 threshold measurements per surround level taken showed that for surround levels of 0.01 and 0.001 ft. lamberts the subjects at or near threshold tended to see each flashrate as faster than it actually was. Thus the 80 flashrate was often confused for the 160 flashrate and the 40 flashrate was confused with the 80 and sometimes the 160 flashrate. Each observer reported this though some manifested it much more clearly in their data. Tenable explanations are offered to explain the appearance of the very fast flashrate for the two lower surround luminances.

INTRODUCTION

A study was undertaken at the Honeywell Research Center Vision Laboratory to investigate flashrate discrimination of human subjects at differential threshold levels of stimuli intensity. The stimulus being a circular aperture which subtended an angle of two minutes from the position of the subject's eye and through which white light from a tungsten source was flashed. Five different white surround luminance levels were chosen as parameters ranging in luminance levels from that of the sky in proximity to the sun, to the sky on a moonless night.

The purpose of the investigation was to conduct a basic expriment on flashrate discrimination at threshold levels of intensity as well as to acquire information on the effectiveness of a flashing light system for a simplified visual telecommunication system. The three flashrates chosen coincided with the three different flashrates used by an air anti-collision light system to inform the observer of the directional path of the observed plane with respect to that of the observer.

BACKGROUND

Very little can be found in the visual literature on flashrate discrimination or of the subjective appearance of different flashrates. Bartley (1) reports that at dim levels of stimulus intensity when the critical fusion frequency is about four flashes per second, a flashrate just lower than this will produce a flutter which has an appearance of being much faster. Increasing the stimulus intensity will produce a subjective flashrate corresponding approximately to that of the actual flashrate. Bartley postulates that this apparent "fast" flashrate should be attributed to the visual pathway at a higher level than the receptors.

An earlier experiment not employing a flashing light in the true sense but rather a rotating disc with an illuminated radial slit was conducted by Charpentier (2). While fixating the center of the rotating disc the illuminated radial slit produced an intermittent stimulus to the retinal receptors in the image pathway of the illuminated radial slit. Charpentier observed that a succession of light and dark bands followed the moving slit and that the magnitude of this effect was dependent upon the adaptive state of the eye, the intensity of the stimulus and the region of the retina stimulated. Computations made by Charpentier showed that the first recurrent image appeared about 200 msecs after the primary image.

Adler (3) in discussing Charpentier's observation points out that after a single stimulus of light of shorter duration than the action time, the primary image will consist of a rapid rise in intensity followed by a less intense fluctuating or pulsing sensation before termination of the primary image.

Experiment I - Apparatus

The experimental apparatus used in this experiment is diagrammed in Figure 1. In the optical system, light emanating from a single source, traverses two separate channels producing the uniform surround luminance in the integrating sphere and the stimulus light. The light source was provided by an incandescent 18 ampere-6 volt, medium prefocus, single coiled filament bulb. Line current run through a varitran and a 6 volt transformer supplied the power for the lamp. Attached by leads to the varitran was a voltmeter which provided for accurate checking and adjusting of the voltage before each judgement. The varitran was run throughout the experiment at 120 volts.

Light from the source traveled nearly identical routes for the two channels. The light was collected and the focused in the plane of the chopper blade. A collimating lens then collected the light past the chopper and directed it to a front surface mirror (M1 and 2) wich reflected the light at right angles to the incident beam. The parallel beam then traveled through a filter holder aperture where neutral density filters were used to make gross attenuations of the light intensity. A subsequent lens then converged the beam for passage through the optical wedge aperture. The optical wedge provided a means to more precisely attenuate the light beam. A rack and pinion mechanism enabled the operator to position the optical wedge to the

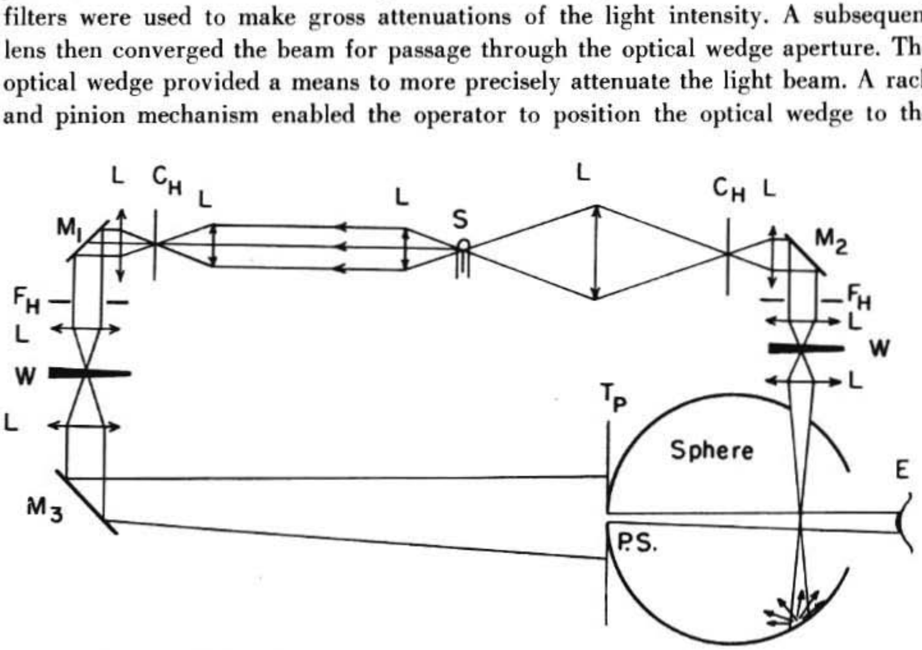


Fig. 1. EXPERIMENTAL APPARATUS

S = Light source; L = Lens; Ch = Chopper blade;
M = Mirror (rt. angle); Fh = Filter holder;
W = Wedge (optical neutral density); Tp. = Target plate;
P.S. = Point source aperture; E = Eye.

desired density. After passing through the wedge aperture the light was then collected. At this point the light is treated differently in each channel. The light illuminating the integrating sphere is converged and directed through a small aperture into the sphere. It is then reflected and uniformly diffused after the first reflection inside the sphere. The chopper blade intersecting the light to the integrating sphere was removed to provide steady light for the surround luminance. Light traveling in the opposite channel is reflected through 90 degrees by a front surface mirror (M_3) which directs it to a target plate. The target plate has a circular aperture with dimensions that provide a 2 minute source of light as subtended at the entrance pupil of the eye. The surround field subtends 40 degrees at the eye.

In order to obtain the two highest surround luminance levels an incandescent bulb, operating at the same voltage to assure a nearly identical color temperature, was placed inside the integrating sphere. The lamp was positioned so that the observer saw no part of the bulb.

This optical system provided the desired surround luminance levels and by using neutral density filters in conjunction with the optical wedge, attenuation to an adequate number of point source intensities was possible.

Eye allignment with the stimulus was assured by a bite-board mechanism. The three flashrates used were 40, 80, and 160 flashes per minute. These were determined by adjustment of the voltage supply to a variable speed motor which drove the chopper. The sector width of the disc was adjusted for each speer to maintain a constant stimulus duration of 4 msecs.

Experimental Procedure

The observers were five young male employees of the Honeywell Research Center, who were screened with their dominant eye and no history of visual disorder. The subjects used only their dominant eye for flashrate determinations. They were given several experimental training sessions during which data was collected. When these data showed a leveling off of the visual thresholds, the observers were considered trained. At the beginning of each session the observer was again shown the flashrates at a high intensity level in order to refresh his memory of them. After the flashrate familiarization period the subject dark adapted for 10 minutes and then light adapted to the surround luminance selected for that session for 5 minutes.

The flashing light stimulus was exposed continually. The neutral density wedge and filters were adjusted so that at the beginning of each trial series the source was too dim to be seen. The intensity was then raised by a .01 density step on each trial, accompanied by a "now" signal from the experimenter. The observer was instructed to judge "no" meaning. I do not see it or, if he saw the light, he was asked to say either "fast", "medium", or "slow".

Flashrates were randomly changed from series to series and frequently a series was continued 3 to 6 steps beyond correct identification so that it was impossible for the observer to obtain information other than visual cues of the correct flash rate. The intensity level of the first of three successive positive responses was taken as the detection threshold. The first of the three successive correct identifications was taken as the correct identification threshold.

Thirty trial series producing 30 determinations of the detection and identification thresholds were obtained for each of three flashrates and for each of the five luminance levels of the surround. The surround levels were: .001 ft. 1 (moonless clear night sky), .01 ft. 1 (twilight), 1.0 ft. 4 (20 minutes after dawn, clear sky), 100 ft. 1 (overcast day sky), 2700 ft. 1 (clear bright daylight sky close to sun). Each of the five observers replicated the entire experiment, producing 450 detection thresholds and 450 correct identification thresholds per condition or 4500 thresholds in all.

