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LATENCY OF PUPILLARY REFLEX TO LIGHT STIMULATION AND ITS RELATIONSHIP TO AGING

* RICHARD FEINBERG AND EDWARD PODOLAK

THIS STUDY is concerned with the latency period of the pupillary contraction to light and the relationship of this latency period to aging. Some findings on pupillary latency periods related to light intensity, as well as to myopes with mydriasis and to an individual with nerve conduction disease, are described.

Analysis of the normal light reflex into its several components of speed and amplitude has been attempted for over 100 years. Techniques of pupillary measurement have been varied and have included: 1) entopic observation in which the observer subjectively measured his own pupillary diameter or reactions; 2) direct observation and measurement of the subject's pupil by ruler, scales, circles, holes, etc.; 3) photographic techniques, and, 4) pupillographs using various cinematographic or electronic devices. In 1956, Lowenstein and Loewenfeld developed the Electronic Pupillograph which was the prototype of the instrument used in this study. A typical curve of the signal output of the Electronic Pupillograph is shown in Figure 1.

In 1845, Listing with entopic observations determined that the latency period for pupillary contraction was about 0.4 second when the eye was opened suddenly, and that the contraction movement lasted about 0.5 second. Since then, numerous investigators have made determinations of the latency period and dura-

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tion of contraction. Most of the investigators (Duke-Elder, 1949; Lowenstein and Loewenfeld, 1958, 1963; Shaknovitch; Talbot, 1938; Tschirren, 1947; Walsh, 1910; Weiler, 1910) agreed that the latency period of pupil contraction ranges from 0.2 to 0.3 second. Some authors, however, have reported shorter latency periods; for example, Fuchs (1903) reported 0.12 second, Dolének (1960) 0.126 to 0.295 second, and Gradle and Eisendraht (1923) 0.1875 second. At the other end of the time scale, von Arlt (1869) found the pupillary latency period to be 0.492 second and Donders (1864) 0.400 second.

There have been relatively few studies relating the pupillary latency period to other physiological factors. Schlesinger (1913) stated that it increased upon repeated stimulation; Loewenfeld and Lowenstein (1963) have maintained that it may vary among individuals and in the same individual under different experimental conditions.

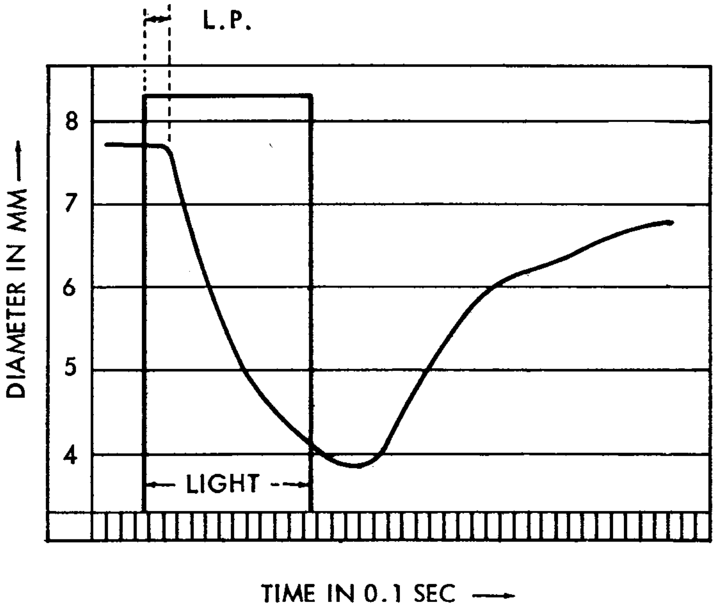

Figure 1. Diagram of pupillary reflex to light stimulus (after Lowenstein and Loewenfeld). L.P. = Latent Period in pupillary contraction.

Kumnick (1956) stated that the latency period of pupil constriction is *not* affected by increasing age* but is affected significantly by the pupillary conditions of restitution and decay of restitution at certain age levels.

METHOD

The over-all features of the instrumentation used for pupil latency measurements are shown in the block diagram of Figure 2 and the photograph of Figure 3. The basic instrument is the Electronic Pupillograph (10, 14). It consists of a scanner, an amplifier-detector assembly and a stimulator.

