

COMPUTER-ASSISTED EYE EXAMINATION  
III. PHYSIOLOGICAL INDICES FOR SUBJECTIVE REFRACTION\*

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ABSTRACT

In a computerized eye examination, there are times when the examiner is not at the patient's side. Hence, it was anticipated that non-verbal indicators (i.e., EKG, blink, GSR) might be used to aid the computer in converging upon the proper lens correction more expediently. During actual clinical examinations at the University of California, Berkeley, EKG, blink, GSR, arm acceleration, and respiration measurements were made on 38 patients to determine if there is any correlation between any of the above and the patient's uncertainty about his/her response as indicated by reaction time and tone of voice. It was found that the EKG (four patients) and respiratory rate (four patients) were usually steady and rather insensitive to uncertainty of response. For three out of ten patients tested in the blink response, a rough correlation was found. The other seven patients produced non-correlating responses. For twelve patients tested, the GSR was found to be an unreliable indicator of uncertainty. Further, eight patients exhibited little or no arm acceleration movements during the attentive portions of the eye examinations.

A computer-assisted eye examination may proceed as follows: an attendant at the reception desk will ask the patient some brief preliminary questions such as name, age, sex, and occupation. Subsequently, the attendant will direct the patient to enter and sit in the clinic examination room. An optometrist or optometric technician may perform some preliminary tests such as retinoscopy and keratometry, ophthalmoscopy and other pathology tests, and measure inter-pupillary distance. After this, the patient is directed to the adjacent case-history room. A controlled pretaped voice will issue from a loudspeaker and ask the patient a series of questions concerning his visual health and problems to each of which the patient may answer yes, no, or doubtful using a three choice answer box. At the conclusion of the case-history session, the pretaped voice will direct the patient to transfer and sit in the adjacent visual acuity room. The patient will operate a five-button answering box in front of him which is oriented to correspond to right, left, up, down, and center positions. With the aid of a series of computer controlled slides which project one of four directional randomly selected Landolt C,s on a screen an appropriate distance away, the pretaped voice will direct the patient to answer successively in the direction of the opening of the letter C as a test of acuity. He will then transfer to the visual evoked potential room and his VEP will be recorded. When this is completed, the patient will be directed to go to the subjective refraction

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room and position himself behind a special computer controlled refractor and then a subjective refraction test will be performed. At the completion of the examination, the patient will return to the clinic examination room, and the optometrist will, with the aid of the computer printout of all the tests and recommended prescription, confirm or refine the proposed lens correction.

Marg and Ng<sup>1</sup> performed a tabular analysis of visual examination time and found that at present the total average examination and office work (i.e., adjustment and delivery) time per patient was 77.2 minutes. A re-delegation of the time was suggested such that: the optometrist time was 9.5 min.; the human assistant time was 33.9 min.; and the computer assistant saving of human performance time was 33.8 min. In this way, an optometrist, with adequate human and computer assistance, could examine up to six patients per hour instead of one per hour.

Pierce<sup>2</sup> investigated the effect of performing a specific task (printing the alphabet upside down and backwards for one minute) on activation, namely, heart rate, electromyogram (EMG), basal resistance level (BRL), and respiratory rate. The 24 emmetropic subjects performed the task while wearing lenses of 0, +0.50, and +1.00 diopter. Pierce found that the average performance for the group (where performance is the total number of letters printed during each trial) was greatest with the lens power of +0.50 diopter, while the performances with the other two lenses were at about the same lower level. The optimal performance was for the same lens power which was predicted by three optometrists as being optimal. Also, he found the inverse relationship to be true for heart rate, EMG, and respiratory rate, where the minimum values for these were at +0.50 diopter. The BRL showed no significant relation to lens power. He concluded that general physiological activity of the body is related to lens power. Although the general trends as indicated above could be observed upon inspection of most of the tabular listings of individual data in the appendix of Pierce's thesis, he did not present the results by using individual data, but rather he examined the average values for the entire group of subjects. Since for clinical purposes, individual data are of greater significance than group data, Pierce's conclusions may not be applicable in clinical situations. Further, in the above experiments, the physiological measurements were made on subjects who were printing rapidly and accurately for one-minute periods, and not while they were performing an actual clinical task.