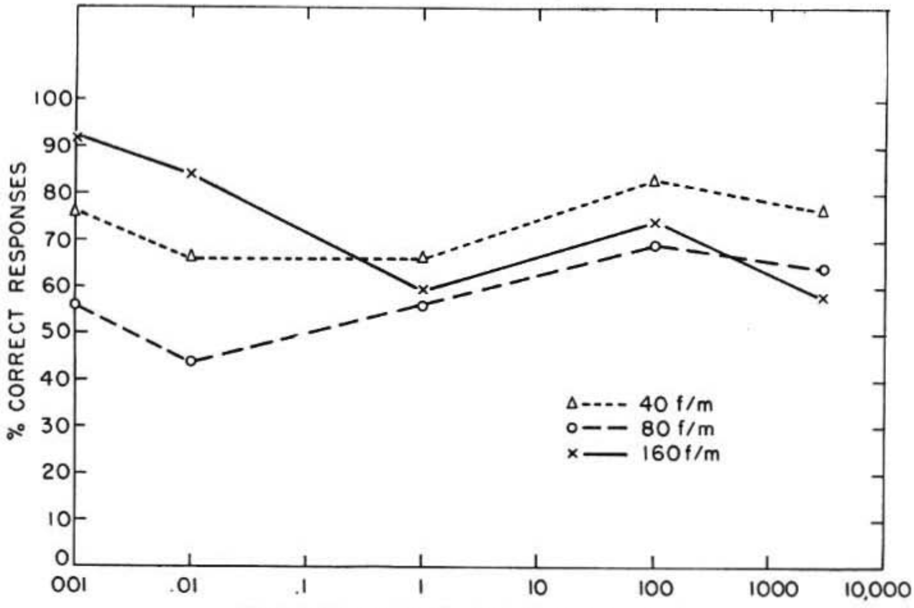


Fig. 2. The percentage of correct identification responses at the threshold level of seeing are plotted against the luminance level of the surround. Each percentage value represents an average of the five subjects combined results.

Results

Figure 2 shows that for the brighter levels of surround luminance (2700 and 100 ft. lambert levels) the slow flashrate (40 f/m) is more frequently identified correctly at the detestion threshold level than the medium (80 f/m) and fast (160 f/m) flashrate. In contrast, the 160 f/m flashrate is more frequently identified correctly with the two lower surround luminance levels. The 80 f/m flashrate was very confusing at the two lower levels of surround luminance as manifested by the graph. With the exception of the 2700 ft. lambert level of surround luminance the 80 f/m was confused more often than either the 40 f/m or 160 f/m flashrates.

Figure 3a, b, and c, display the distribution of wrong responses for the five different surround luminance levels. Of significance for the 160 f/m flashrate is the decrease in incorrect responses for the 0.01 and 0.001 ft. lambert level of surround. Of additional interest is that for all surround luminance levels the

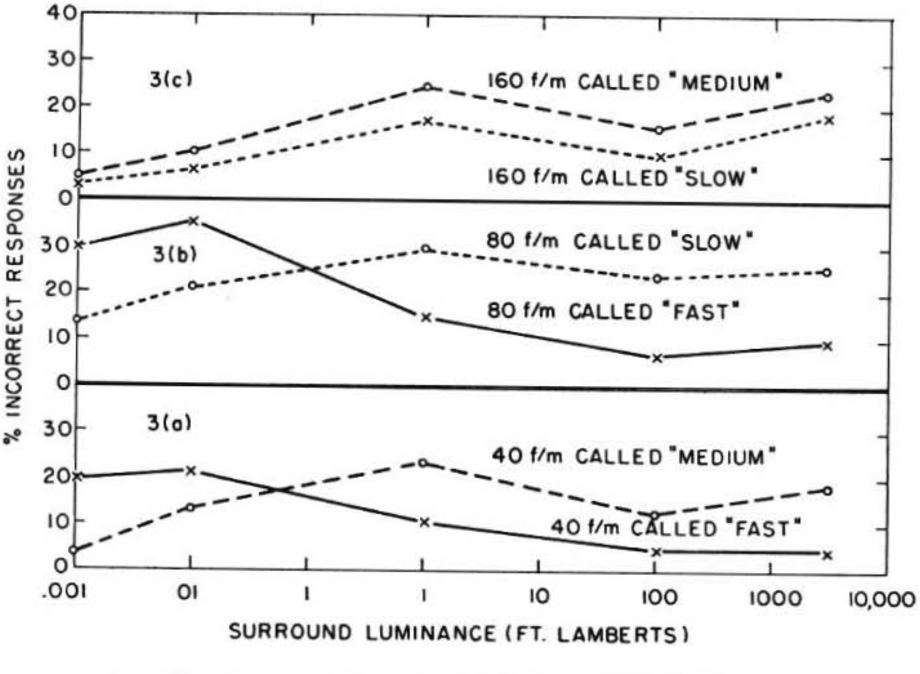


Fig. 3a, b, c. The above graph shows the distribution of the incorrect responses as reported by the five subjects. This is to demonstrate for which flashrate the correct flashrate was confused with at each of the five levels of surround luminance employed in the experiment.

160 f/m flashrate when reported incorrectly was reported more often as the "medium" flashrate rather than the "slow" flashrate.

Of importance for the 80 f/m and the 40 f/m flashrates is that the incorrect responses are more frequently the slower flashrate of the two possibilities for the higher levels of surround luminance and the faster flashrate of the two possibilities for the two lower levels of surround luminance. To elaborate on this, Figure 3b shows that above the 0.1 ft. lambert surround level the 80 f/m flashrate is reported, when reported incorrectly, as "slow" more often than "fast". Figure 3a demonstrates that above the 0.1 ft. lambert surround level the 40 f/m flashrate, when reported incorrectly, is more frequently called "medium" than "fast".

Observer's Reports

The two lower levels of surround luminance proved to be the most interesting and will be the two levels dealt with most extensively in this paper. When adapted to the two dimmer surround levels the subjects at times reported that a flashrate appeared very fast at first. This was reported by all subjects.

Experiment II - Flash Rate Discrimination in Different Retinal Locations and With Chromatic Stimuli.

The objective of this supplementary experiment was to determine if the apparent "very fast" flashrate is evident with conditions other than with foveal vision and white light stimuli.

Apparatus

The apparatus was the same as that used for the previous experiment except that an interference filter to provide chromatic stimuli was inserted into the optical system at F_H (Figure 1) in the channel providing the flashing light stimulus. In addition small red fixation points, two minutes in angular size as subtended from the observer's eye, were placed at 1, 2, 3, 4, 7.5, 10, 12.5 and 15 degrees outward in the right eye field of vision. The intensity of the fixation spots were reduced to just above foveal threshold. A switching mechanism enabled the operator to select the desired fixation spot.

Experimental Procedure

Two male observers who were subjects for Experiment I were used for this experiment. Because of their training in the previous experiment, it was assumed that the subjects were well trained without any additional training sessions for this experiment.

The flashrate was set at 40 f/m. This same flashrate was used throughout the experiment. The same procedure was followed as described under Experiment I. After dark adaptation, the subject was instructed to look at the red fixation spot, or, when foveal vision was desired, to look at the aperture while the operator increased the intensity of the flashing light by assigned increments. He was instructed to report after each increment "NO" if he did not see a flashing light, or to report, "slow", "medium" or "fast". When the black surround was used the one degree fixation spot was left on to help orient the subject with respect to the aperture.

In addition to studying the dependence of confusion upon chromatic stimuli and eccentric foveal angles of fixation, two luminance surround levels were selected. The two surround levels chosen were 0.0 and 0.01 ft. lambert of luminance. The 0.0 surround was established by completely blocking of the channel of light which could enter the sphere. The observer's aperture was left open but the minute amount of stray room light which may have entered the sphere was not measurable. The 0.01 ft. lambert surround level was established by setting the sphere at one ft. lambert using the McBeth illuminometer and then introducing a neutral density filter and wedge setting to obtain a density of 2.0.

The color of the flashing light was established with interference filters. The two interference filters used and their characteristics are as listed below:

	Dominant Wavelength
Blue (2nd order)	428 mμ
Red (2nd order)	633 mμ

A blocking red filter with a cutoff between 600 and 605 mμ was used in conjuction with the 2nd order red interference filter.

Results

Figure 4 summarizes the results on two observers. Only preliminary findings were taken concerning the relationship between the colors of the stimulus and the number of "fast" responses reported. These findings indicated that this phenomenon was independent of the color stimulus used. The duration of the dark adaptation period also did not seem to influence the number of "fast" responses.