The scanning unit is a rotating drum with slits in its periphery through which a light beam is projected. This beam is divided into two identical paths which scan both irises in rectangular patterns, comprised of twelve horizontal lines, at a rate of sixty times per second. A Wratten 87C filter placed between the drum and the eye renders the scanning light invisible to the dark-adapted person. The light of the two scanning beams is reflected onto two photoelectric cells. The outputs of these cells are amplified in two identical channels and converted into DC analog voltages, whereby the voltage amplitudes are proportional to the largest horizontal diameters of the pupils.

The stimulator lamp energy is reflected from a mirror located just above the optical path of the infrared scanning unit. The same mirror is used to reflect a dim, red fixation light which is placed on the ceiling above the scanner at a distance of four feet. The line of regard and the direction of the stimulating light beam are 15° above horizontal.

The Grass Photic Stimulator (model PS-2) provided a high intensity flash of approximately one million peak candle power for 10 microseconds. The flash was seen by the left eye only, while measurements of latency period were obtained from the consensually reacting right pupil. For these measurements, the derivative of the Electronic Pupillograph scanner voltage was used rather than the analog voltage which represents the pupil

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* Kumnick noted means of initial latency of pupil constriction to be 0.200 for age group 7.5—15.0 years; 0.222 for 18.1—28.2 years; 0.226 for 30.5—52.7 years; 0.226 for 70.4—90.8 years.

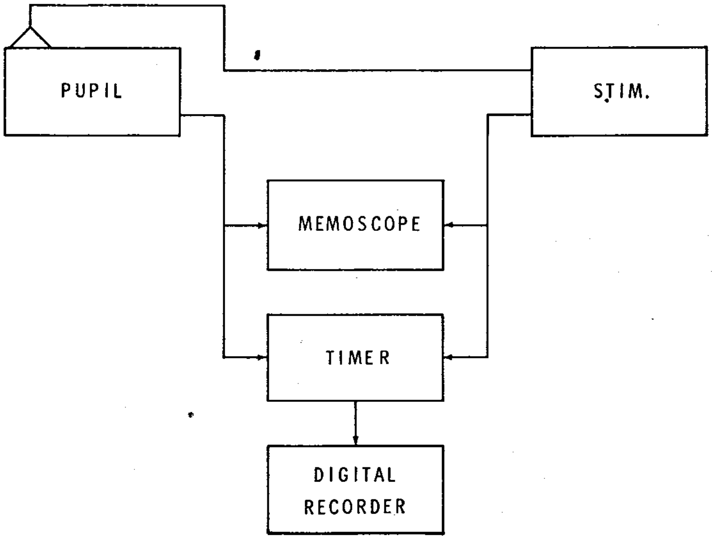

Figure 2. Block diagram of instrumentation for pupil latency measurement.

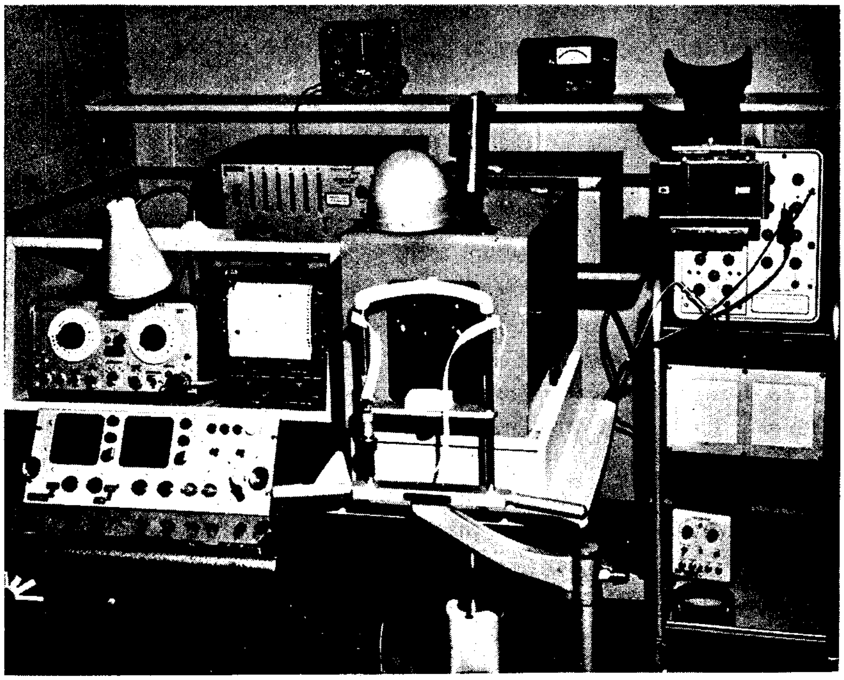

Figure 3. Photo of test apparatus.

diameter. The derivative voltage, representing the velocity of the pupil, was used as the following description indicates.

