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THE INFLUENCE OF STIMULUS SIZE AND BINOCULAR AND MONOCULAR

VISION ON VISUAL REACTION TIME

by

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A Thesis Submitted to the Faculty of the Graduate School

of Loyola University in Partial Fulfillment of

the Requirements for the Degree of

Master of Arts

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VITA

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Chapter I

Background and Purpose of this Study

The study of reaction time has a long history in psychology. Helmholtz pioneered the field with his study of the speed of nerve impulse transmission in frogs (Woodworth, 1938). Time lapse in nerve conduction had been previously observed, though unwittingly, in discrepancies of transit readings given by different observers at the Greenwich Observatory in 1795. By 1860, Hipp and Hirsch had developed their chronometer to measure "physiological time." The Dutch physiologist, Donders, timed what he called "mental processes," which were simple reactions to stimuli. His work was developed at the Leipzig laboratory, and it was there that the first American professor of psychology, James McKeen Cattell, came into contact with it. Cattell and the Austrian physiologist, Exner, who coined the term "reaction time", came to the conclusion that very little mental activity was involved in reaction time responses. They thought of them rather as "prepared reflexes".

Cattell returned to America where he established laboratories at Pennsylvania and Columbia. During the years he remained at Columbia, he directed many students in reaction time studies. So numerous were reaction time experiments at the end of the last century, that Boring (1957) calls it a period of mental chronometry.

Simple reaction time (RT) is defined as "the time interval between the onset of the stimulus and the initiation of the response under the condition that $\underline{S}$ has been instructed to respond as rapidly as possible" (Teichner, 1954). In RT experiments various stimuli have been used: light, sound, pressure, pain, and taste. It has been almost universally observed that each

1.

sense modality has its own typical RT. For example, the generally observed RT for light is 180 msec., and for sound it is 140 msec. But within each modality significant variations in RT have been found under different experimental conditions. Although these variations may depend on a number of factors, in general they seem to be due to the conditions either of the stimulus or of the organism.

In RT experiments with a light stimulus, three conditions of the stimulus have been of principal concern to experimenters: the intensity, area, and duration of the stimulus. The present study will investigate the effect of the area of the stimulus on RT. One of the first psychologists to be interested in this problem was Froeberg (1907). He noted that scarcely any attempt had been made to determine the influence of the size of the stimulus on the time of reaction, although several investigators had found that the "smaller the size of the retinal image the greater must be the intensity of illumination in order that the object be perceived". Ricco had expressed this relation in mathematical terms: The product of the area of the retinal image and its intensity, or the product of the visual angle and the square root of the intensity is a constant as long as the visual image does not exceed the limits of the fovea. The application of Ricco's law was limited to experiments in which the constant was the threshold of sensation.

Piper (1903) also formulated a law relating the area and intensity of visual stimulation for cases in which the retinal images lay entirely outside the limits of the fovea. He found that the product of the intensity by the square root of the area is a constant at the threshold. However, later researchers questioned the validity of both Ricco's and Piper's laws (Wood-

worth, 1938). Piéron (1929; 1952, p. 210), for example, found that Ricco's law didn't even apply for foveal vision at threshold level. Further, his data indicated that the formula for the constant in Piper's law is better given as $I \times A^m = K$, where the value of m for light is 0.3.

Froeberg wanted to determine how stimulus size affected sensation at supraliminal levels of intensity. To do this he measured the effect of stimulus size on RT. The stimuli were squares of white paper the sides of which ranged in size from 3 mm to 48 mm. The papers were mounted on a revolving iron wheel and were illuminated by daylight. They were exposed to the S through an aperture which was masked in black. Averaging Froeberg's results for data from four Ss it can be seen that the RTs decrease arithmatically as the size of the stimulus increases geometrically (see Table 1).

Table 1

Froeberg's Results

Size of Stimulus in mm sq.	48	24	12	6	3
Average RTs in msec.	172.4	175.5	176.0	179.0	184.9

In 1927, Ferree and Rand studied the relation between the length of exposure time required to perceive a stimulus and stimulus size. They conducted their experiment in a day-lighted room with illumination intensities varying between 1.25 and 100 foot-candles at the test surface. A rotary tachistoscope presented the test object, a broken circle (apparently a Landolt

ring), at various speeds. The S's task was to indicate for five out of eight trials the direction in which the opening pointed. Only the S's right eye was used since previous studies had indicated that the observer's speed was as good with the right eye as with both eyes. Speed of vision in this experiment was the reciprocal of the length of exposure required for the subject to make correct judgments. The results showed that "large increases in speed are produced at each intensity of illumination by increasing the size of the object. Also for the ranges of size and intensity used, the effect of increase of size is much greater than the effect of increase of intensity."

Both Froeberg's and Ferree and Rand's experiments have indicated that RT is decreased as the size of the stimulus is increased. Every other investigation of this problem has, to the knowledge of this writer, produced similar findings. Physiologists, studying the characteristics of firing in the optic nerve, also found that by increasing the area of the stimulus they could shorten the latency of discharge. Further investigation revealed an anatomical basis for this phenomenon. Finally, the physiologists attempted to formulate some general principles in regard to the effect of light on the retina.

Adrian and Matthews were the first to really investigate the physiological basis for the effect of stimulus size on the larceny of discharge in the optic nerve. They investigated the effect of light stimuli of different sizes and intensities on the retinal potential, and on the firing of the optic nerve in a common eel, Congar vulgaris (1927a). The same basic experimental procedure was used throughout this series of experiments: A preparation was made from the eye and optic nerve of the eel, in which elec-

trodes were attached along the optic nerve to record diphasically the action of nerve impulses. Although this eye has no fovea, it is equipped with intermuncial neurons.