Since an examiner may not be at the patient's side during large parts of the examination, we anticipated that psychophysiological clues, such as galvanic skin response, EKG, blink, arm acceleration, and respiration might be helpful in converging upon the proper lens correction more expediently. The underlying concept is that when the patient approaches the limit of his visual correction and must make fine discriminations or judgments, he begins to be doubtful of his answer. In the present patient-optometrist examination, the

optometrist can set these criteria for doubt as a prolonged reaction time, a non-enunciation or even stuttering in the patient's voice, and in the possible change of tone of his voice. However, the observation of these clues may not be possible in the computerized examination. Hence, we had hoped that the psychophysiological responses which may co-exist with the vocally evident uncertainty might be used as analogous criteria for doubt in order to facilitate the speedy completion of the examination.

After the completion of most of the psychophysiological experiments, we found that our anticipated quest for discovery turned out to be a rather quixotic search for some very subtle and imprecise phenomena. Yet, this report is of value because it is the first to make these kinds of measurements during actual examinations, and it will provide a basis for those who wish to consider these and similar measurements and approaches in the future.

#### PREPARATION FOR EXPERIMENTS

On the day before the experiment, the necessary equipment (e.g., the Sanborn Chart recorder, etc.) must be set up in the clinic (see Fig. 1). On the day of the experiment the patient should read and sign the appropriate consent form. Finally, the electrodes or transducers must be attached, the circuit and equipment adjusted, and the data recorded.

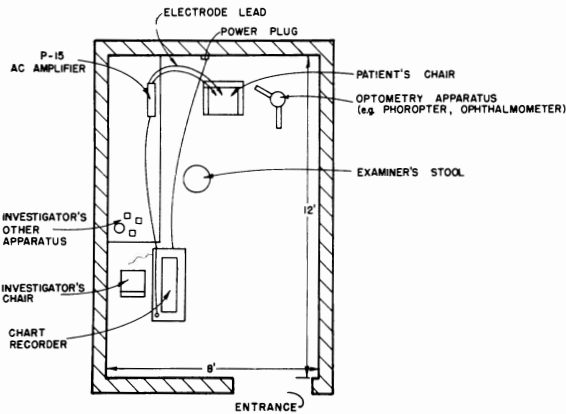


Fig. 1. Plan View of Refraction Room

#### CRITERIA FOR EVALUATING A PATIENT'S UNCERTAINTY ABOUT DISCRIMINATING BETWEEN TWO STIMULI

As stated previously, the qualitative criteria for judging a patient's uncertainty about his response were the prolonged reaction time, non-enunciation of his answer and even possible stuttering, and/or a possible change of tone in his voice. These were all arbitrarily categorized under the headings of quick (*Q*; less than 1 sec. for the elapsed time between stimulus presentation and onset of vocal response), medium (*M*; 1 to 2 secs.), or slow (*S*; greater than 2 secs.) on the chart paper next to the response. Also, on the chart paper, an open arrow ( $\rightarrow$ ) marked the presentation of the stimuli, and a simple arrow ( $\rightarrow$ ) indicated the onset of vocal response. Arrow marking

could not be drawn for the EKG with any accuracy because the chart paper was moving too fast (20mm/sec.). Hence, only line segments were drawn at the stimuli presentation and at the vocal response.

#### ELECTROCARDIOGRAM (EKG)

Luckiesh<sup>3a</sup> investigated the effect of illumination on the heart rate of subjects who were performing a simple reading task—"Outline of History" by Wells. He concluded that variables other than illumination, such as excitement at onset of experiment, reading material, and attention, may play a greater role in affecting heart rate than illumination. Luckiesh further found that introduction of a bright glare source into the visual field while the subject was reading did not produce an observable change in EKG response during the next minute.

Slack<sup>4</sup> recorded concomitantly heart rate and response latency during medical history interviews. However, the heart rate measurements were made over a relatively long period of time (average of response latency—7 secs.) and for some probably psychologically significant questions. Still he drew no conclusions concerning the relationship between heart rate and response latency during medical history interviews.

*Principles of electrocardiogram measurement*<sup>5a</sup>: Due to the asymmetry of the heart pulse electrical distribution to the limbs, two electrodes, one at each wrist, can be used to measure the heart pulse amplitude and rate.

*Set-up and results of EKG experiment*: Beckman skin electrodes (with paste) were adhered to each wrist and the leads from these electrodes were connected to a Grass P-15 amplifier. The ground electrode was attached to the earlobe. The output was registered on a chart recorder.