A signal coinciding with the stimulator light current is available at the External Monitor receptacle of the Grass Photic stimulator. This signal started both the sweep circuit of a Hughes Memoscope (model 105) and the "Start" circuit of a Beckman Berkeley Universal Timer (model 7350). The timer was stopped when the derivative pupil signal exceeded a pre-set voltage level of its "Stop" circuit. The time measured from the "Start" to the "Stop" signal was read out on a Digital Recorder (model 1452).

Initially, a comparison of the analog signal representing the pupil diameter and its derivative was made simultaneously to determine which of the two signals available from the Electronic Pupillograph was the more suitable for timing purposes. In this

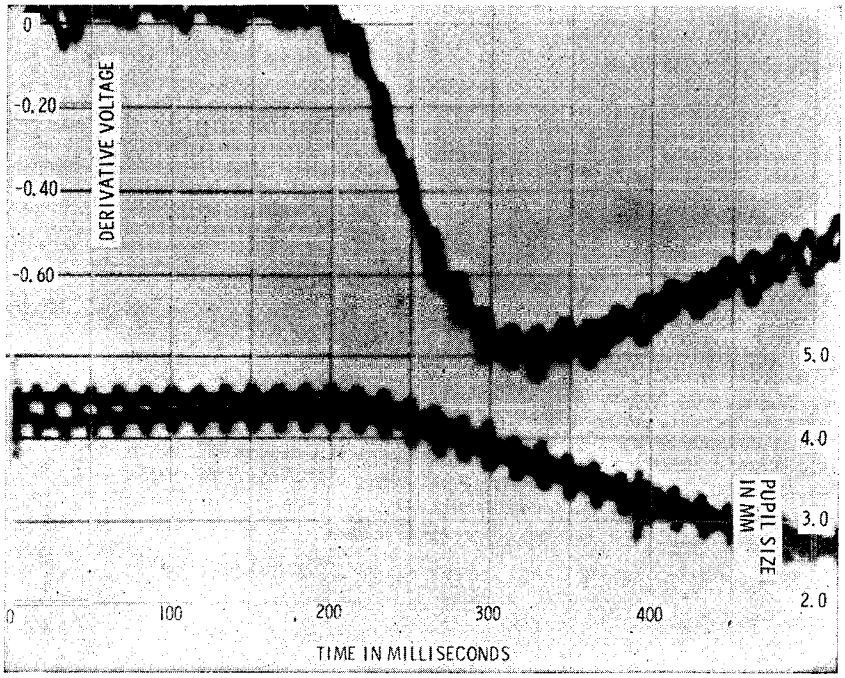

Figure 4. Analog voltage of pupil diameter and its derivative in response to high intensity light.

comparison for each flash of light from the Photic Stimulator two traces were generated on the dual beam Memoscope face, whereby the lower trace showed the analog voltage of the diameter, and the upper trace its derivative. It can be seen that the curve representing the derivative voltage has a much steeper slope than the analog signal of the diameter. The definition with which a single sweep can be resolved on the Memoscope is adequate for measurements within ± 3 milliseconds (Figure 5). The readings used for this study were taken from the Digital Recorder. For our purposes, this recorder had an accuracy of ± 0.0001 seconds. Figure 5 also shows that the 60 cycle per second scanning rate of the pupillograph modulates the derivative signal.