The most significant dependent variable is retinal position. For angles of fixation beyond 2° the subjects did not report seeing the "fast" flashrate during two trial sessions. Sessions were then begun using only foveal vision and 1° and 2° angles of fixation. Figure 4 illustrates that subject B.E. only reported the flashing light as "fast" when he was observing the light with foveal vision. J. D.'s results are not

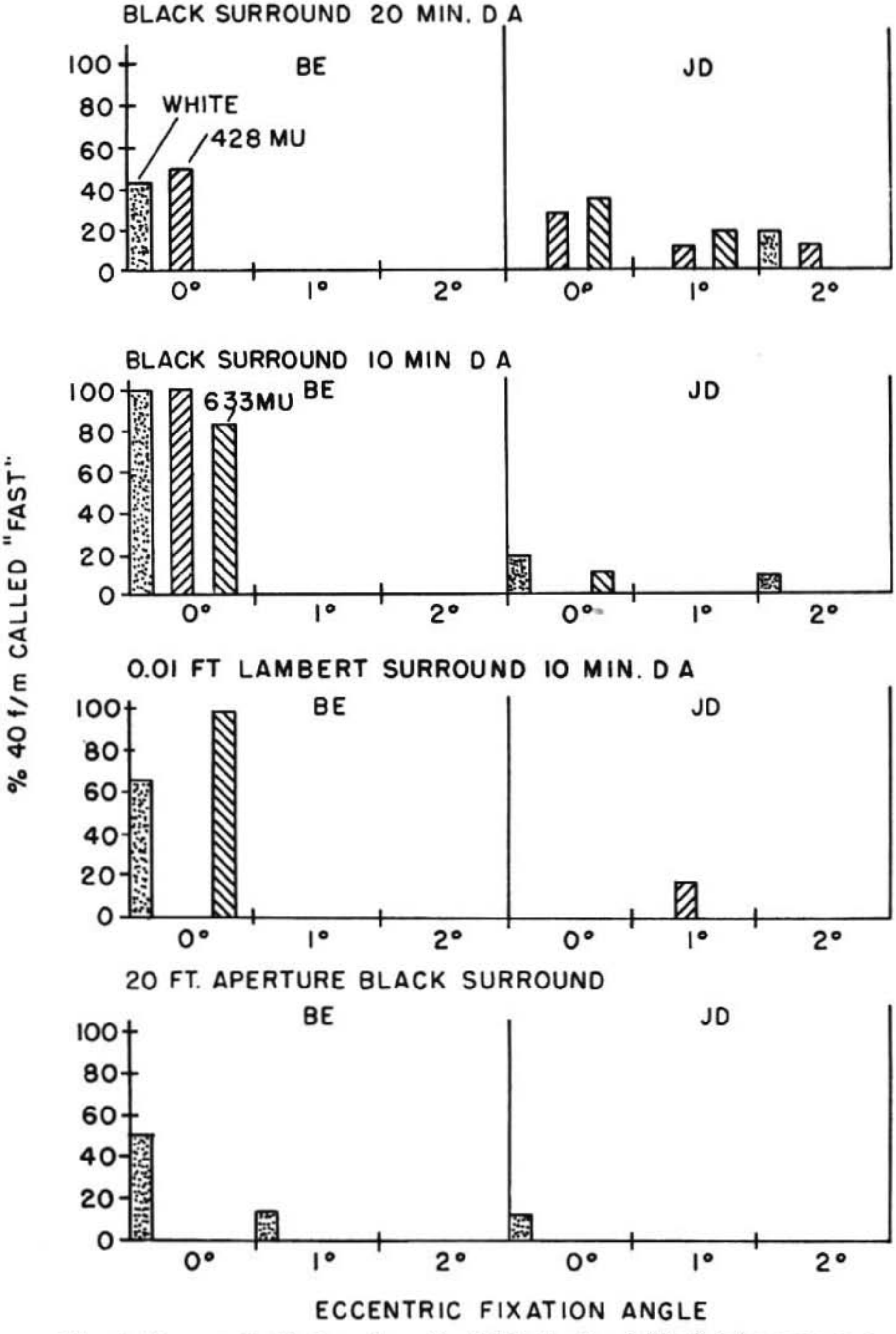


Fig. 4. Per cent distribution of combined "Medium" and "Fast" judgements as a function of fixation angle and stimulus color.

quite as clearcut. With the surround level at 0.01 ft. lamberts he did not report a "fast" response for nine of the colored stimuli with foveal vision. The combined data on the three fixation positions are shown in Figure 5.

In addition to the above results the two minute flashing aperture was replaced with an aperture subtending a 20 minute angle at the eye. Only enough experimental trials were conducted to indicate that this phenomenon was not restricted to a point source of light.

By changing the experimental procedure and allowing the subjects to adjust the intensity of the flashing light, the subjects could find an intensity just above threshold that would produce a "fast" response the majority of the times attempted. This was found to be true when the subjects fixated either the 20 minute or 2 minute stimulus.

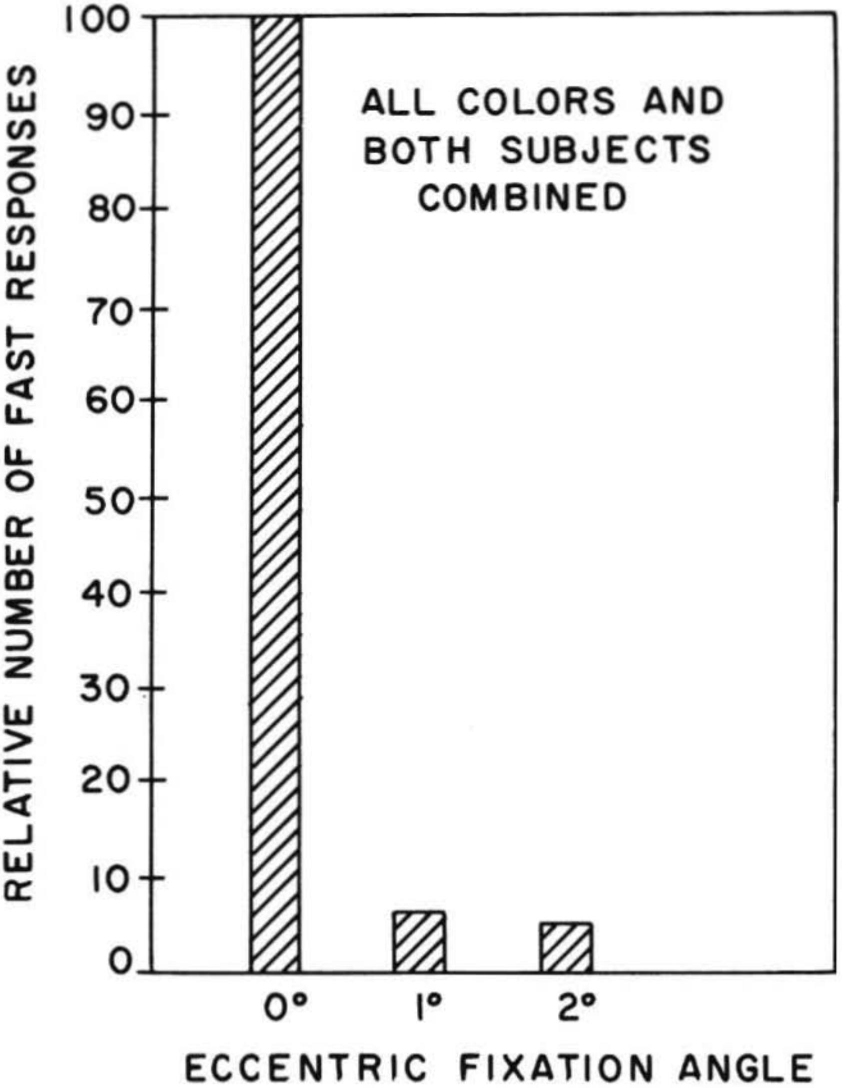
Discussion

In attempting to answer why a flashrate may appear slower at threshold with a surround luminance above 0.1 ft. lambert, one may consider the "probability of seeing zone" which is present with threshold judgements.

A light flash of a given and sufficient intensity to fall within the boundries of the "probability of seeing zone" would have a certain probability of eliciting a sensation. A series of light flashes of constant frequency at the same given intensity level may be expected to produce an apparent flashrate proportional to the probability of seeing a single light flash.

The subject, when vie wing a flashrate at such an intensity, may then see only occassional flashes in a randomized order. Because of the uncertainty of threshold measurements these occassional pulses may be judged as a slower flashrate than the actual flashrate. During the comment period the subjects were sometimes questioned as to what they had based their flashrate judgements on. One subject reported that he normally would call the flashrate "slow" when he only saw one or two flashes. One subject stated he would report "medium" when he saw pulses at irregular intervals.

Judgin from these subjective reports it seems safe to say that a flashrate response slower than the actual rate is due to the failure of each flash to elicit a light sensation. It may be suggested that the probability of seeing a light flash at threshold where the number of quanta is critical may rest upon the constancy of the source and experimental apparatus and on the level of the subject's "visual conscienceness" which may be in a constinuous state of vacillation.