When the intensity of the stimulus was increased without any change in area, three things happened: (a) the latent period was reduced; (b) the maximum frequency of discharge was increased; and, (c) the maximum frequency was reached at a shorter interval after the beginning of the discharge. The frequency of discharge was found to be an exponential function of the intensity. When the intensity of the stimulus was held constant and the area was increased, three events followed: (a) there was a reduction in the latent period of the discharge--nerve reaction time; (b) there was a quicker rise to the maximum frequency; and, (c) there was an increase in the frequency which was small in proportion to the area stimulated.

Because the increase in area with intensity held constant had the same effect as an increase in intensity with area constant, Adrian and Matthews concluded that the "character of the discharge is really determined by the total quantity of light which falls on the retina in a unit time without regard to the distribution of the light". To test this hypothesis they suggested that one might compare the discharges produced by keeping the quantity of light per unit time constant while varying the area and intensity. Their observations also led them to expect that RT in man would change according to to the area of the stimulus, when the intensity is held constant.

At this point it seems that one qualification should be made in regard to Adrian and Matthews' position. In view of the findings of Piéron and many others, that area and intensity do not bear a pefectly reciprocal

relationship to one another, it would seem more exact to interpret Adrian and Matthews' findings as showing that area and intensity have a similar, but not the same, effect on the eye. An increase in area does not seem to have as great an effect on the retina as does an increase in intensity. Adrian and Matthews themselves observed this difference.

Having found that the intensity and area of the stimulus has a profound effect on the discharge in the optic nerve of the <u>Congar vulgaris</u>, Adrian and Matthews next related stimulus change to the retinal currents. According to Einthoven's analysis, the retinal current is composed of three processes: A, B, and C (see Fig. 1). When the light stimulus is presented there is first a short latency period, then the negative deflection <u>a</u> occurs in the A Process. This is followed by a positive delfection, due to the B Process, which decreases under steady illumination, but may rise again owing to a slower C Process. When the light is turned off there is a rapid positive deflection, <u>a'</u>, which is part of the A Process. Finally, there is a slow return to a resting condition. As far as the discharge in the optic nerve is concerned, the A Process with the <u>a</u> deflection is the most important, particularly in regard to the latency of discharge and ultimately the RT response. Retinal currents and the discharge in the optic nerve are not at all the same thing. There is a constant interval between the <u>a</u> deflection and the beginning of the optic nerve discharge. Adrian and Matthews found that this constant interval had an average length of about 100 msec. It was further observed that the magnitude of the <u>a</u> deflection depended on the area and intensity of the stimulus.

The investigators explain the relationship between the <u>a</u> deflection
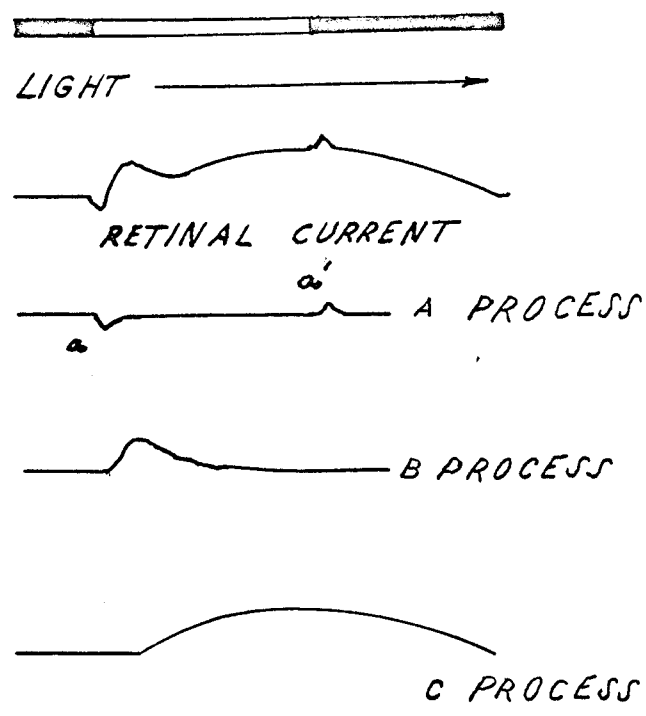
Fig. 1. General form of retinal current and Einthoven's analysis into three processes A, B, C. (After Adrian & Matthews, 1927a.)

and the latency of discharge in the optic nerve this way. Since the interval between the a deflection and the firing of the optic nerve is constant, differences in the latency of discharge must be due to processes occuring before the a deflection, which processes presumably are responsible for the a deflection. Adrian and Matthews considered several possibilities in attempting to explain what might be the cause of the time lag preceding the a deflection, which was dependent on the intensity and area of the stimulus. They finally concluded (1928) that "the parallel effects of an increase in the intensity of the light and an increase in the size of the illuminated area must be due in some way to nervous summation of the excitations from different points". Thus the varying delays in optical nerve discharge would seem to be due to the time required for impulses from the receptor cells, stimulated by lights of different sizes and intensities, to summate through the bipolar and ganglion cells in the retina. The a deflection occurs after this summation has taken place but before the impulses from the internuncial cells produce a discharge in the optic nerve. However, it is still not certain what retinal activity is responsible for the a deflection.

Since Adrian and Mathhews' articles were written, it has been generally accepted that the facilitating effect of the area of the stimulus on the speed of firing in the optic nerve is due to retinal summation. Granit (1933) observed that Adrian and Matthews' conclusion had been confirmed by Graham who found that "in the eye of the Limulus, which lacks internuncial neurons, the influence of area on the latent period is absent, though the intensity effect is present". Later, Granit (1947) somewhat qualified his position and offered what is probably the most complete explanation of the

area effect on latency. He said that the area effect was probably due both
to neuronal interaction in the retina (summation), and to further electrical
stimulation set up around the excited nerves.

Polyak (1957, pp. 578-579) offers a description of the anatomical
basis for summation:

> A combination of neurons by means of which impulses of the same or dif-
> ferent kinds may be added and the resulting excitation concentrated or
> intensified is exemplified in the primate retina by the rod and mop bi-
> polar synapses alone, or together with those of the cones . . . . Each
> mop bipolar can be in contact with a compact group of rods and cones,
> the groups being larger in the extra-areal periphery.

