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Oscillation of Attention

A Study of Retinal Rivalry

Historical Introduction—

IT is a commonplace experience that one cannot direct one's attention to any problem for any length of time without being compelled to drop from a high level of efficiency to a lower, or to let the mind wander from one subject to another. When we consider the universality of this experience it is not surprising that this phenomenon should have interested psychologists at a very early date.

The earliest systematic study of the subject was undertaken by Urbantschitsh (1875), although reference to the phenomenon was first made by Hume (1739) in philosophical literature.

It is a characteristic of the phenomenon that while the stimuli remain (approximately) constant, the response changes. In reviewing a series of experiments performed in his laboratory Wundt (1903)[1] concludes that attention is discontinuous from force of circumstances and intermittent by its very nature.

The phenomenon has been investigated in many different ways. They may be classified as follows :—

(1) The variation of performance in supraliminal tasks, e.g. simple arithmetical calculation.
(2) The rhythmical oscillation in awareness of liminal sensory stimuli ; visual, auditory, tactual etc.
(3) The alternations of perspective seen with reversible figures.
(4) The alternating fields in binocular rivalry.
(5) Fluctuations in memory images and after images.

In supraliminal tasks the practice is to construct curves of mental output (work curves) by plotting amounts of mental work done in successive equal intervals of time (usually 5 seconds). Such curves are never smooth. The main shape of these curves is hyperbolic. There is a sharp initial fall, after which the curves tend to become more and more horizontal, but they tend to swing more widely.

The pattern of these curves have been studied in some detail by Dr. J. C. Flugel[2] and by Dr. S. J. F. Philpott.[3]

Flugel was interested in the amplitude of work curves. The amplitude of a wave is the vertical distance between the highest and lowest points, in crests and troughs respectively. He found that people vary in respect of their amplitudes, some tending to swing widely whatever they were doing, and others much less. In other words, he discovered a general factor "o", corresponding to Spearman's " g " but in quite another field.

Philpott concentrated on periodicity, inquiring just where maximum and minimum points (troughs and crests) appeared and how far apart they were on the time scale. He discovered that the dominant waves of the curves were geometric, that is to say successive pulses got longer and longer as time went on, troughs and crests occurring at times that were in geometric progression.

Owing to the comparative ease with which oscillation in the awareness of liminal sensory stimuli might be studied, much work has been undertaken in this field. The results of these experiments are interesting, both in themselves and because of the light they throw on the general problem of oscillation. The stimuli are so weak or so little different from their surroundings that the slightest lapse of attention will mean their complete disappearance from awareness. Visual, auditory and cutaneous stimuli have been employed—light and colour, tone and noise, mechanical pressure and induction current. It is not necessary to go into fuller detail as a comprehensive review has already been given by Guilford (1927).[4]

When we turn to the next field of inquiry we notice the rhythmic alternation showing itself when, under any circumstance, two nearly equal stimuli are applied to the same sense organ.

Helmholtz (1867)[5] studied the rivalry present when the two eyes are stimulated with discrepant stimuli. He concluded that the change of field is due to a change of attention. He maintained that rivalry does not depend on organic structure or condition of the nervous system, but on mental condition—" Attention is ever seeking something new."

Breese (1899)[6] was interested in the same phenomenon. The two main problems he studied were :—

(*a*) the rate of rivalry, and

(*b*) the condition of predominance.

When parallel changes were made in the two fields he found that conditions which make for efficient vision, favour rapid fluctuation. With regard to the conditions of predominance, he found that the percentage of time devoted to one of the monocular fields was increased by strengthening it objectively by light-intensity, contour, or movement, and subjectively by favouring that aspect.

In the field of reversible perspective, Lange (1888)[7] showed that if a prism was drawn in ambiguous perspective so that it might be interpreted to be either concave or convex, it would be found that two interpretations would succeed each other at regular intervals. He mentions that the rate of fluctuation is not different, for the same individual, from that for minimal stimuli.

Some attempts at studying the fluctuations in after-images and memory images of auditory impression have been made, but they need not be reported here.

Turning to the theories of fluctuation, we find they fall into three distinct classes :—

(1) Fluctuations are regarded as due to peripheral factors, e.g. fatigue of the muscular organ or adaptation.

(2) They are supposed to be the expression in some way of the physiological rhythms of circulation or respiration.

(3) They are considered to be the manifestations of a rhythmic activity of the mind—oscillation of attention.

A discussion of these theories cannot be undertaken here. Taking all the available evidence into consideration, one might conclude that there is a strong presumption in favour of the view that the phenomenon of oscillation is the manifestation of the rhythmic activity of the mind, but the proof is difficult. The situation is best summed up in the words of Myres[8] :

"When we call to mind that similar fluctuations occur in visual after images, in memory images, in retinal rivalry, and in volitional tension, we may feel disposed to believe that they are each the expression of the oscillatory character of psychical processes in general."

Experimental Procedure

The present study is concerned with the oscillation of percepts when two discrepant stimuli are presented to the retinae separately but simultaneously with the aid of a Brewster Stereoscope. The common use of a stereoscope is to combine two similar pictures to yield a clearer three dimensional view. But in our experiment the contrast between the two stimuli were exaggerated to such an extent that their combination was obstructed. Retinal rivalry was the result; the subject being, as it were, compelled to pay attention to one percept at one time, and then to the other in quick succession.

Two types of apparatus were set up, one to be used with reflected light and the other with transmitted light; but it will suffice to describe one of them.

The Apparatus: A box 14″ long and 8.5″ wide and 3″ high was constructed. An opening 5″ × 2.5″ was made on one 8.5″ × 3″ end to permit a Richard Verascope to be attached to it. The box carried inside it two 15 watt Mazada lamps, which ran on metal slides: there was sufficient range to make suitable adjustments for balancing intensities. A wooden partition separated the lamps from each other so that illumination from one source might not spread to the other. The box had a sliding lid over it. The lamps were in series with two resistances, thus providing a means of varying the intensities of the stimuli independently.