RELATIVE NUMBER OF FAST RESPONSES
100
90
80
70
60
50
40
30
20
10
0
ALL COLORS AND
BOTH SUBJECTS
COMBINED
0°
1°
2°
ECCENTRIC FIXATION ANGLE

Fig. 5.

A conflict arises when one views the results of the data for the luminance surround levels of 0.01 and 0.001 ft lamberts. At these levels of surround luminance the 40 f/m flashrate is not identified correctly as often as the 160 f/m flashrate. Also Figure 2 shows that at the 0.001 ft lambert level the 160 f/m flashrate is identified correctly 92% of the time. One must conclude from this information then that at these levels of adaptation the dimension of the "probability of seeing zone" has been constricted or that another form of visual behavior has become of greater consequence.

The frequency with which the subjects saw all flashrates as "very fast" may answer in part why the 160 f/m was identified correctly most often at these two lower surround levels and also it may explain why, as shown in Figure 3a and 3b, the 40 f/m flashrate and the 80 f/m flashrate was confused more frequently for the faster flashrate.

To explain why a flashrate may appear much faster when observed at or near threshold intensity one may speculate on the retinal activity following a single light flash. When a flash of light is incident on a foveal cone population after dark adaptation, the group of cones excited may discharge not only once but several times thus sending a volley of impulses to the higher visual centers. One may assume that the individual cones would fire in near synchronization to produce an appearance of discrete flashes.

Another postulation may be offered which would permit the excited cones to fire in a random order. This would permit allowance for the fact that each cone may have a different firing threshold or a different latency period. It would be necessary to propose that there is a certain summating and phasing of these foveal receptor impulses to produce a degree of order. Anatomical evidence which indicates that most foveal cones have a "private line" within the retina, as indicated by Polyak(4) would rule out spatial interaction of the foveal impulses on the retinal level. On this premise if summation and phasing of the foveal impulses is assumed to occur it must be relegated to a higher level than the retinal level. The end result of such summating and phasing may be an apparent flashrate which would not be in accordance with the actual flashrate.

A necessary condition for observing the "very fast" flashrate was a critical level of stimulus intensity for a given dim or dark surround. Only when the intensity of the stimulus was adequate would the visual activity which followed the light flash be such as to produce the apparent "very fast" flashrate.

Summary

Flashrate discriminability of human subjects is influenced by the adaptive state of the eye and the retinal location of the stimulus. Dimmer levels of surround luminance may induce an apparent fast flashrate as judged by the subject. Brighter surround levels tend to favor the identification of the slow flashrate.

Failure of every light flash to elicit a sensation may have resulted in judgements slower than the actual flashrate. A very fast flashrate may be produced by groups of receptors firing more than once for a given stimulus or a group of receptors firing randomly with subsequent summating and phasing.

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THE PRESUMED AND APPARENT ROLE OF LENS ELASTICITY IN THE ETIOLOGY OF PRESBYOPIA

BY

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Presbyopia is defined by the Dictionary of Visual Science[22] as "A reduction in accommodative ability occurring normally with age and necessitating a plus lens addition for satisfactory seeing at near, sometimes quantitatively identified by the recession of the near point of accommodation beyond 20 cm." Webster[24] and Dorland[5] attribute the disminution of accommodation to the "loss of elasticity of the crystalline lens" which is generally believed due to sclerosis, or hardening of the nucleus of the lens.

Thomas Young[25], who proved conclusively that the act of accommodation was mediated through the alteration in shape of the crystalline lens in man, commented, "It has been observed that the central part of the crystalline becomes rigid by age, and that this is sufficient to account for presbyopia"[26]. This remark makes it evident that the classic concept of the cause of presbyopia dates back even before 1860.

A statement by Donders[4] crystallizes the reasoning regarding lens sclerosis as the basis for presbyopia. "In the first place, it may be asked, in general, how and from what cause it is, that at so early a period in life, while all functions, and especially that of the muscles, are in a state of progressive development, the power of acommodation, which depends upon muscular action, already loses in extent? As it must be admitted, that the ciliary muscle has continued normal, and is therefore still in full force, we come readily to the inference that, at least in the first instance, the disminution is to be sought exclusively in the condition of the parts, which in accommodation are passively altered, and by no means in the state of those whereby the

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* The contents reflect the personal views of the author and are not to be construed as official Air Force policy.

change is actively produced. Now the organ which is passively altered is the lens. Is the early disminution in the range of accommodation $\frac{1}{A}$ to be explained from this? We know that at an advanced time of life, the lens is firmer than in youth. I think. I may even assert that the increase in firmness commences at an early period. Now, it is in consequence of this greater firmness that the same muscular action can no longer produce the same change in form of the lens. It is therefore very probable that the early disminution of $\frac{1}{A}$ depends thereon".

Fuchs[11] differentiated between physical accommodation, the actual alteration of the lens, and physiological accommodation, the action of the ciliary muscle. The "myodiopter" was introduced by Flierenga[10] as a unit of the physiological component in accommodation, i.e. the contractile power of the ciliary muscle required to increase the refractive power of the lens by one diopter. Regardless of age, they believed, the same amount of ciliary contraction is required to produce a given change in the form of the lens within the limits that the lens can change form. With increasing age, less and less of the muscle force available can be utilized.

The reaction of 2013 subjects to homatropine was studied by Duane[6]; the drug produces a gradual paresis of the ciliary muscle. If the same amount of physiological accommodation is available regardless of age, then the young, who do manifest a close nearpoint of accommodation, should show an almost immediate recession in response to the cycloplegic, and the older individuals should not react until the physiological accommodation in excess to need had been absorbed. His results showed a more rapid reaction by the *older* people. Duane's findings led him to conclude that the "ciliary energy diminishes with age almost in proportion as the manifest accommodation diminishes".

This conclusion stimulated Henderson's[13] histological study of a series of eyes in successive decades from ages 10 through 60, and he reported progressive sclerosis of the interstitial tissue of the tensor and sphinctor divisions of the ciliary muscle. "Ciliary sclerosis" in the sixty year old was the description given to the muscle fibers imbedded and walled in by connective tissue, and thereby prevented from exerting their physiological action.

Henderson further noted that if lens is subluxated in an individual in advanced presbyopia it presents a myopic lenticular refraction. Although the nucleus becomes compressed and sclerosed, the cortex is never senile since new fibers are always being added to it, therefore regardless of age, the lens capsule will assume a more spherical form if it is released from tension.

A detailed study of the lens capsule convinced Fincham[8] it is highly elastic, and due to varying thicknesses, the lens would be flattened where the capsule was thickest, and would bulge where it was weakest upon relaxation of the suspensory ligaments. Maximum curvature occurs at the posterior pole for the capsule there is very thin; capsular thinning at the anterior pole is also seen, and in accommodation the thicker peripheral anterior capsule compresses the lens substance to a greater degree resulting in the assumption of the hyperbolic shape.

By an ingenious slit lamp arrangement, Fincham[9] photographed the unaccommodated and accommodated lens of a 22 year old individual who had suffered traumatic aniridia of one eye. It was evident that the nucleus as well as the cortex underwent a change in form, and this convinced Fincham that sclerosis of the nucleus is sufficient to account for the development of presbyopia.

Fincham[9] measured the radius of curvature of the anterior surface of extirpated levels from subjects aged 11 and 65, and found 5 mm and 9.5 mm respectively at the center of the surface. Since these lenses are assumed to be free of all restraint they are accommodated as far as the nature of the lens substance and capsule will permit. He therefore concluded "the loss of accommodation in the senile lens is due to the inability of the capsule to mould the more rigid lens substance into the accommodated form". Fincham expressed doubt that the recession of the near point at an age as early as it is manifested is the result of a loss of ciliary power due to increasing interstitial tissue among the muscle fibers. Graves[12] had reported an individual who had sustained injury to his eye, and the entire lens substance had been absorbed after trauma, leaving the empty transparent capsule in situ. Fincham observed the capsule response to accommodation when this individual was 40 years old, and he was convinced that the change which occurred could not be produced by a ciliary muscle with only "one-third of its original power".

To explain why full accommodation cannot be maintained indefinitely by a presbyope, and why optical help is preferred even when his accommodative nearpoint is shorter than his working distance. Fincham offered the following reasoning. "As the lens substance becomes harder with age, greater force from the elastic capsule will be required to produce a given change of curvature. This force, in view of the elasticity of the suspensions can only be applied by greater contraction of the ciliary muscle. Consequently, a force approaching the full capacity of the muscle may be required to produce maximal accommodation whether it be some 15 or 16 diopters in youth or only 1 or 2 diopters in presbyopia". The amplitude of accommodation, then, is limited by the balance between the freedom given the capsule by the contracting muscle, and the resistance of the lens substance to deformation.

Morgan and Peters[16] took issue with this explanation. If the only effect of the ciliary muscle is to release zonular tension so that the capsule can mold the lens, ciliary contraction in excess of capsular response should result in no increase in accommodation, but in a sinking of the lens under gravitational effect. Therefore, each diopter would require the exact same relaxation of the suspensory ligaments regardless of the degree of lens sclerosis.