> The principle of anatomical spacial summation may be applied on a
> larger scale, in successive tiers or links of a neuron chain making up
> a system. In the initial portion of the vertebrate system, not only
> does each bipolar of the diffuse varieties assemble into a common path
> influences arising from a group of rods and cones, or from cones alone,
> but again on the ganglion level each cell unites the influences from
> several--in the extra-areal periphery of the retina from hundreds--of
> bipolars into larger functional units. The size of these units varies,
> the smallest belonging to the midget ganglions of the central area, the
> largest to the diffuse ganglion varieties of the extra-areal periphery
> . . . . Possibly such units may also vary among themselves in density,
> depending on the number of bipolars related to a given ganglion variety
> per surface area in the retina.

> The probable effect of the "summative synaptical organization" is
> the increased intensity of influences passing through it.

After having shown that both the intensity and the area of the light
stimulus effect the retinal potential and the firing in the optic nerve,
Adrian and Matthews next investigated the effect of the duration of the stim-
ulus on retinal action (1927b). They found that nerve reaction time decreased
as the duration of the stimulus was increased up to 100 msec. The effect of
duration was also related to the intensity of the light, but for many lights
durations longer than 50 msec. no longer had any effect on latency. Hence,
Adrian and Matthews concluded that decreases in nerve reaction time were a

function of the "total quantity of light" striking the retina. The "total quantity of light" was defined as $I \times A \times T = K$, where I is the intensity of light, A the area of the stimulus or the corresponding area stimulated in the retina, and T the duration of the stimulus. K is a constant representing the value of the "total quantity of light," when components I, A, and T may be varied experimentally. This formulation would seem to be a combination of Ricco's law ($I \times A = K$), or Piper's law ($I \times \sqrt{A} = K$) and the Bunsen-Roscoe law ($I \times T = K$). However, all these "laws" seem to be valid only under very restricted conditions, and the reciprocity of these laws is by no means perfect. Therefore, it would seem more accurate to regard the I, A, T relationship enunciated by Adrian and Matthews as a schematic, rather than as a mathematical formulation.

Research evidence clearly indicates that I, A, and T do have a similar, though certainly not an identical, effect on RT. Cattell and Berger (1886) performed a classical experiment varying the intensity of a light stimulus. By placing pieces of smoked glass and lenses over a light source they were able to provide eight light intensities. They set the "normal" light equal to 1000, and then measured the first six lights as 1, 7, 23, 123, 315, and 1000. The two authors served as subjects for this experiment and their results showed that "when the light is taken very weak, just strong enough to be seen, the times are longest . . . and the greater the intensity of the light, the shorter the time of the reactions. I cannot, however, formulate a general law from the table."

Hull (1949) was able to formulate a general statement from Cattell and Berger's data. In an article in which he attempted to express the relation-

ship between the stimulus intensity and the reaction potential for trained responses, he concluded that, "other things being constant, the magnitude of the reaction potential . . . has an increasing monotonic relationship to the intensity . . . of the stimulus in question, the increases taking place at a progressively slower rate according to the equation $_S E_R = V = A(1 - 10^{-b \log \underline{i}})$." Wilcoxon, working with Hull, fitted Cattell and Berger's data for their first six intensities to a curve with the formula $_S t_R = .113 \times 10^{-.590 \log \underline{i}} + .167$.

In a review of RT studies, Teichner (1954) noted that both early and recent studies all agree that visual RT becomes shorter as the intensity of light is increased. He also says that "attempts have been made to fit the intensity data into mathematical, theoretical frameworks, with exponential, hyperbolic, and parabolic functions all being used more or less successfully on the same sets of data."

However, there is some evidence which suggests that RT is not a simple monotonic function of the intensity of the stimulus. Johnson (1918) and Steinman (1944) found that RTs decrease with increases in intensity only to a certain point after which the RT begins to increase again. This suggests that the function is not monotonic, but rather has an optimum at some moderate intensity. This finding indicates at least one limitation of the application of the $\underline{I} \times \underline{A} \times \underline{T} = \underline{K}$ principle, even when $\underline{A}$ and $\underline{T}$ are held constant.

Besides the experimental evidence already cited to indicate that RT is a function of the area of the stimulus, the following studies might be noted for their emphasis on the limitations of this relationship. Adrian and Matthews (1927a) found that when they increased the size of the retinal image beyond a .9 mm in diameter the effect of size on latency was lost. Bartley

(1935) studied the cortical response to short flashes of light in the rabbit. He found that the latency was reduced very rapidly while the stimulus subtended only a small visual angle, but as the image increased, the rate of this shortening was reduced considerably. When the size of the stimulus reached 20° of visual angle, there was again a sharp increase and then a tapering off in the rate of decrease of latency. This abruption after 20° led Bartley to conclude that the explanation for the effect of size on latency was more complex than Adrian and Matthews' summation theory. This need not be the case, however, particularly in view of Polyak's description of the internuncial structures in the retina. Since the ganglion cells unite many more bipolar cells in the peripheral area than in the central area of the retina, there may be some point on the retina at which a new and powerful summating effect appears, due to the action of peripheral ganglion cells. It may be that this later increase in facilitation was responsible for the abruption observed by Bartley. The curvilinear relationship between stimulus size and latency after the abruption then possibly shows the summating effect of the peripheral ganglion cells responding to peripheral stimuli of increasing sizes, just as the reduction of latencies in the central area is due to the summating effect of the bipolars and midget ganglion cells with many fewer connections. But whatever may be the explanation for the effect of stimulus size on latency, it seems clear that the size effect is obtained in a predictable way only over a limited range. Again it should be noted, as was mentioned earlier, that Piéron (1929) failed to find a perfectly reciprocal relationship between size and intensity. The effect of area was not as great as the effect of intensity. Thus, $\underline{I} \times \underline{A} \neq \underline{K}$.