The timer has a crystal controlled oscillator operating at a frequency of 100,000 cycles per second; for the present application, a 10,000 cycles per second rate was used. A gate in the

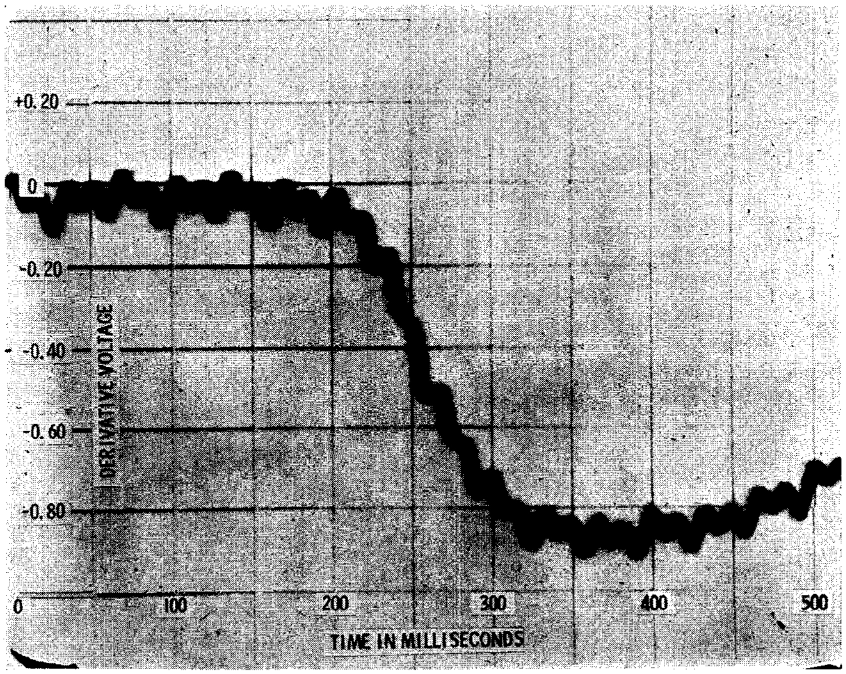

Figure 5. Definition of single sweep on memoscope.

timer was opened by the "Start" circuit when the Photo-Stimulator was triggered. The gate was closed by the timer "Stop" circuit when the voltage from the derivative signal exceeded a pre-set level of the "Stop" circuit. The counter, in the meantime, counted the number of cycles that passed from the crystal oscillator through the gate at a 10,000 cycle per second rate.

The "Stop" level of the timer was pre-set so that a derivative signal of -0.30 volts did not stop the timer, while -0.35 volts did stop it. A voltage of -0.35 was equivalent to a pupil contraction velocity of 3.5 mm. per second (manufacturer's specifications).

One of the advantages of using the derivative pupil signal is that the same "Stop" level on the timer can be used for all subjects. Once the diameter of the pupil attains equilibrium (in darkness), its derivative becomes zero and all measurements are taken from this zero point, i.e., *all measurements are independent of the initial absolute diameter of the pupil or of the iris color.*

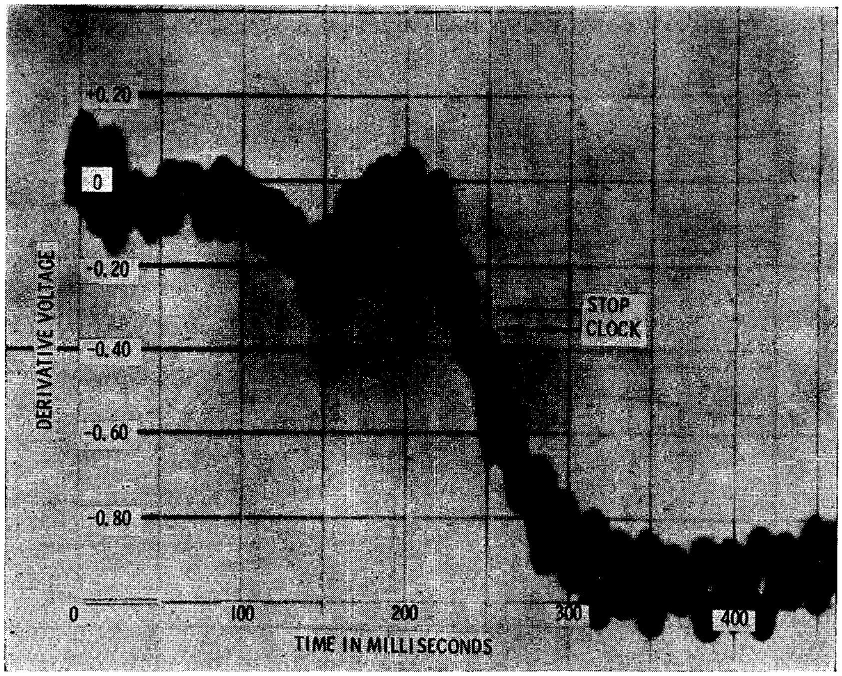

Figure 6. Presetting of "stop-clock" timing circuit.