The development of presbyopia as Morgan[17] explains it, is a result of sclerosis of the lens nucleus, sclerosis of the ciliary muscles, and a decrease in the mass of the ciliary body resulting from a loss of vessel elasticity, all due to aging. In 1946, Morgan[18] related the tension on the suspensory ligaments to the mass of the ciliary body which depends on the changes in blood volume in this highly vascular structure. Constriction of the blood vessels leads to a decrease in mass which increases the pull on the suspensory ligaments causing lens flattening. Ciliary contraction would necessarily need to be greater to make up for the decreased mass.

Although the etiology of presbyopia is still shrouded in the unknowns of the accommodative mechanism, lens sclerosis receives the major attention for the recession of the near point of accommodation with age. It has been stated that the lens loses its elasticity from the day of birth by a continuous process of sclerosis[23], but it must be conceded this would be exceedingly difficult to demonstrate experimentally. Duke-Elder[7] subscribes to the same cause and development of presbyopia commenting, "It follows that the power of accommodation gradually diminishes, a process which cannot be considered as abnormal and which proceeds gradually throughout the whole of life".

A number of interesting experiments and conclusions have been presented in the literature concerning correlations between accommodation and aging which are worthy of brief review.

Lancaster and Williams[15] investigated the effect of prolonged accommodation at or near the punctum proximum in subjects ranging in ages from 28 to 64 years. No surprise was expressed when it was found that the far point moved in. This was evident by the necessary addition of a minus spherical lens to a previously determined distance correction to again obtain maximum visual acuity at six meters; closing or resting the eyes brought recovery of the original refractive status in approximately ten minutes. The authors assigned the cause of the advancement of the far point to "contracture" of the ciliary muscle which was defined as "a state of maintained contraction" or retarded relaxation, i.e. at the end of the contraction the muscle does not return to its resting position but remains more or less shortened. This was distinguished from spastic rigidity since applied stimuli still produced a quick further contraction, and on removal of the stimuli a rapid partial relaxation occurred, these being superimposed on the contracture. Here, then, the mechanics operating in latent hyperopia were made evident.

The effect of maximum accommodation upon the near point amazed the investigators. The expectation was for the ciliary muscle to fatigue after a short time interval and cause the punctum proximum to recede, but, in fact, the near point was found to be closer to the observer than initially after about one half minute. It continued to advance with repeated measurements for approximately half an hour at which time a gradual recession occured for most subjects. Even after an hour of reading, exerting full accommodation, subjects were able to read at a nearer point than at the start with remarkably few subjective symptoms. A curve plot for a 54 year old individual and a 13 year old revealed an interesting comparison. The presbyope initially showed 1.225 D of accommodation, and after five minutes of concentrated near point exertion 1.846 D was measured, an accommodative gain of more than 50 per cent. The youngster registered 11.75 D of accommodation at the beginning, and achieved 16.00 D at the end of the same time period showing about a 35 per cent gain.

The enhanced near point effect could not be explained on a muscular basis, for the ciliary muscle does not act directly on the lens, but on the suspensory ligament, and an excess contraction would only cause the lens to become more movable and sag under gravitational pull. The authors therefore concluded that under sustained ciliary muscular contraction for punctum proximum with resultant zonular relaxation, the lens gradually continues to become more and more convex. "Perhaps its surface does not become more convex; it may be that it is some of its deeper layers that gradually become more convex". Lens "viscosity" was employed to explain the initial rapid change followed quickly by a tapering off in a slower and slower change under continuously acting forces applied to the lens from without or within. The change in shape which results under the influence of stress is still within the limits of elasticity of the lens.

The effect of aging on the speed of accommodation was studied by Allen[1], and he noted that the time to accommodate seems to increase as the amplitude decreases. It was also found that for all ages the time to relax was decidedly faster than to accommodate. In an illustrated comparison, where amplitudes were equal the younger individual showed more rapid adjustments both in accommodation and relaxation. Allen employed a Badal optometer with the distant target set at theoretical infinity and the near target was variable as to distance. A timing circuit recorded the subject's reaction time response to accommodate or relax. The age spread of his subjects was 7 to 49 years. Kirchhoff[14] in 1941 had made accurate objective measurements of accommodation relaxation responses by photographing the changes in lens shape, but correspondence of findings was not discussed.

The faster changes in accommodation in younger observers were assigned to a lower viscosity of lens substance, or to a greater separation of the lens fibers bathed in viscose material, with preference expressed for the latter explanation. This would account for the decreasing rate at which the ceiling of accommodation is approached, indicating that the limit of stretch or deformation of the lens fibers has been reached. With the number of fibers increasing and the amount of viscose material decreasing with age "the amount of total 'slip' of the components within the lens must therefore be reduced while the friction between them is increased". This agrees in concept with the Lancaster-Williams conclusion expressed above.

The tables of accommodation of Donders and Duane apply to amplitudes of accommodation for mid-Europeans. In 1950, Rambo[19] offered that Egyptian, Greek, Italian and other people closer to the equator develop presbyopia earlier, and Scandinavian people later, than to the mid-Europeans. When ethnic Asiatic Indians and mid-Europeans were compared in an accommodative age study[20], it was found that practical equality exists for the two groups at age ten, but the Indian accommodative ability is less for all ages beyond. Considering an amplitude of 3 D as the criterion for presbyopia, Indians become presbyopic at age 38, while mid-Europeans reach this state at age 46. The findings were reported without conjecture as to the cause of the marked spread in accommodative amplitude between these groups. Said and Weale[21] found as much as a 5 per cent density difference in comparing the transmissivity of lenses in situ in Egyptian and British subjects aged 25 to 42 years; the former's lenses being yellower than the British. The sample was small and the cause for the increased density was not established, but the authors opined that a genetic basis was more likely than prolonged exposure to the sun. The possibility that the denser lens may be less amenable to deformation due to pigmentation adding to viscosity is suggested by this writer.

The development of presbyopia from five to ten years earlier in Negroes than Whites was reported by Covell[3] after analyzing "several thousand" clinical records of workers in the Panamá Canal Zone. Although the number of Caucasians who had spent their entire lives in the tropics were too few to draw a definite conclusion, he believed the clime might well precipitate a predisposition to lens sclerosis. Covell ruled out diet as a cause, for an abundant and easily obtainable supply of natural food was available to the tropical natives. The higher percentage of degenerative diseases in the Negro population was offered as another possible factor in the earlier onset of presbyopia*.

The last correlation between presbyopia and aging to be reported here concerns a study made by Bernstein[2]. The fact that individuals differ in the age where retraction of the near point necessitates spectacle correction, indicated that presbyopia does not develop at the same pace for all persons. Working with the records of individuals whose death was attributed to natural causes, Bernstein found the association between expected length of life and the degree of presbyopia was stronger than in comparison with graying. Four thousand cases provided a mean presbyopic value for each age considered, and three classifications were made: those with greater presbyopia were considered the class of unfavorable risk (U); those of lesser presbyopia were considered the class of favorable risk (G); and the middle were considered class (M). At age 47, persons in class (U) had a life expectancy of 17.9 years, class (M) an expectance of 22.5 years, and class (G) and expectancy of 31.8 years based on 86 cases for (U), 83 for (M) and 83 for (G) respectively. The 13.9 year difference in life expectancy between classes (U) and (G) when only those persons who had died a natural death were considered indicated an obviously different risk existed. Natural death causes were given as "senility, heart, cerebral hemorrhage, arteriosclerosis and so forth". The differences between the three classes were evident at each age in equal magnitude when expressed in percent which was employed because of the reduced life expectancy at the higher ages. When the death causes due to different diseases were considered, the differences still appeared, but to a lesser degree. Although women exhibited the same mean presbyopic values as men, a more temperate mode of life was considered responsible for their greater life expectancy.

Summary

Although sclerosis of the ciliary muscle has been advanced as the cause for presbyopia, and the decreasing mass of the ciliary body due to reduced blood volume has been offered as a contributing factor in the etiology of presbyopia, the classical concept of a hardening lens nucleus of increasing proportion with aging is still the most universally accepted basis for presbyopia. The varying thicknesses of the human lens capsule, and the elastic property assigned to this membrane is deemed the responsible agent for the molding of the lens into its characteristic hyperbolic shape in accommodation. The lens contents do not play

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*** M. J. Turner in England is attempting to collect data from practitioners in scattered points throughout the world to study the variations of accommodation according to climate and race. Infocus Nº 23, p. 8, Dec. 1961, London, England.**

a completely passive role, for the extent of response is governed by the viscosity or the relative freedom of the lens fibers in a viscous medium to intermesh as accommodative pressure is exerted by the capsule.