Finally, it has been observed in several instances that increased stimulus duration reduces RT. However, this relationship holds only over a very limited range of durations. Froeberg (1907) found that increasing stimulus duration ceased to have an effect on RT after 50 msec. Adrian and Matthews (1927b) found that increasing stimulus duration over 100 msec. no longer affected RT. Raab, Fehrer, and Hershenson (1961) presented three $\underline{S}$s with light flashes of .30, 30, and 3000 foot-lumens at durations of 10, 25, 50, 100, 250, and 500 msec. They found that RT did not vary with stimulus duration, except possibly when the .30 foot-lumen light was presented for 10 msec. Then there was a tendency for RTs to be longer. Thus evidence showing that RT is a function of duration is somewhat inconsistent, and undoubtedly varies according to the conditions of the individual experiment.

In the summary then it would seem that the $\underline{I}$ x $\underline{A}$ x $\underline{T}$ = $\underline{K}$ formulation can be accepted only as a schematic formulation. Indeed, by increasing either the intensity, the area, or the duration of the stimulus one can reduce the RT, but only within definite limits and according to different rates. Although RT is undoubtedly a function of the "total quantity of light" striking the retina--RT = $\underline{f}(\underline{K})$, as Adrian and Matthews (1927b), Granit (1947, p. 175), and Hull (1949) suggest, still it is not clear that the "total quantity of light" is the mathematical product cf intensity, area, and duration-- $\underline{I}$ x $\underline{A}$ x $\underline{T}$ = $\underline{K}$, as previous theorizers and law makers have indicated. However, in view of the relationships which have been shown to exist between intensity, area, and duration and the retinal potential, the optic nerve discharge, and RT, it would probably be more accurate to conceptualize the relationships between these factors in this way: RT = $\underline{f}(\underline{K})$; $\underline{K}$ = $\underline{f}(\underline{I}, \underline{A}, \underline{T})$; and therefore,

$RT = f(I, A, T)$.

Research, then, has shown that increasing the size of the stimulus has the effect of reducing the RT, and it seems very likely that this phenomenon is due to the summating action of the connective cells in the retina. Is it possible that there could be further summation at visual centers in the brain, such as the lateral geniculate bodies? The evidence in regard to this question is inconsistent. Ferree and Rand (1927) found, in a preliminary study, that their S was able to react as rapidly when using only his right eye as he could when using both eyes. This finding would suggest that there is no spatial summation beyond the retina. However, Poffenberger (1912) found that RT is shorter with binocular vision than with monocular vision. In his experiment an electric light was attached to a revolving iron wheel which exposed a two-candle-power stimulus over an area of one centimeter square for 1.25 sec. The S's eyes were kept at a distance of 92 cm from the stimulus, and the area around the stimulus was masked in black. A ready signal was given before each exposure, and a screen was used to effect the monocular condition. Poffenberger used three Ss and gave them each 800 exposures. His results show a reduction of RT for the binocular condition (see Table 2). Poffenberger interpreted his results as suggesting the possibility of summation in the cortex.

Table 2

Poffenberger's Results

Subjects	Reaction Times in Milliseconds		
	One Eye	Both Eyes	Diffs.
T	201.3	184.6	16.7
P	174.8	160.4	14.4
A	191.2	178.1	13.1

The purpose of the present study will be to replicate the findings of Froeberg (1907) and Poffenberger (1912), under somewhat different experimental conditions. This experiment will be run in two parts. In the first part the purpose will be to test the hypothesis that RTs decrease as a function of the increase in the size of the stimulus. In the second part it will be to test the hypothesis that RTs will be shorter with a binocular condition than with a monocular one.

Chapter II

Method

Subjects: Thirty male college students who, as members of under-graduate general psychology courses, were required to participate in experiments, volunteered to be Ss for this experiment. These Ss were right handed, and were screened for right-eye dominance. The Ss ranged in age from 17 to 22 years. Fifteen Ss were used in each part of the experiment. The mean age for Ss for the first part of the experiment was 18.13, with a standard deviation of .71; for the second part the mean age was 18.40, with a standard deviation of 1.02 years.

Apparatus:

1) Stimulus and response apparatus. A box, 10" x 18" x 3", enclosed four 12 volt lights arranged behind a translucent plexiglass panel. The panel was evenly illuminated, but tended to be yellowish in color perhaps due to the low intensity of light used. An aperture through which the panel was viewed was 100 mm in diameter. The box and the wall on which it hung were painted gray. Approximately six inches above the stimulus patch there was a small rod ready light. An eye rest was provided to maintain a constant distance of approximately 144 cm between the S's eyes and the stimulus which was suspended at eye level. A telegraph key was placed on the table within easy reach of the first two fingers of the S's right hand.

During the first part of the experiment, a series of gray shutters were placed immediately in front of the 100 mm aperture to produce the independent variables. The diameters of the apertures of these shutters were 33.2 mm, 10.0 mm, 3.3 mm and 1 mm. The difference between any one variable

and the next was equal to approximately one-half log unit.

To produce the independent variables in the second half of the experiment, large eye patches were used. A patch was placed over the S's left eye for the dominant-eye condition. For the nondominant-eye condition another patch was placed over the right eye. A binocular condition was also used. The patches were large enough so that the S's eyes could easily remain open behind them. The diameter of the stimulus for this part of the experiment was always 5 mm.

2) Presentation and recording apparatus. A Gerbrands interval timer--Model 2A, pulling two 16 mm tapes--was used to program the ready and stimulus lights. The eight-feet-long tapes had 40 presentations punched into them, and these were divided into two blocks of 20. Holes in the ready light tape tripped a microswitch which presented the ready light to the S. When the stimulus-light microswitch was tripped by a hole in the program tape, a relay was closed which simultaneously presented the stimulus light and started a Lafayette chronometer, calibrated in hundredths of a second. S broke the circuit between the microswitch and the relay by lifting his finger from the response key as soon as he saw the stimulus light, thus stopping the chronometer and turning off the light. Another Gerbrands time--Model 1 A-- was used to start and stop the stimulus programmer at the beginning and end of each block of 20 trials.