RESULTS

Our sample consisted of 86 persons ranging from 14 to 67 years of age (Table 1). The average latency period in these subjects was 0.252 second, with a range from 0.214 to 0.314 second (Figure 7). It should be noted that the true latency periods are somewhat shorter than the values indicated in this communication. The latency period as determined in this experiment was the time interval from the start of stimulation to the moment when pupillary contraction had reached a speed of 3.5 mm. per

TABLE 1

AGE OF SUBJECTS USED IN THIS EXPERIMENT

Age in Years	*No. of Subjects*
14-20	15
21-30	17
31-40	10
41-50	22
51-60	20
61+	2
	N=86

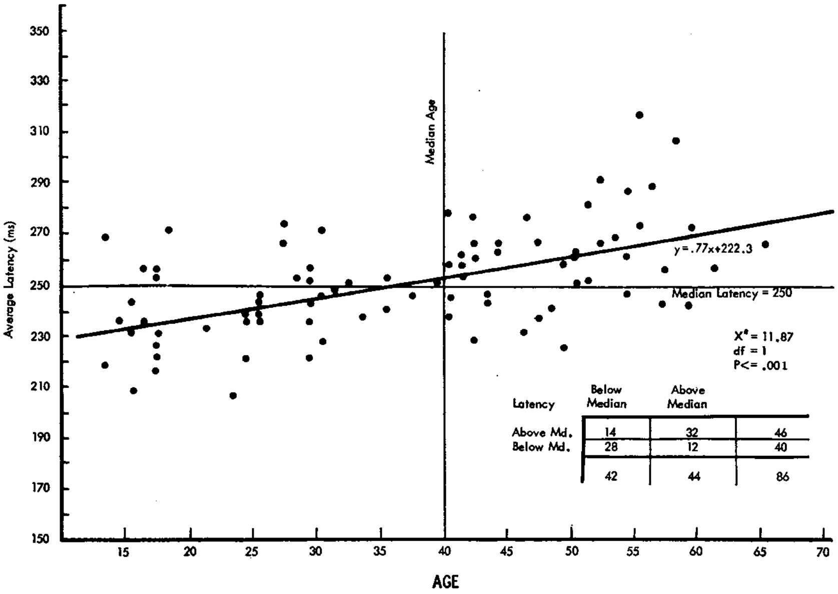

Figure 7. Scattergram of average pupil latency periods by age.

second. It is obvious that this time is longer than the period of pupillary inactivity that follows the initiation of stimulation. If we wish to redefine latency period as the time from photic stimulation to the first detectable response, we must re-examine our data. Figure 5 shows that the voltage level used for a single sample measurement was reached approximately 0.034 sec. after the moment of first noticeable change. Though it would have been preferable to trigger the "Stop" circuit of the counter by this first minute voltage change, it was necessary to chose the higher voltage in order to operate beyond the noise level of the system.

Consciously or unconsciously, most authors have run into similar difficulties. For example, it is impossible to detect with the unaided eye the exact moment of initiation of the contraction movement, especially when the stimulus intensity is low and the reactions shallow. Since, in addition, the latency period increases with decreasing stimulus brightness (Lowenfeld and Lowenstein, 1959), the large range of values for the pupillary latency period reported by competent authors is not surprising.

The prolongation of the latency period beyond its true value depends upon the steepness of the slope of increasing contraction velocity. For this reason mainly, we chose the maximal light intensity conveniently available for our experiment on aging. The values obtained on the readout of the Digital Recorder and those marked on the Memoscope at the —0.35 volt cutoff point agreed very well (maximal discrepancy ± 4 milliseconds), and since all of our normal subjects responded to the powerful light flashes by reactions with steep velocity slopes, the differences between the true latency periods and the mean times measured at the -0.35 volt cutoff point varied only little among individuals.