People native to hot climates apparently demonstrate an earlier onset for presbyopia than those living in more northerly regions of Europe. Both genetics and environment have been proposed for this predisposition, and since Egyptian lenses have been found to be yellower than British it may be that pigmentation affects the viscosity. It appears that life expectancy can be predicted by the rate of development of presbyopia; those individuals experiencing a slower progress are expected to enjoy greater longevity.

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THE INPLANT EYE PROTECTIVE-CORRECTIVE PROGRAM

BY

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In a recent report, the New York State Workmen's Compensation Board indicated that during 1960 there occurred the least number of industrial accidents since 1940 —even though the number of people covered by Workmen's Compensation has been on the increase during this period.

The report further pointed out that "this favorable trend is reasonably attributal to an increase in safety practices on the part of both the employers and employees throughout the state".

Injury curtailment such as this, is not just an accident. It comes about through years of tireless work and all out effort. One must beware of the tendencies that sometime develop after establishing a favorable trend, and that is to forget the past human suffering and costly expenditure and to begin to take safety for granted. One must guard against such a let down and be constantly alert to recognize this state of mind.

It is important to continue this injury reduction trend throughout the world and to continue on to set new records. To accomplish this one must learn more about eye safety and vision programs in industry. To learn how to go about building a top notch eye program, what type of eye program would be most suitable and efficient for your particular plant, how to improve your present program, to get maximum results with a minimum of expenditure and how to conserve and guard most effectively what is probably the employee's most valuable possession —their eyesight.

There are numerous variations of eye programs in industry to-day. But, in my opinion only one type is really complete, comprehensive and totally effective, it is called the "In-Plan Eye Protective And Corrective Program". It renders the complete eye services industry needs right within the plan. In-plant programs have been used for many years with great success, achieving tremendous records in such plants as Eastman Kodak Company, Sperry Gyroscope Company, Brooklyn Naval Ship Yard and many others. This does not mean that an in-plant eye program is suitable only for large companies that employ thousands of people but it can be effectively employed even in small plants having as few as 200 employees, but conducted on a proportionate basis.

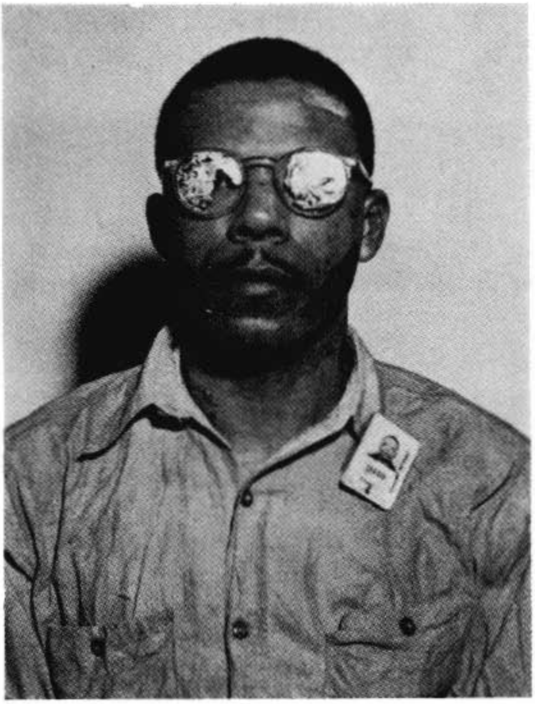

Fig. 1

Directing the in-plant program and assuming total responsibilities for it, is the trained professional eye man, either the in-plant Optometrist or Ophthalmologist. It is amazing to hear of the many so-called industrial eye programs that do not retain the direct services of a professional eye man to guide the program. Everybody in the plant seems to assume these responsibilities. In some plants it may be the personnel manager or general shop foreman, in others it may be the security officer or shop steward. Everybody seems to get into the act except the properly trained individual, the Optometrist or Ophthalmologist and they wonder why the program fails.

Can you imagine a company having an Industrial Relations Program, an Employment Program or a Manufacturing Program without having qualified, experienced and trained personnel in their respective fields to guide these operations? How then can an industrial vision program be effective without the same?

I would hate to have responsibility thrust at me to design and engineer a new, sophiscated missile guidance system for Sperry. It might be wrapped in an impressive looking cabinet, but if it was supposed to guide a space ship to the moon it would probably direct it to Pluto instead.

The in-plant Optometrist is in most cases a salaried company employee. In some smaller plants, remuneration may be either on a salary basis, a per session fee, an annual retainer or paid on an hourly basis.

Usually the in-plant Optometrist reports directly to the Medical Director or Administrator. In some plants he might come under the Industrial Relations Director, the Personnel Manager, the Safety Director or the Administrative Vice President. Where he appears on the organization charts is not too important. The important thing is that the company recognizes the need for his professional services.

The role of the in-plant Optometrist is quite extensive. His three major areas of responsibility include:

1. Examination and proper correction of employee's vision for the job.

2. Dispensing of the corrective and plano safety glasses of various types to eliminate eye injuries and eye losses.

3. To develop and administer a pre-placement vision screening program, so that applicants with proper visual qualifications are selected for the job.

In tackling the first job, the in-plant Optometrist must make a careful analysis of every job classification and determine its specific visual job demands. Some factors to be considered include working distance, eye movements, lighting environments, position of employee at job, whether or not multi-focal lenses will be suitable or if other supplementary vision aids migth be necessary. The intimate knowledge of these factors gives the in-plant Optometrist a decided advantage over the outside practitioner in examining and prescribing more accurately the corrective lenses required for the job.

If the company is paying for these materials it is important that the prescription incorporated into the safety glasses be accurate so they can be worn comfortably on the job, otherwise the safety glasses will not be worn and new prescription glasses may have to be ordered.

This would make it considerably more costly to the company. This is one of the major advantages of examining the employee's eyes in the plant.
Here are just two examples where an employee's outside prescription was of no value to him on the job.

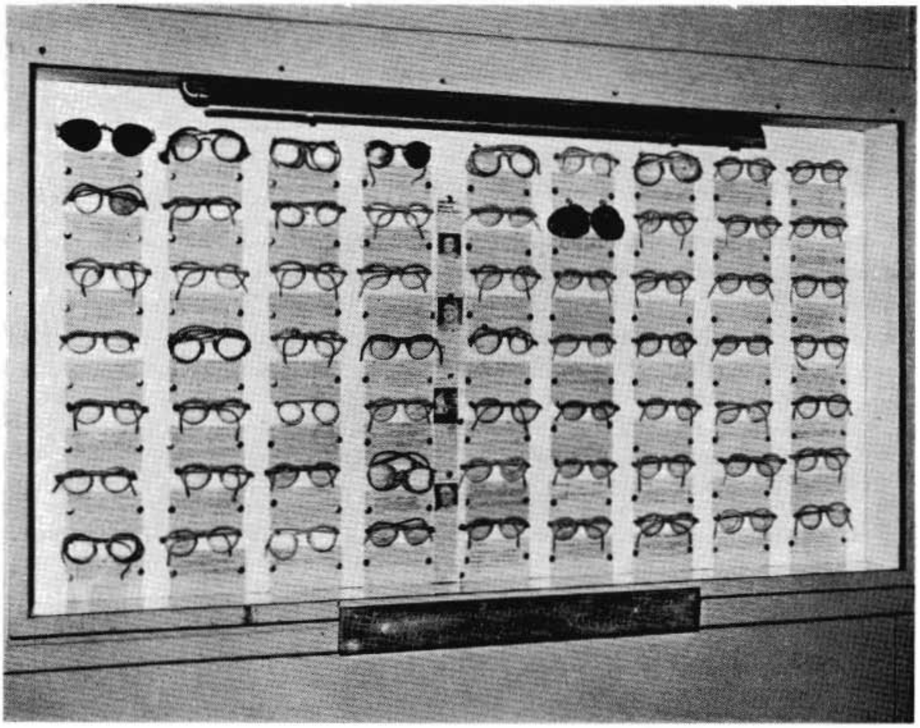

Fig. 2

One employee had a correction issued to him for maximum seeing at 13" when his job working distance was 18".

Another example involved an employee who during World War II was transferred from the day shift to the night shift. He suffered unusual discomfort. The outside practitioner told him after examination that the lighting in the plant at night was the cause of his trouble. Tinted green prescription glasses were prescribed for him. But little did the outside practitioner realize that the lighting conditions in the plant at night were identical to those during the day. This company produced defense weapons and all of the plants windows were blacked out. The in-plant Optometrist certainly would have recognized this.

To carry out the second major task, dispensing corrective and plano safety glasses, the in-plant Optometrist cooperates with the Safety Engineer in making a through study of the possible eye hazards of each job, and determines what type of safety eye protection will be most effective in each case.

Various types of safety glasses are utilized. Included are regular spectacle type with or without side shields' goggles or plastic shields. All contain tougheny-ed or case hardened lenses 3 mm. center thickness or plastic lenses. Some contain various types of filter lenses for absorption of harmful radiation or glare occupations such as welders, silver solderers, heat treaters, pourers, etc.