Procedure: As E led the Ss into the experimental room he told them that he was running this experiment for a research project and that he would appreciate their cooperation. He then seated them behind a table on which was the response key and the eye rest. After recording the name, age, and

handedness of the Ss, E tested them with a manoptiscope to be certain that all Ss were right-eye dominant. Ss were then asked to sit up straight in a comfortable position and to look directly at the stimulus aperture. E then adjusted the height of the eye rest to suit the S. The S was then asked to place both arms on the table, and the telegraph key was placed under the first two fingers of the S's right hand. Then E gave S the following instructions:

> This is an experiment to determine how fast you can react to a light stimulus. What I want you to do is to look straight ahead at this hole in the box, and keep your eyes generally fixed in this area. When you see the red light, depress the telegraph key and hold it down. Shortly after that, a white light will come on down here. As soon as the white light comes on, release the key as fast as you possibly can. The whole object of this experiment is to see how fast you can release this key when the white light comes on. After you have released the key, there will be a short pause of about ten seconds during which time you can rest. Then the red light will flash again, and you will do the same as before.

After the instructions were given, the S was asked to stuff his ears with wads of cotton to keep out any "distracting noises." In both parts of the experiment, ten practice presentations were given to the S using the 5 mm aperture. At the end of each block of 20 trials the experimental condition was changed. In the first part of the experiment, the size of the aperture was changed, and the S made 20 responses to each of the five variables. In the second part, the eyedness condition was changed, and here the S responded 40 times to each of the three variables. In reading RTs, E estimated the position of the indicator between the hundredth second calibrations in order to obtain a reading correct to 5 msec.

Controls: Because of the many factors which may influence the RT, it was necessary to introduce a number of controls into this experiment:

1) Stimulus controls. In order to control adaptation and to prevent

contrast effect which might spuriously increase the strength of the stimulus, the S sat in a small room which was illuminated by an incandescent, overhead fixture. The general illumination of the room was between 12 and 16 foot-candles; the luminosity of the stimulus at the test surface was 12 foot-candles, all measures being taken on a Brockway light meter. Since the same evenly illuminated panel was used as the stimulus throughout the experiment, it was felt that the intensity of the stimulus was held constant. The dura-tion of the stimulus was variable according to the RT of the S. This duration was never less than 100 msec., and in almost every case not less than 200 msec. Even by the most conservative estimates (Raab et al., 1961), these durations were well above the critical duration, i.e., that time less than which the duration of the stimulus might have an effect on the RT. Thus, the effect of duration was held constant. Therefore, in the first part of this study the only consequential variable was the change in area; in the second part only the conditions of eyedness were changed. To maintain constant visual angles throughout the experiment, an eye rest was used to keep the S's eyes at a constant distance of approximately 144 cm from the stimulus. The visual angles subtended by the five apertures are shown in Table 3.

Table 3

Visual Angles Subtended by Stimuli

Diameters of Stimuli	1 mm	3.3 mm	10.0 mm	33.2 mm	100.0 mm
Visual Angles	2.42'	7.94'	23.86'	1° 19.20'	3° 58.76'

2) Controls for the S. Since motivation can play an important role in RT, the S's cooperation was solicited at the beginning of the experiment. However, after that no further reference was made to the S's motivation. Neither reward nor punishment--knowledge of results or criticism--was given during the course of the experiment. Set or readiness was controlled by randomly varying the length of the foreperiod after the ready signal between 2, 3, and 4 sec. Practice and fatigue effects, which can be considerable during RT experiments, were principally controlled by varying the order of presentation of the experimental conditions by incomplete systematic counterbalancing. Also, to familiarize the S with the equipment and procedure, ten practice trials were given before the experiment was actually begun.

3) Environmental controls. The presentation mechanism signaled onset of stimulus with a click. Since Ss respond to sound more rapidly than to light, the effect of the click was controlled by placing the S in a room separate from E and the presentation apparatus. He was also asked to stuff his ears with cotton, and a ventilating fan was turned on to mask the sound. The ventilator also served to keep the rooms comfortable for both S and E.

Dimensions: The means were obtained for the Ss' RTs on the variables on which they were tested. Data from the first part of the experiment were fitted to a curve. To test the significance of the differences between the results obtained in the second part of the experiment, t tests were used.

Chapter III

Results

The relationship between the diameters of the aperture, which were used in the first part of the experiment, and the corresponding RTs is shown in Table 4. These results are represented graphically in Figs. 2 and 3.

Table 4

The RTs for Different Sizes of Stimuli

Diameters of stimuli	1 mm	3.3 mm	10.0 mm	33.2 mm	100.0 mm
Reaction times in msec.	348.0	300.0	285.0	277.5	259.5

The graphs suggest that RT is a hyperbolic function of the diameter of the stimulus. The following formula was used to fit these results to a curve: $\log y = -.05795 \log x + 2.5245$, where y = RT, and x = the diameter of the stimulus.