The average normal alert resting heart rate was 75.3 beat/min., with a standard deviation of 1.9 beat/min. In some cases, we observed that after discrimination, the patient's responses drifted indicating a change in attention.

We could observe no significant correlation (i.e., no change of over 5% from pre-stimulus EKG responses) between heart rate or heart pulse amplitude (order of 1.5 mV for wrist measurement) and uncertainty of response. For example, see Fig. 2. Further, the t-technique analysis of the patients' heart rates indicated that there was no significant difference between the heart rates during Q, M, and S responses.

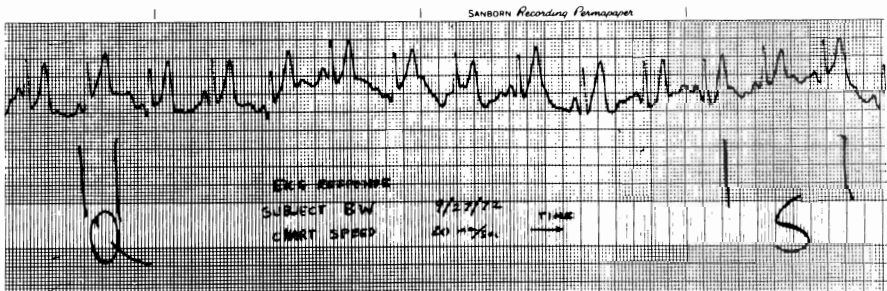


Fig. 2. EKG Response

### Blink Responses

*Discussion of previous related experiments:* Luckiesh and Moss (1937)<sup>3b</sup> found that as their subjects read, increasing the illumination caused a steady decline in the blink rate. They concluded that this indicated that it was easier to read at 100 ft-c than at 1 ft-c. That is, less effort was needed at higher illuminations. However, Bitterman and Soloway (1947)<sup>6</sup> simulated the same experiment and found that “condition of glare influenced neither the speed nor the accuracy of performance.” Meyer (1953)<sup>7</sup> studied the relationship between manifest anxiety and blink rate and concluded that “blink rate can be used as an index of generalized muscle tension.”

*Principle of blink measurement:* Two not necessarily mutually exclusive theories concerning the electrical measurement of the blink had been set forth. Mowrer (1936), as well as Hoffman (1939)<sup>8</sup> and Carpenter (1948)<sup>9</sup>, contended that the electrical activities derived from the electrodes, one above the eyebrow and the other at the inferior margin of the orbit, were due to the small upward movement of the eye redistributing the corneal-retinal potential (the cornea being positive relative to the retina) in the surrounding tissue, and not to the action potentials in the orbicularis oculi.<sup>9a</sup> On the other hand, Gordon (1951),<sup>10</sup> Kugelberg (1952),<sup>11a</sup> and Rushworth<sup>11b</sup> (1962) believed that the blink electrical activity was due to the action potentials of the orbicularis oculi. Gordon found that the motor discharge frequencies of up to 182 per sec. could be observed in the orbicularis during the blink as compared with that of 50 per sec. found in the other human eyelid muscles during voluntary contraction.

The average rate of blink is about 12.5 per minute and the duration of the blink is about 0.3 seconds. Vision is interrupted every 5 seconds with a 0.1 second blackout, which means that an average person is without vision 6% of his waking hours.<sup>12</sup> We found that the average down-blink velocity is about 150mm/sec. and the average up-blink velocity is about 80mm/sec.

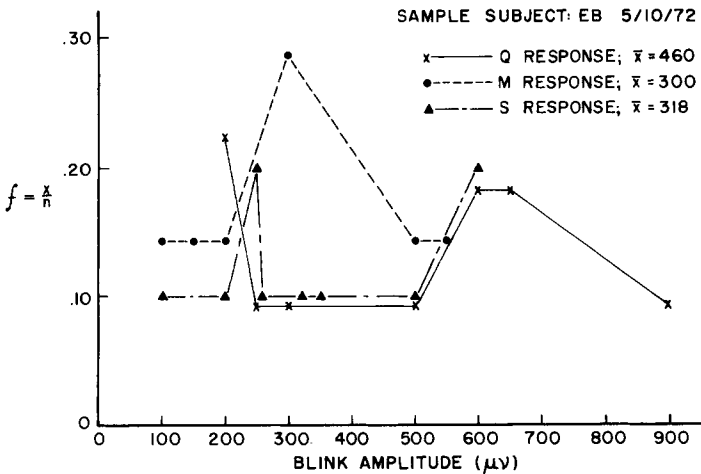


Fig. 3. Frequency Distribution of Q, M, and S Blink Amplitudes.