The in-plant Optometrist is responsible for dispensing, adjusting, maintenance and repair of all eye safety equipment. In addition he assists the purchasing department in the purchase of the safety eye equipment with a view toward maintaining a constant quality standard. He is also responsible for the maitenance of the stock and inventory.

The third basic duty of the in-plant Optometrist — developing and administering pre-placement vision tests. Selection of applicants with the proper seeing skills for the job is of major importance to industry, particularly in plants where fine precision type of seeing is necessary. Spoilage, waste and mistakes because of faulty seeing skills is no small loss to industry. And make no mistakes about it. It is a factor well worth considering in to-days highly competitive markets.

With to-days Space and Electronic Ages, with quality control demands of infinitesimal dimensions, employees must meet extremely close tolerances. The in-plant Optometrist with his intimate knowledge of job vision needs, will set up employment vision job standards that are pertinent for his particular plant. Using job standards derived by a national statistical average are of no value. Each plant has its own particular production problems, its own administrative problems, as well as its own specific job characteristics and environments. Each plant has to be individually considered.

Vision screening results ahould be analyzed by the in-plant Optometrist. Many plants are deprived of skilled personnel or many assign applicants to jobs where they fail to succeed because of lack of certain seeing skills. This occurs only in plants where there is no analysis by an in-plant Optometrist of the screening results.

The screening instrument and the battery of vision skill tests to be used should be determined by the in-plant Optometrist. Only by employing such a battery of tests rather than the use of a wall eye chart can an applicant's true eye status be quickly evaluated. For example, an applicant who will have to use a binocular microscope for inspection, would not fare well at this job, if he has a suppression of vision of one eye which could be detected by the screening instrument. An assembler working with colored wires, would not make out well if he is color deficient; or a moderately nearsighted applicant who couldn't pass a Snellin wall chart test might make an excellent inspector or assembler.

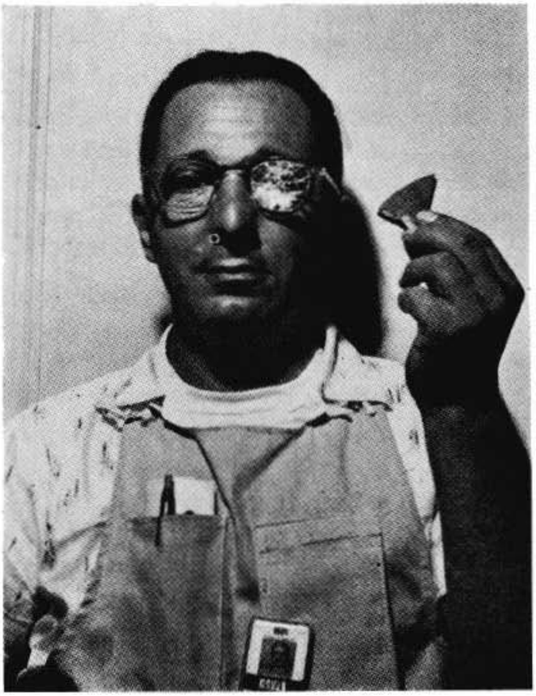

Fig. 3

In addition to the three basic responsibilities I have discussed, the in-plant Optometrist usually participates in a number of activities to insure the effectiveness of the in-plant eye program.

He will develop an educational eye safety program. He will have posters and other safety eye displays — particulary of smashed and mutilated safety glasses that have saved eyes — strategically displayed throughout the plant for all to see. He will have his plant become a member of the Wise Owl Club, sponsored by the National Society For The Prevention Of Blindness. The Club's members are workers whose vision had been saved by safety glasses.

Working through the editor of the plant newspaper, the in-plant Optometrist presents stories on the accomplishments of the eye program, to the employees. Pictures and stories of eyes that have been saved by safety glasses are items an editor always finds space for.

The in-plant Optometrist will on many occasions be called upon for advice regarding lighting problems in the plant, color problems, optical problems, problems in physiological optics, plant layout problems, etc. Because of his background and training he on numerous occasions comes up with an effective answer —with no extra cost to the company.

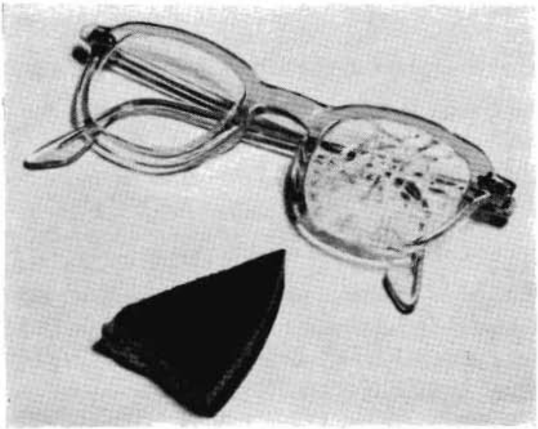

Fig. 4

Research is another aspect of his job. He might be engaged in a project correlating work spoilage with need for visual correction, or be engaged in a surveillance program to determine whether or not there may be premature changes in the eye media or eye lens of those employees engaged in work requiring use of radioactive materials or he might develop a screening program for glaucoma detection.

He maintains statistics on work performed by his department and its effectiveness in curtailing eye losses and eye injuries. The in-plant Optometrist is always on the alert to detect eye pathology which he immediately refers to the Ophthalmologist for treatment.

Although his responsibilities are many, he knows that a successful program not only depends upon him, but upon his cooperation with many other plant personnel, professional people and outside agencies.

He will work in close cooperation with the in-plant physician, the ophthalmologist, will acquaint the nursing staff with his duties, will work hand in hand with the safety engineer, the foremen and supervisors, the optical companies that manufacture the eye safety materials, and societies such as the National Society For The Prevention Of Blindness, National Safety Council, American Society of Safety Engineers, Illuminating Engineering Society, etc.

To give you a concrete example how effective an industrial in-plant program with an in-plant Optometrist can be, I will describe briefly some of the tangible results and accomplishments of the Eye Program of the Sperry Gyroscope Company.

In more than seventeen years since the inception of our Eye Program we have not had a single lost eye, but we have accummulated one hundred and six pairs of smashed and mutilated safety glasses which indicates a potential of a little over six eyes a year would be lost if we had no eye program. Six eyes was exactly the number we lost in the year prior to the inception of the program.

The direct monetary savings to the company of these six eyes a year alone, far more than covers the cost of the eye program each year.

We have reduced the number of first aid eye cases by more than ninety percent as compared to the years prior to the installation of the program.

All other benefits derived from the program can be considered as dividends.

Our pre-placement vision selection program assures our supervisors that new employees have appropriate visual skills for the job. Vision at least can be discounted as a factor for unsatisfactory performance on the job by a new employee. Other reasons can then be sought.

The correction program assures continued maximum visual performance of our personnel. Management is assured that our company ranks among the highest of all industrial companies in-so-far as efficient seeing performance for the job is concerned.

Annual eye examinations are given to our supervisory personnel as part of the annual physical examinations.

The continuous operation of our eye program for more than seventeen years is convincing proof that the Sperry Gyroscope Company considers this in-plant eye program valuable and successful. It also prooves that a properly functioning in-plant program can completely eradicate blindness caused by industrial eye accidents.

More programs like this throughout the world would help eliminate human suffering, save millions of dollars each year in insurance premiums and compensation costs and conserve the priceless eyesight of the industrial population of the world.

Sperry Gyroscope Company

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NUEVOS INSTRUMENTOS

Modificación a nuestro equipo de Bomba y Porta-ventosas para la extracción total de la catarata por Facoerisis

POR

JOSE I. BARRAQUER M., M. D.