In the second part of the experiment, the attempt was to determine whether there were any significant differences between RTs obtained with a binocular condition, a dominant-eye condition, and a non-dominant eye condition. Table 5 shows the means of the RTs obtained under these conditions, the differences between the means, the standard errors of the means of the differences, and the resulting t ratios. From these results it is evident that there are no differences among the RTs obtained under the three experimental conditions.
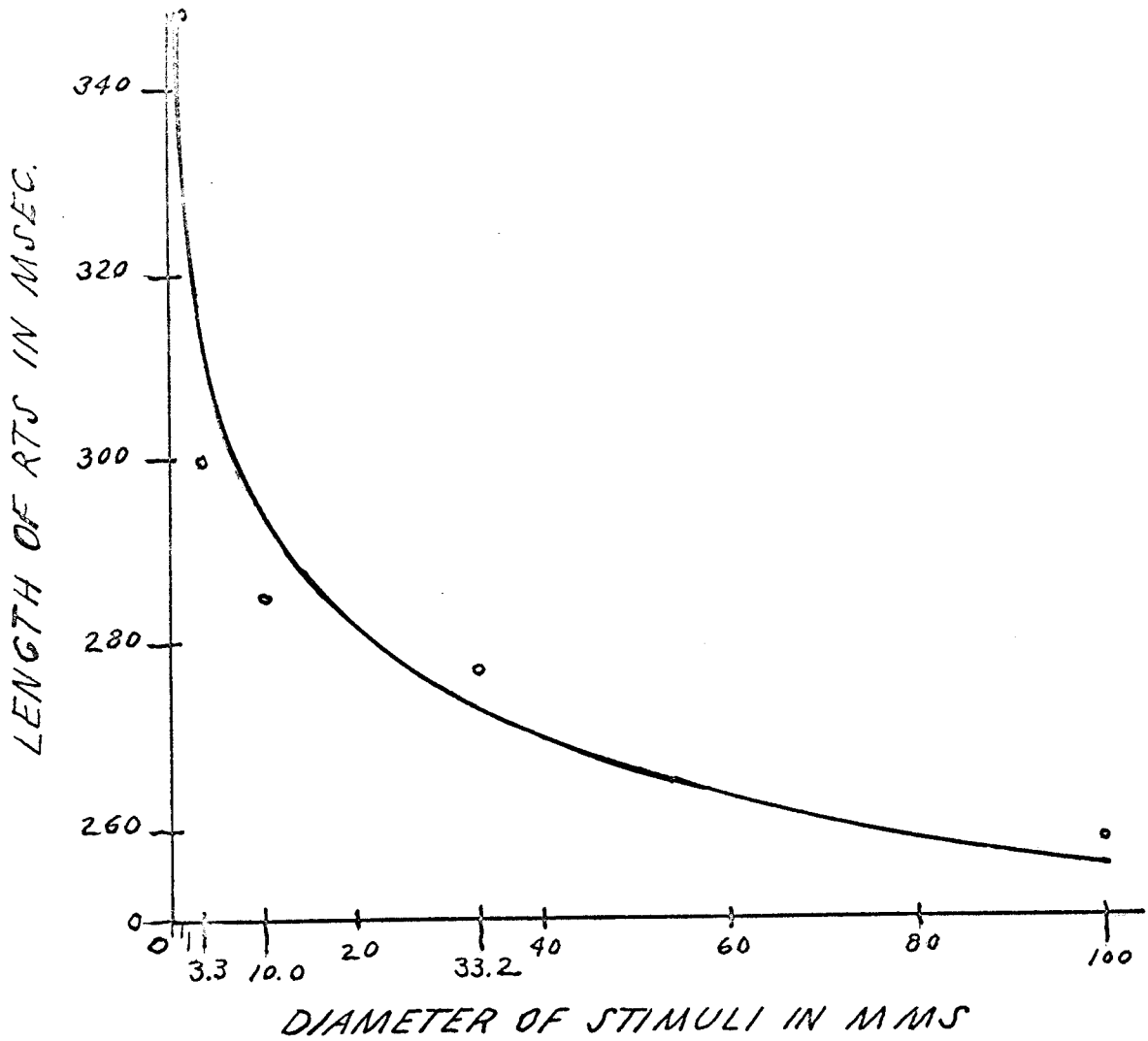
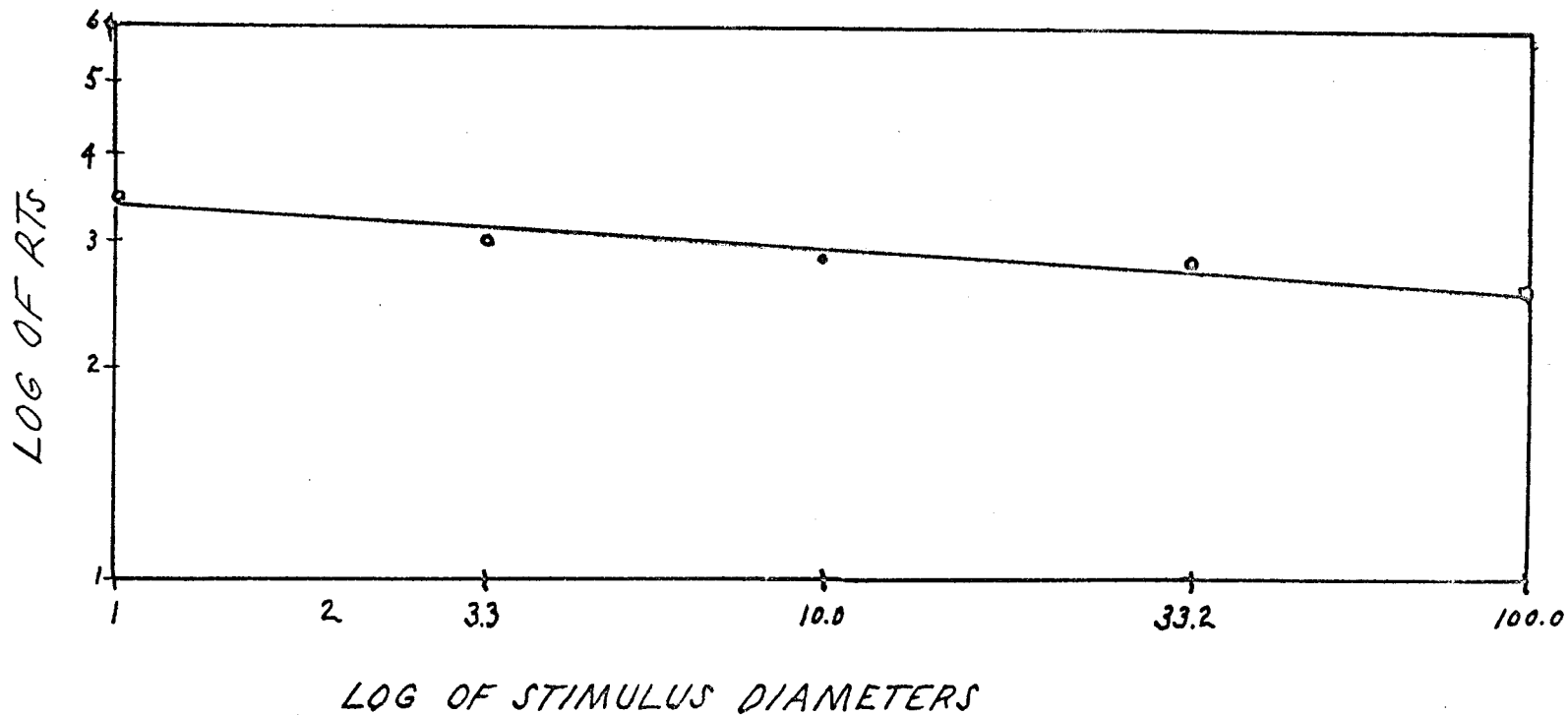Fig. 2. Reaction times obtained for different stimulus sizes.