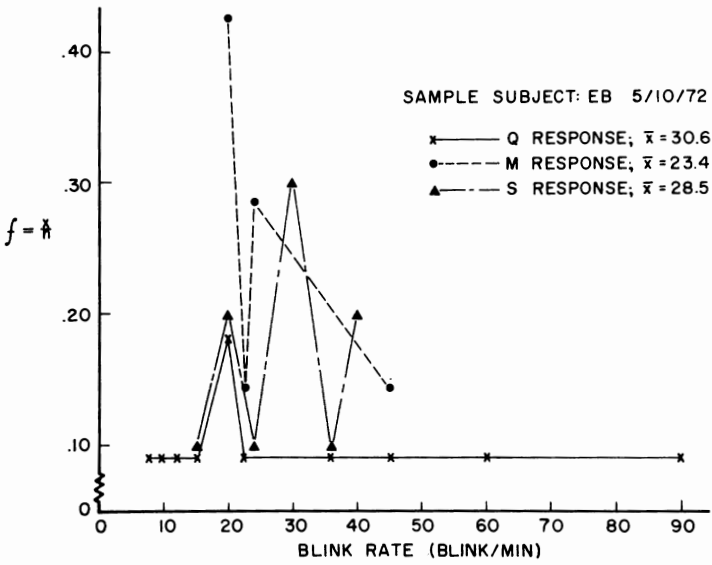


Fig. 4. Frequency Distribution of Q, M, and S Blink Rates.

*Set-up and results of blink experiment:* Using medical tape, tape two electrodes were taped (chorided AgCl electrodes without paste) one above the eyebrow and another electrode at the cheek below the eye.

For almost every subject tested, there was an eye movement following each discrimination (e.g., blink or oblique gaze movements of the eye).