Bogotá, Colombia

En el volumen cuarto de Estudios e Informaciones Oftalmológicas, artículo Nº 6, publicamos las características de nuestro equipo para extracción total de la catarata por facoerisis. Esta nota es para dar cuenta de dos pequeñas modificaciones

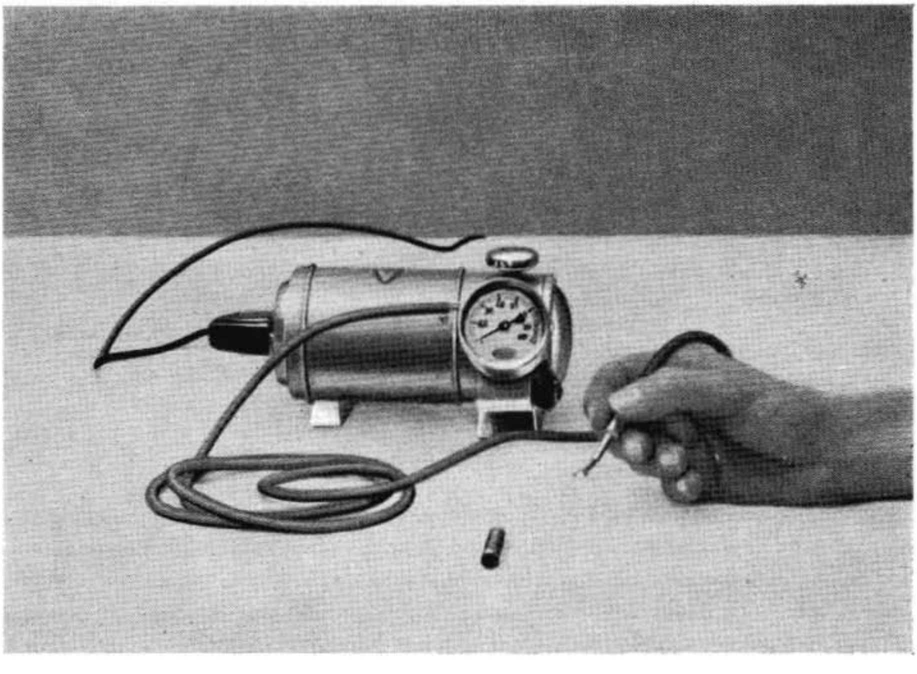

Fig. 1. Bomba y portaventosas sujetado tal como se emplea para el ojo derecho.

que hemos realizado hace años y que hemos empleado regularmente a nuestra entera satisfacción y que consideramos constituyen una mejora al aparato original.

Aspirador:

En la bomba aspiradora de vacío, la modificación introducida ha sido con relación a la situación de la toma de vacío. Está, situada en la parte inferior del manómetro regulador en los primeros modelos, actualmente lo está en la superior, con el fin de evitar que el aceite que lubrica la bomba aspiradora penetre con facilidad en el tubo de caucho que une ésta con el porta ventosas (Fig. 1).

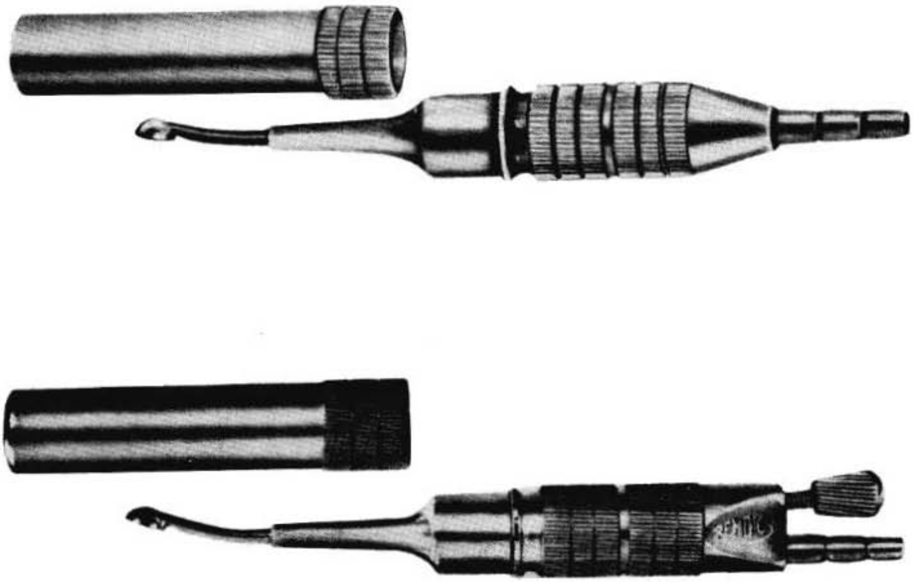

Fig. 2. Portaventosas con y sin regulador.

Porta Ventosas:

El porta ventosas construido en 2 modelos con o sin regulador (Fig. 2) se ha hecho fabricar en Duraluminio. Con ello el peso del instrumento queda sumamente reducido permitiendo una mayor sensibilidad en la mano del operador, factor este importante en todas las intervenciones y especialmente cuando se emplea zonolulisis enzimática con alfaquimotripsina en la cual el contacto de la ventosa con la cápsula del cristalino debe ser sumamente suave. El peso del porta ventosas construído en acero inoxidable es de 24,5 grs. El peso del porta ventosas construído en Duraluminio es de 8,2 grs.

Estos porta ventosas en duraluminio deben ser esterilizados en la estufa seca. Las substancias químicas pueden atacar más fácilmente el aluminio y determinar dificultades en el funcionamiento del regulador y también favorecer la obstrucción de los conductos interiores del instrumento. Si se dispone de un solo instrumento, no hay inconveniente, en intervenciones sucesivas, en flamear la ventosa a la llama de una lámpara de alcohol para esterilizarla. Sin embargo, este procedimiento a la larga afecta la soldadura de la ventosa y la duración de la misma se acorta en forma considerable. Esta conducta puede seguirse en caso de necesidad solamente con las ventosas de platino.

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Arch. Soc. amer. oftal. optom. (1962) - 4 - 221

REVISION DE LIBROS

"THE ESSENTIALS OF PERIMETRY"

(Factores Esenciales en Perimetría)

Autor: HOWAR REED

Este importante libro contiene tres partes en su presentación: I) Anatomia Aplicada del Mecanismo Visual; II) El Campo Visual y su "assessment" y III) Defectos de Campos Visuales y su Interpretación.

La parte II de este tratado me ha llamado la atención de manera especial, ya que analiza de manera completa la validez y criterio de los instrumentos usados en la interpretación cualitativa y cuantitativa de los campos visuales, incluyendo aquellos que de manera extraordinaria simplifican la elaboración de datos y diagramas al profesional.

Su autor, Howard Reed, M.D., M.S. (Lond) F.R.C.S. (Eng.). F.R.C.S. (c), F.A.C.S., Departamento de Oftalmología, Universidad de Manitoba, Departamentos de Oftalmología-Winnipeg General Hospital, children's Hospital, Winnipeg y la Clínica de Winnipeg, a quien tuvimos el gusto de tenerlo en nuestro país por breves días hace unos pocos meses.

El libro ha sido editado por la "Oxford University Press" de Inglaterra. Cuenta con 167 dibujos hechos especialmente para la publicación de este libro.

"VISION OF THE AGING PATIENT"

Compendio Optométrico, editado por Monroe J. Hirsch y Ralph E. Wick. Este libro analiza en 16 capítulos, escritos por diferentes autores, entre otros los siguientes aspectos relacionados con la visión en el campo de la Geriatría:

1 — Cambios Anatómicos y Fisiológicos asociados con la vejez.
2 — Aspectos Psicológicos del anciano.
3 — El efecto que causa la edad en la agudeza visual.
4 — Cambios en la refracción inducidos por la edad.

5 — Cambios en el mecanismo de la acomodación en el estado de la Presbicia y su corrección.
6 — Anomalías del Sistema Neuromuscular del anciano.
7 — Consideración breve de condiciones patológicas en ancianos.
8 — Fenómenos Patológicos Generales que causan efectos en la visión del anciano.
9 — Visión Sub-Normal y las ayudas ópticas disponibles.
10 — El Ajuste y Adaptación de Anteojos en los pacientes ancianos.
11 — El Manejo del paciente anciano en la práctica Optométrica.
12 — Adaptación de Lentes de Contacto en pacientes ancianos.
13 — Rehabilitación Social y Vocacional del paciente anciano con problemas de Visión Sub-Normal.
14 — Aspectos económicos en Programas de asistencia social a pacientes ancianos.

Los capítulos del libro han sido escritos por los siguientes autores. todos ellos ampliamente conocidos, por sus directas asociaciones con entidades Universitarias, Clínicas y Profesionales:

Dr. John E. Archer
Dr. How and Bartley
Dr. Robert S. Eakin
Vicent J. Ellerbrock
Monroe J. Hirsch
Henry Hofstetter
Félix A. Koetting
Bernard O. Mazow
Incredith W. Morgan
John C. Neill
Alfred Rosenbloom
Arthur W. Shlaifer
Grace Weiner
Frank W. Weymouth
Ralph E. Wick

Un aspecto bastante interesante es la variada información relacionada con múltiples aspectos de la visión, presentados en forma de gráficas, tablas estadísticas y comparativas.

El libro fue impreso por la Chilton Company de Estados Unidos en Inglés y su precio de venta es de US$ 7.50.

HERNANDO HENAO R., O. D.
Bogotá - Colombia.

Arch. Soc. amer. oftal. optom. (1962) - 4 - 223

NOTICIAS - NEWS

Temos a satisfação de levar ao conhecimento que o Conselho Brasileiro de Oftalmologia, até julho de 1964, quando se realizará no Rio de Janeiro sob seu patrocínio o XIII Congresso Brasileiro de Oftalmologia, tem sua Diretoria com a seguinte constituição:

Presidente, Prof. Dr. Sylvio Abreu Fialho.

Vice Presidente, Dr. Joviano de Rezende Filho.

Secretario Geral, Dr. Evaldo Machado dos Santos.

Tesoureiro, Dr. José Barbosa da Luz.