Fig. 3. Reaction times obtained for different sizes of stimuli. Reaction times and the diameters of the stimuli are both represented in log values.

Table 5

Means, Mean Differences, Standard Errors,

and $\underline{t}$ ratios for Binocular, Dominant, and

Nondominant Conditions of Eyedness

Conditions of eyedness	M	D_M	SEs	$\underline{t}$
Binocular	293.55			
		7.40	13.06	.566
Dominant	300.95			
		2.65	13.30	.199
Nondominant	303.60			
		9.05	13.80	.656
Binocular	293.55			

Chapter IV

Discussion

The results from the first part of the experiment concur with the results from previous experiments in which the area of the stimulus was varied, and those in which the intensity of the stimulus was varied. RTs decrease as the area or the intensity of the stimulus is increased such that the decrease in RT is greater as the area or intensity of the stimulus is increased gradually at the lowest end of the scale. In the middle range of the area or intensity scales, decreases in RT become smaller. Teichner (1954) found that such relationships could be expressed in terms of exponential, hyperbolic, and parabolic functions. The data from the present study seem to fit a hyperbolic function.

RT is thus seen to be a function of the size of the stimulus--RT = $\underline{f}(\underline{A})$, when the effects of intensity ($\underline{I}$) and duration ($\underline{T}$) are held constant. The fact that the results from this RT experiment agree with those from experiments in which the facilitation of the optic nerve discharge in animals was thought to be due to retinal summation (Adrian & Matthews, 1927a, 1927b, 1928; Granit, 1933, 1947; Hecht, 1935; Bartley, 1935) suggests that the decreased RT in human $\underline{S}$s as a result of increased stimulus size is also due to retinal summation.

The present experimenter also attempted to relate area and intensity of the stimulus to the strength of the reaction potential using an adaptaion of Ricco's ($\underline{A} \times \underline{I} = \underline{K}$) and Piper's ($\sqrt{\underline{A}} \times \underline{I} = \underline{K}$) laws. Since intensity in this study was constant, the following formula was used in an attempt to find that constant:

$$\frac{RT}{A \text{ (or } \sqrt{A})} = I$$

where RT = reaction time or strength of reaction potential,
   A = area of the stimulus, proportional to the stimulated
       area of the retina, and
   I = the intensity of the stimulus.

The diameter, the square root of the diameter, the radius, the square root of the radius, and $A^{.3}$ (as Piéron suggests) were also used in the denominator. In all cases no constant was found. This failure is not surprising, however, since both Ricco's and Piper's laws have been found to apply only when the stimulus is at threshold intensity. This failure to find a constant would also support this writer's contention that Adrian and Matthews' formulation for the "total quantity of light"--$I \times A \times T = K$--should be understood as a schematic rather than as a mathematical expression of this relationship.

In comparing the present data with Froeberg's (1907), it is interesting to note that a much wider range of RTs for similar differences in stimuli was obtained in this study than in his. For example, the difference in RTs which he obtained from his 48 mm square and his 3 mm square (a difference of more than one log unit) was 12.5 msec. The differences which were obtained in this experiment for a one log unit difference in the diameter of the stimuli are shown in Table 6. The total range of RTs obtained here was 88.5 msec., while the total range of Froeberg's RTs was only 12.5 msec. Of course the range of stimuli in the present experiment was wider as well, but over a range of stimulus differences comparable to Froeberg's entire range, 3.3 - 33.2 mm, the difference in average RTs was approximately 12 msec. greater than that found by Froeberg. One possible explanation for these greater differences in RTs may be that generally the stimuli used in the present

Table 6

Differences in RTs for One Log Unit Difference

in the Diameter of the Stimulus

	Differences in Diameter of Stimulus		
	1 - 10 mm	3.3 - 33 mm	10 - 100 mm
Differences in RTS	63.0 msec	24.5 msec	25.5 msec

study were smaller than stimuli used in Froeber's study. It has been shown that RT decreases faster with smaller stimuli than with larger stimuli, so it might have been the differences in the absolute sizes of the stimuli which produced the greater reductions in RT found in the present study.

A word might be in order about the extraordinarily long RTs which were obtained in this experiment. It is generally believed that typical RTs for visual stimuli under normal conditions are about 180 msec. The shortest average RT in this study was about 260 msec, a difference of 80 msec. The length of these RTs may have been due to the fact that the luminosity of the stimulus was not greater than that of the experimental room. In fact the stimulus was not as bright as the illumination in the room. Previous studies (Hovland, 1936; Steinman, 1944) have shown that RT is a function of the difference between the stimulus and the field--the shorter RTs being associated with the greater differences. In this experiment, then, it appears that the length of RTs may well have been due to the lack of difference between the stimulus and field. However, this condition was constant throughout the experiment

and so, probably, did not contaminate the results.