We found that for three subjects, blink amplitude for sure responses

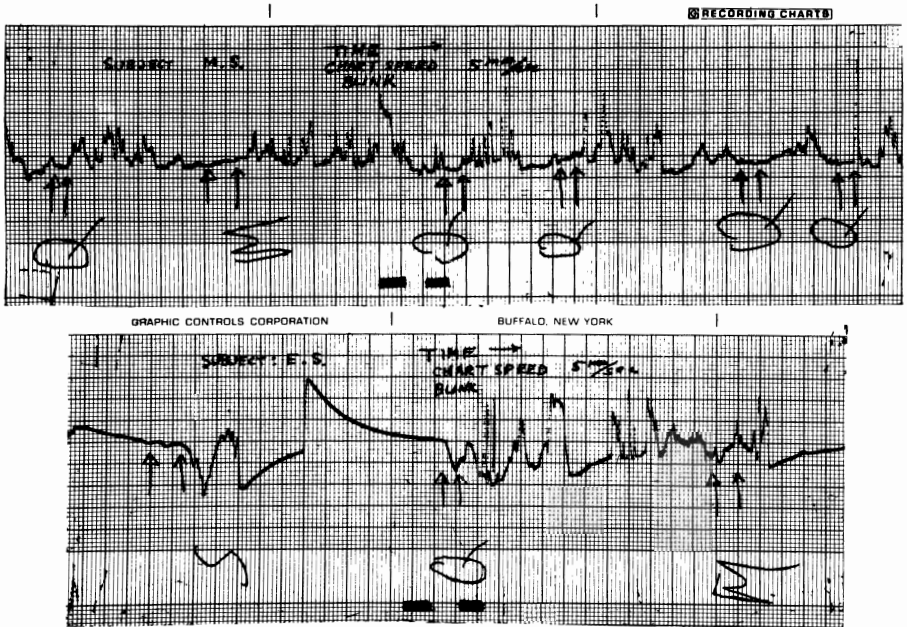


Fig. 5a. (top) Blink Response—Moved Around Too Much

Fig. 5b. (bottom) Blink Response—Responded Quickly in Almost All Cases

tended to be greater than those for unsure responses about 150%. For example (see Fig. 3), the subject EB's average *Q* response blink amplitude was  $460 \mu\text{V}$  as compared to an average *M* response blink amplitude of  $300 \mu\text{V}$  and an average *S* response blink amplitude of  $318 \mu\text{V}$ . However, we found no significant difference in blink rates for *Q*, *M*, and *S* responses. For example (see Fig. 4), subject EB's average *Q* response blink rate was 30.6 blinks/min., as compared to an average *M* response blink rate of 23.4 blinks/min., and an average *S* response blink rate of 28.5 blinks/min. The other patients tended to blink too much (e.g., see Fig. 5A), or responded quickly in almost all cases (e.g., see Fig. 5B) for any relevant observation of the blink response, while still others simply gave inconsistent results.

### Galvanic Skin Response

*Principles for the measurement in the present experiment:* A three-electrode technique for the measurement of skin resistance at a single site<sup>13</sup> (Barnett, 1938; Horton and Van Ravenswaay, 1935) (see Fig. 6) has several attributes: 1) If the measuring device is an amplifier with high input impedance, very little current will flow in the circuit A-C-A and variations at C will not influence the measurement. 2) Since electrode A is placed at the contralateral homologous site to active electrode C, there will be negligible error attributable to endosomatic potential difference since this will be approximately zero. 3) With this particular arrangement, the resistance at electrode B is not of great significance, and hence, the preparation of the skin at B need not be stringent (i.e., just soap and water cleansing is required). The fluctuations being measured are of the order of  $200 \mu\text{V}$ .

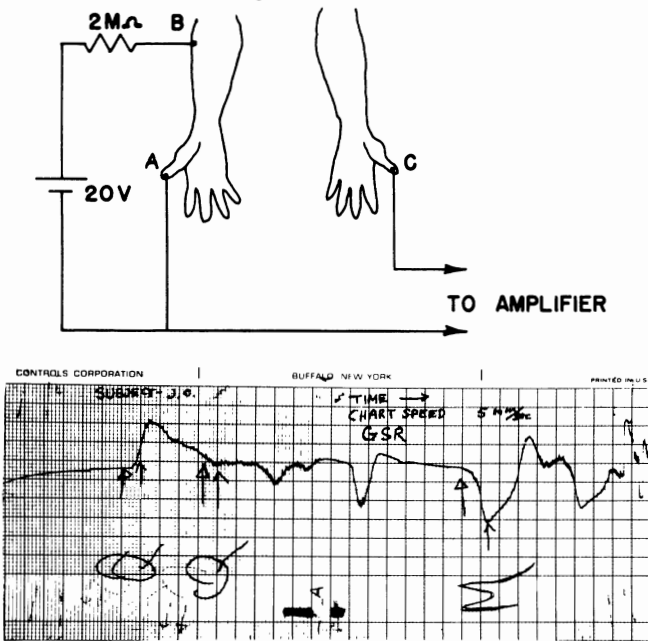


Fig. 6. Three electrode Technique for GSR Measurement

Fig. 7. GSR Response.

*Set-up and results of GSR experiments:* Beckman skin electrodes (with paste) are adhered at the positions A and C, respectively in Fig. 6.

The changes in amplitude and the rates of fluctuation of the GSR are seen to be independent of the sureness of the responses during the examination. That is, for each patient, the changes in direction, amplitude, and rate of fluctuation of the GSR varied a great deal, and no trend could be found. For example, see Fig. 7.

#### Arm Acceleration

*Principles of the arm acceleration measurement:*<sup>14</sup> The piezoresistive strain gage element is a solid state silicon resistor which changes electrical resistance in proportion to the applied mechanical stress. The significant characteristic of the element is that its change of resistance is large relative to the change in length. The arm acceleration, during writing, is of the order of 0.1 g.

*Set-up and results of arm acceleration experiments:* The Endevco 2265-20 accelerometer was taped on the back of the patient's hand. Arm accelerations of no more than 0.05 g were observed during most of the examination except for gross movements such as that during crossing of the legs or an occasional shifting of the body. The occasional arm acceleration that could be observed bore no relationship to the response during the examination. For example, see Fig. 8.