LATENCY PERIOD AND LIGHT INTENSITY

Even at the high brightness levels used in this experiment, the latency period tended to lengthen when the stimulus intensity was reduced. Figure 8 shows the responses of the pupil to five different flash light intensities ranging in intensity ratios from 1 to 80.

The logarithms of the relative intensities (10 log relative intensity in db) are 0, 6.0, 12.0, 16.8, and 19.0. Peak intensity

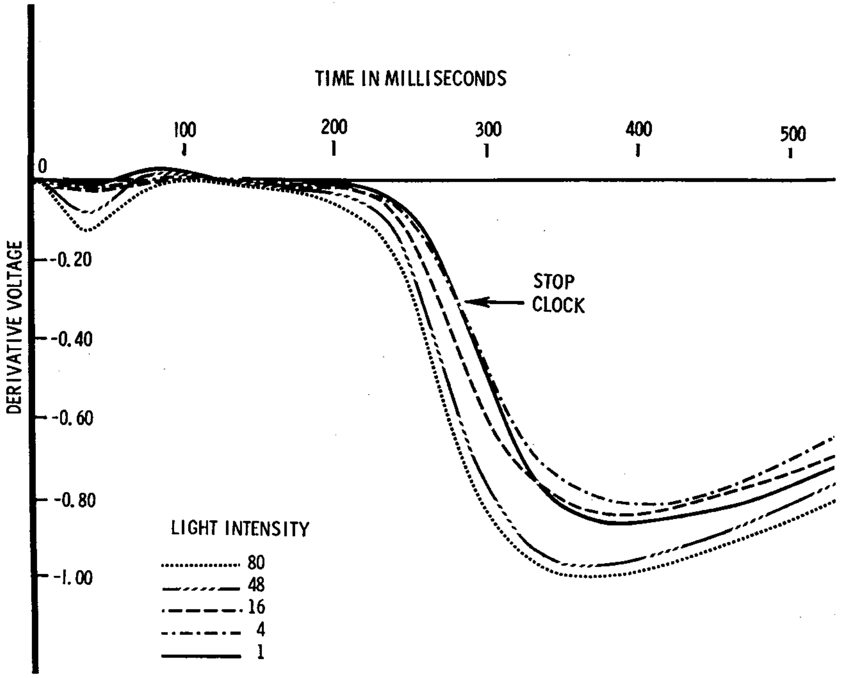

Figure 8. Composite curves of average response of pupil vs. light intensity.

with the highest setting is approximately one million peak candles measured on the axis of the parabola at a distance of 10 inches from the glass face plate. The latency values used at each intensity setting were means of 10 digital readings, a plot of which is shown in Figure 9. The standard deviation of the readings about each mean was approximately five milliseconds, and their standard deviations did not vary significantly from one intensity level to another.

LATENCY PERIOD OF PUPILLARY CONSTRICTION AND AGING

A scattergram (Fig. 7) of the average latency period by age shows a positive relationship ($r = .54$) between pupillary latency period and aging. As one grows older, his pupillary latency period increases. A chi-square of 11.87 (each variable split at the median) with one degree of freedom, a $p < .001$ shows that this is highly significant. The slope of this increase is shown by the regression equation $y = .77x + 222.3$.