The failure of the present study to find any significant differences between RTs resulting from different conditions of eyedness was not altogether unexpected in view of Ferree and Rand's comment (1927) that their S's speed of vision was as great with his right eye as with both eyes. Actually, in a preliminary study the present experimenter also was unable to find differences similar to those reported by Poffenberger (1912). In view of this, one might really wonder how Poffenberger obtained his results. On the basis of the present findings, then, there seems to be no evidence for summation in the optic tract above the retinal level.

Further, there were notable improvements which could have been made in the conduct of the present study. First, the duration of the stimulus should probably have been controlled, even though the exposure time was never below the critical duration so that it might effect the RT. Secondly, it would have been well to have used more variables in the first part of the experiment in order to have obtained a more reliable curve. Third, the illumination of the field around the stimulus should have been less intense so that more typical RTs could have been obtained. Lastly, Ss should have been more thoroughly practiced to reduce the variability in RTs. But even with these shortcomings, it was felt that the present study was interesting, and that the first part of it offered promise for further investigation.

RT technique could probably be applied in the clinical area. There is some evidence that RT differences are associated with various psychopathological states. If these differences can be shown to be consistent and discriminating, then RT testing could become a useful diagnostic indicator. Some

investigators have found that anxious persons obtained significantly shorter RTs than non-anxious groups. However, the evidence is not conclusive. Wenar (1954), for example, found that both anxiety and an increase in the intensity of the stimulus were effective in reducing RTs. However, there was no significant change in the difference between anxious and non-anxious groups as a function of the difference in stimulus intensity. Castenda (1956), on the contrary, found that there was significant interaction between anxiety and the speed of reaction to an auditory stimulus. His anxious group reacted slower to a weak stimulus than the non-anxious group, and faster to the strong stimulus. Palermo (1961) found that anxiety had no effect on the length of RT. Walker and Nicolay[1] found a negative relationship between scores on the Personal Inadequacy scale of their Personal Reaction Schedule and RT, indicating that persons who felt themselves to be inadequate tended to react faster. In general, however, it seems that no consistent relationship between anxiety and RT has as yet been demonstrated.

Comparisons between the RTs of schizophrenics and other groups have yielded more positive results. Tizard and Venables (1956) compared the RTs to light of 25 schizophrenics and 10 mental defectives and 10 normals, and found that there were large, significant differences between schizophrenics and the other two groups. Schizophrenics were 300 to 500 msec. slower than both mental defectives and normals. Venables and Tizard (1956) also found that schizophrenics react irregularly to an increase in the intensity of the stimulus. Whereas the RTs of normals typically decrease with an increase in stimulus intensity, schizophrenic RTs decreased, increased, and decreased again,

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1. Walker, R. E., & Nicolay, R. C. A reexamination of anxiety: the Walker-Nicolay Personal Reaction Schedule. Study in preparation. Loyola University.

as the intensity of the stimulus was increased. The investigators could offer
no explanation for this finding. King (1962) obtained contrary results. He
found that both the length and variability of schizophrenic RTs were reduced
by increasing the intensity of an auditory stimulus. However, the RTs pro-
duced by schizophrenics, over the range of stimuli, averaged about 400 msec.
longer than RTs from normals. Thus, consistent, significant, and useful dif-
ferences have been found between the RTs of schizophrenics and other groups.
Further RT study in this area might prove extremely useful.

One form of investigation suggested by the results of the present
study would involve comparing the latencies of schizophrenics and normals at
peripheral and central afferent, and central-peripheral efferent levels of
nervous conduction. The time differences between the onset of stimulus light,
the a deflection, the blocking of the alpha rhythm, and the RT might be
measured. The size of the stimulus should be varied in order to discover the
differences between normals and schizophrenics in the time required for
retinal summation. Further, Cruikshank (1937) has found that the latency of
blocking of the alpha rhythm is dependent on the intensity and duration of the
stimulus, and Bartley (1935) discovered that the latency of electrical dis-
charge in the cortex was related to the size of the stimulus. It would seem
possible, then, to find time differences between the a deflection in the
retina and the latency of blocking of the alpha rhythm with different stimulus
sizes. The time between the onset of stimulus and the a deflection would
seem to measure peripheral afferent conduction, and the time between the a
deflection and the blocking of the alpha rhythm would relate to central affer-
ent conduction. These differences might reveal interesting contrasts in

afferent conduction between schizophrenics and normals. Finally, time differences between alpha rhythm blocking and RT should show differences in central-peripheral efferent conduction for normals and schizophrenics. Comparison of time differences observed at these points between the onset of stimulus and the RT may help explain or localize the tremendous lag in schizophrenic RT, and possibly even offer some new insights into schizophrenic process. But an investigation such as this must be reserved for a later time.

Chapter V

Summary

Previous investigation has shown that the size of the stimulus has an effect on the latency of the retinal _a_ deflection, and the firing of the optic nerve in laboratory preparations, and also on the length of RT in man. The relationship between these time lags and the "total quantity of light" with its components of intensity, area and duration was discussed theoretically. Time lag due to differences in stimulus size was thought to be due to spatial summation in the retina.

RTs obtained from college males with stimuli of different sizes showed, as predicted, that RT decreases as the diameter of the stimulus increases. The relation between stimulus size and RT was found to be hyperbolic. Binocular vision did not facilitate a decrease in RT over monocular vision.

The effect of stimulus size on RT in this study was thought to be due to retinal summation. The present study found no evidence for spatial summation at higher levels in the visual system. An attempt to verify Piper's and Ricco's laws, as well as Piéron's adaptation of Piper's law, at supraliminal levels of stimulus intensity failed. Some possible applications of RT study to clinical diagnosis were discussed, and it was suggested that a study might be undertaken to investigate latency differences for peripheral and central afferent, and central-peripheral efferent conduction in schizophrenics and normals.

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Approval Sheet

This thesis submitted by Rev. Ralph F. Dunn, C.S.C. has been read and approved by three members of the Department of Psychology.

The final copies have been examined by the director of the thesis, and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Arts.

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