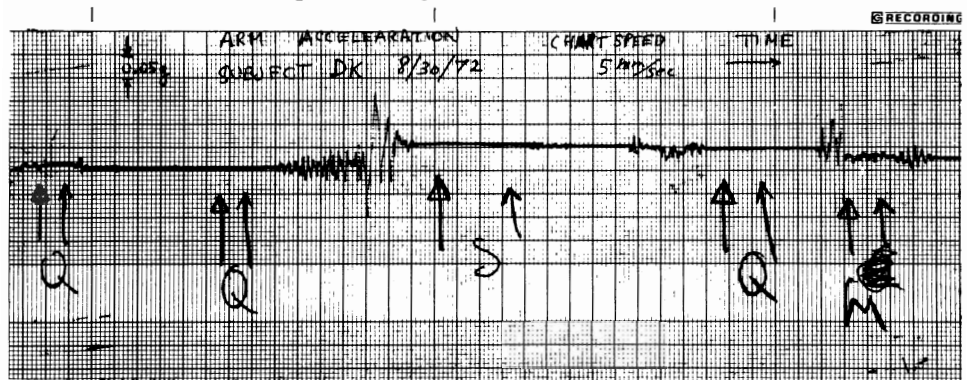


Fig. 8. Arm Acceleration Response.

*Principles of the respiration measurement:* The pressure transducer is based on the same principle as the accelerometer. The average respiratory rate is about 12 per minute.<sup>5b</sup> We found a standard deviation of 1.70 breath/min.

*Set-up and results of respiration experiments:* Endevco Model 8503 pressure transducer was taped about 5 mm below one of the patient's nostrils. A patient hand signal answering system (e.g., one finger for yes, and two fingers for no) was used to avoid vocal disturbance of the measured response. Four subjects were tested.

The patients adapted quickly (after three to four responses) to the hand signal answering system. The hand signal reaction times were estimated to be

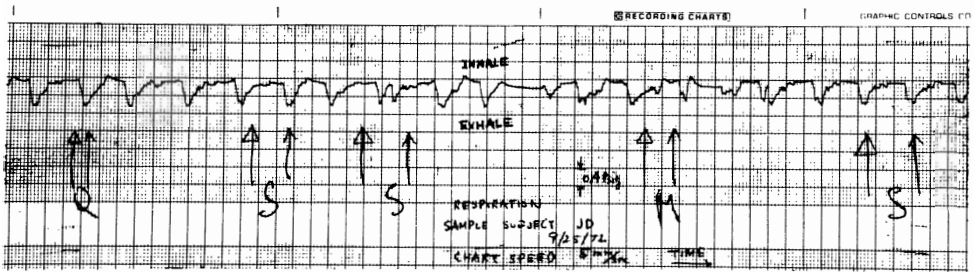


Fig. 9. Respiration Response.

about 0.2 sec longer than the corresponding vocal reaction times. This was of no consequence in our experiments because all the reaction times that we recorded were based on the hand signal system (see Fig. 9). t-Technique analyses indicated that there was no significant difference between Q, M, and S responses for those tested.

#### CONCLUSIONS AND COMMENTS

The criteria for judging the uncertainty of a patient's response were: prolonged reaction time, non-enunciation of responses, and/or a possible change of tone in the patient's voice. In considering the physiological correlations with uncertainty of response, the individual statistics were considered more significant than the group statistics. Hence, when very low correlations were found for most individuals for a particular test condition, even relatively higher group statistics for a small part of the group (e.g., blink) were not considered significant. Particularly, in view of future clinical applications, high individual correlations must be found for a significant percentage of a small random sample of patients before large scale group statistical analyses should be made.

Immediate transient responses of EKG, blink, GSR, arm acceleration, and respiration do not tend to be correlated to the patient's degree of uncertainty about his discrimination between mild stimuli such as those induced at an eye examination. However, a rough correlation was found for three out of ten blink patients which indicated that blink amplitude increases with greater certainty of response. t-Technique analyses suggest that little or no change in heart rate (four patients) and respiratory rate (four patients) exist during Q, M, and S responses for each patient tested. Also, we found no correlatable trends for the GSR of twelve patients during the eye examinations. Further, eight patients exhibited little or no arm acceleration movements during the attentive portions of the eye examination.

This report is of value because it illustrates the methods of approach, the solutions to some of the problems that may be encountered, and the analysis of the results of the psychophysiological experiments that were performed during actual clinical examinations.

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