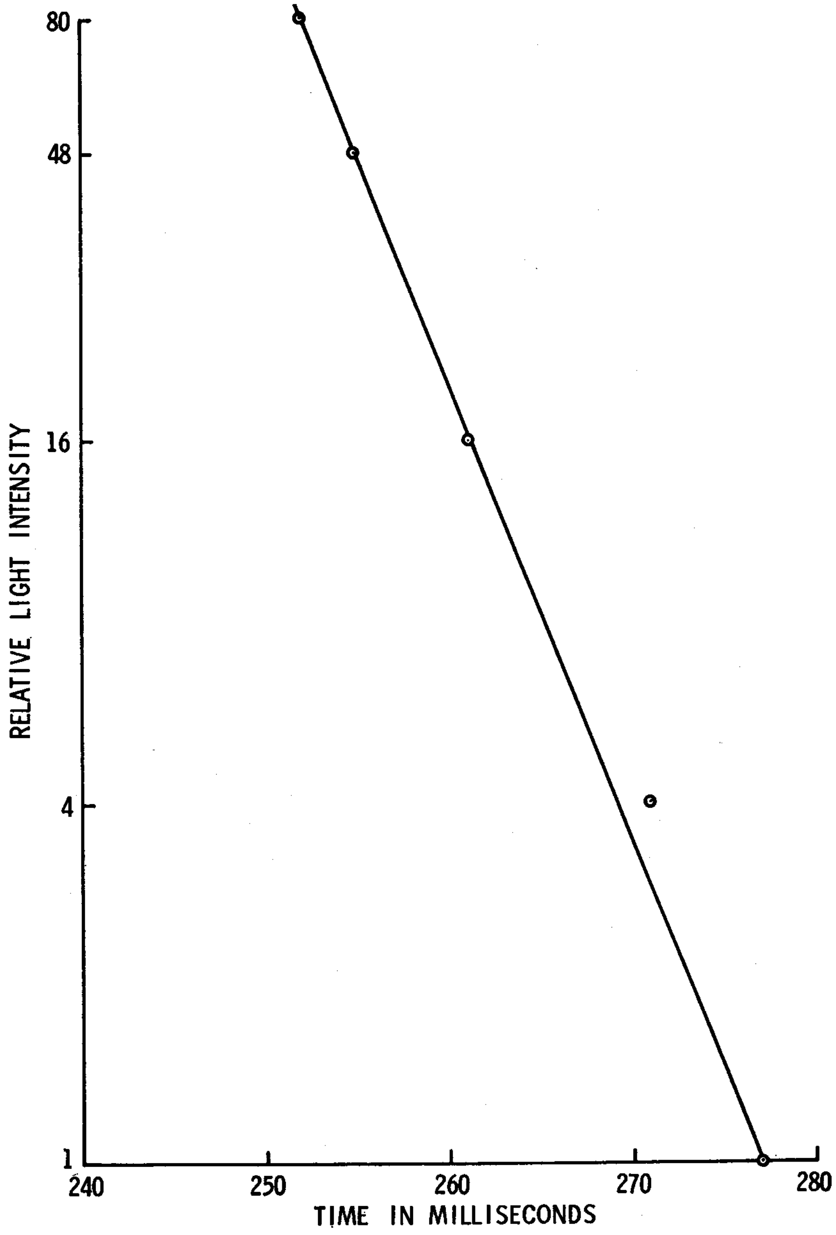

Figure 9. Means of pupillary latency vs. relative light intensity (one subject).

Moreover, if we compare the means for the extremes in the ages studied, namely, those under twenty-one and those over fifty years of age, we find that the older group definitely has a longer pupillary latency (0.273 sec.) than the younger group (0.238 sec.). Comparing the means of these two groups, a highly significant t value of 3.92 was found with 34 degrees of freedom. The probability that the two populations would have the same mean would be less than 1 in 1000.

If we compare the original pupil size and aging, we find that with aging, the pupil diameter decreases. Statistically, this may be expressed by a Pearsonian r of -0.55, a regression line $y = 0.36x+7.5$, a chi-square of 11.20 ($df = 1$; $p<.001$).

The average latency of response to original pupil size in darkness shows a negative relationship.

A possible relationship between latency of response and myopia with mydriasis has been brought to our attention in five cases which we have studied. In each instance, regardless of age, the latency period has been longer than 0.260 sec. Whether these longer latency periods have occurred by chance or not will have to be determined by further studies.

Longer latency period in pupillary constriction as a possible correlate of nerve conduction disease was introduced to us by a physician, who, himself, was the victim of Charcot-Marie-Tooth disease, a progressive disorder that symmetrically affects only the distal muscles of the legs and occasionally the arms. It is associated with pathologic changes in the anterior horn cells, peripheral neuromuscular units, posterior columns and frequently other tracts of the spinal cord including the pyramidal (Baker, 1962). Our patient showed, at the age of fifty-one, a pupillary latency period of 0.299 sec.

CONCLUSIONS

1) A method is described for measuring pupillary contraction latency period regardless of initial absolute pupil diameter.

2) Pupillary contraction latency period increases with age. The data presented show that the normal pupil, as usually found in healthy young people, has a shorter latency than is found in older normal subjects.

3) Original pupil size decreases with age.

4) A limited number of subjects with myopia coupled with mydriasis had relatively long latency periods.

5) One subject with a nerve conduction disease was found to have a relatively long latency period.

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