Coloured gelatine filters, *green* and *red*, of approximately equal brightness were placed immediately behind the lenses, and a darkened slide carrying two transparent squares were inserted through a slot in the side of the Verascope. The transparent squares, 2 cm. in size, were crossed by five black strips of paper forming thick diagonal lines. Approximately 65% of the area of the square alone permitted transmission of light. The rest of the slide was rendered impervious to light. A ground-glass behind the slide and just out of focus in respect of the viewing lenses gave the necessary diffused and even illumination. It was necessary to help "optimum convergence" by making adjustments for varying interocular distances of subjects.

The room was made sound proof, and to stabilise lighting was illuminated by a 200 watt lamp.

The duration of each of the alternating percepts was recorded. The recording was made on continuous roll paper by depressing one or other of two reaction keys, which were connected with the terminals of a Palmer Kymograph, the centre pen of which was in circuit with a time marker beating 1/10 seconds. The kymograph was driven by a small electric motor.

Sixteen sets of experiments were planned. For convenience they may be grouped in three classes :—

(1) The two stimuli, the " red " and the " green ", were equally balanced, and the subject was required to adopt a passive attitude towards them.

(2) Each of the stimuli was strengthened in turn by increasing the light intensity.

(3) The stimuli were again balanced, but the subject was asked to exercise a preference for each stimuli in two separate experiments.

Each experiment was duplicated by interchanging the stimuli to equalise ocular dominance. Once an experiment was set there was no further interference with the stimuli.

172 curves were obtained each containing 400 plotting points in a time scale of 200 seconds. Curves were summed on the basis of experiments and of subjects to obtain strong curves. 27 curves were finally prepared and examined.

Over 40 subjects took part in the experiment, but the records which were statistically examined came from 22 subjects.

Aims of the study

(1) To detect any resemblances between the curves of the experiment and work curves, and in particular to discover—

(*a*) whether the curves of retinal rivalry conform to the Philpott System of periodicity.

(*b*) whether periodicity, if it were present, could be upset by altering the level of stimulation either by subjective or by objective means.

(2) To study the rate of oscillation i.e. the number of times a subject moves from one percept to another in a given interval of time ; and to examine the nature and limits of the variability of the rate of oscillation.

(3) To compute conventional mean periods ; to examine how far they can be said to be functions of stimulus intensity ; and to understand the meaning of the mean—period curves.

Examination of the Data

(A) PERIODICITY

A concise statement of the Philpott Theory is not readily available. The main lines of his theory are, therefore, set out below.

(1) Curves of mental output dip down to a number of minimum values, corresponding to a fall of attention at those points on the time scale. These trough points, in the main, appear rhythmically at times which are in geometric sequence. On a given occasion it may be that trough points appear on a line scaled in -econds at 37½, 49, 63½, 82½, 108, 140, 183 and so on. If that be the case, the geometric ratio of the curve is 1.30. (Other sequences are possible with different geometric ratios.) If the X axis is scaled in terms of logarithms these trough points will fall at equal intervals, because logarithms of numbers in geometric progression are themselves in arithmetic progression.

(2) In the example given above the geometric ratio of the curve is 1.30. Its logarithm is 0.1152 which is 72 x 0.0016. An examination of empirical curves show that each elementary ratio expressed in logarithms was always some integral multiple of 0.0016. Philpott, therefore, posits a system of integral log. waves.

(3) Where do these waves start on the time line ? By mathematical calculation Philpott argues that they start at a common trough point very near zero at T_o, where $T_o = 4.076 \times 10^{-23}$ seconds. Having determined a common starting point, Philpott constructs a table of calculated trough sequences for wave-lengths within the range of those generally met with in practice.

(4) Oscillation curves are often complicated. A given curve may contain not one but several log. waves e.g. 2, 3 and 5 in the integral system. The curve will tend to trough at points corresponding

to each of these waves, and deeper troughs will appear where these waves come together according to the L.C.M. law in arithmetic.

(5) Philpott built a Grand Total Curve by summing over 700 experimental records. This curve has certain marked characteristics with the deepening of troughs at 38, 64, 105, 155 seconds and high output at 60, 120 and 240 seconds. There are some other characteristics as well.

Subsequent research has shown that grand total curves of good weight come to resemble each other. For example Denton[9] took the grand total curves of Akil and Rath (each N = 160) and cutting their length to that of her own experiment obtained the following correlations

$$r_{ar} = 0.48,\ r_{ad} = 0.47 \text{ and } r_{rd} = 0.32 \quad (\sigma_r = 0.14)$$

Akil's and Rath's curves were their own individual records, while Denton's curve was obtained from a group of women students.

Resemblances between grand total curves have also been demonstrated by using the Analysis of Variance and Shape Numbers.

Curves of the Experiment. To what extent do the curves of the present experiment conform to the Philpott System ?

The curves are not of grand total weight. They were examined for evidence of periodicity by plotting output against the log. of time, because if the trough sequence were in geometric progression, the troughs would appear equally spaced on log. paper.

There was surprising conformity to the Philpott System. Not only were Geometric Ratios found in the curves, but the troughs were in phase. That is to say that the troughs appeared at points predicted by theory. Only a very few cases defied analysis. It is not possible to reproduce some 27 odd curves. For purposes of illustration two curves are presented here. In order that the evidence might be seen at a glance, a summary of the results are given in tabular form.

Tables I A and B give the geometric ratios, and Tables II A and B give the corresponding log. wave lengths according to the Philpott System.

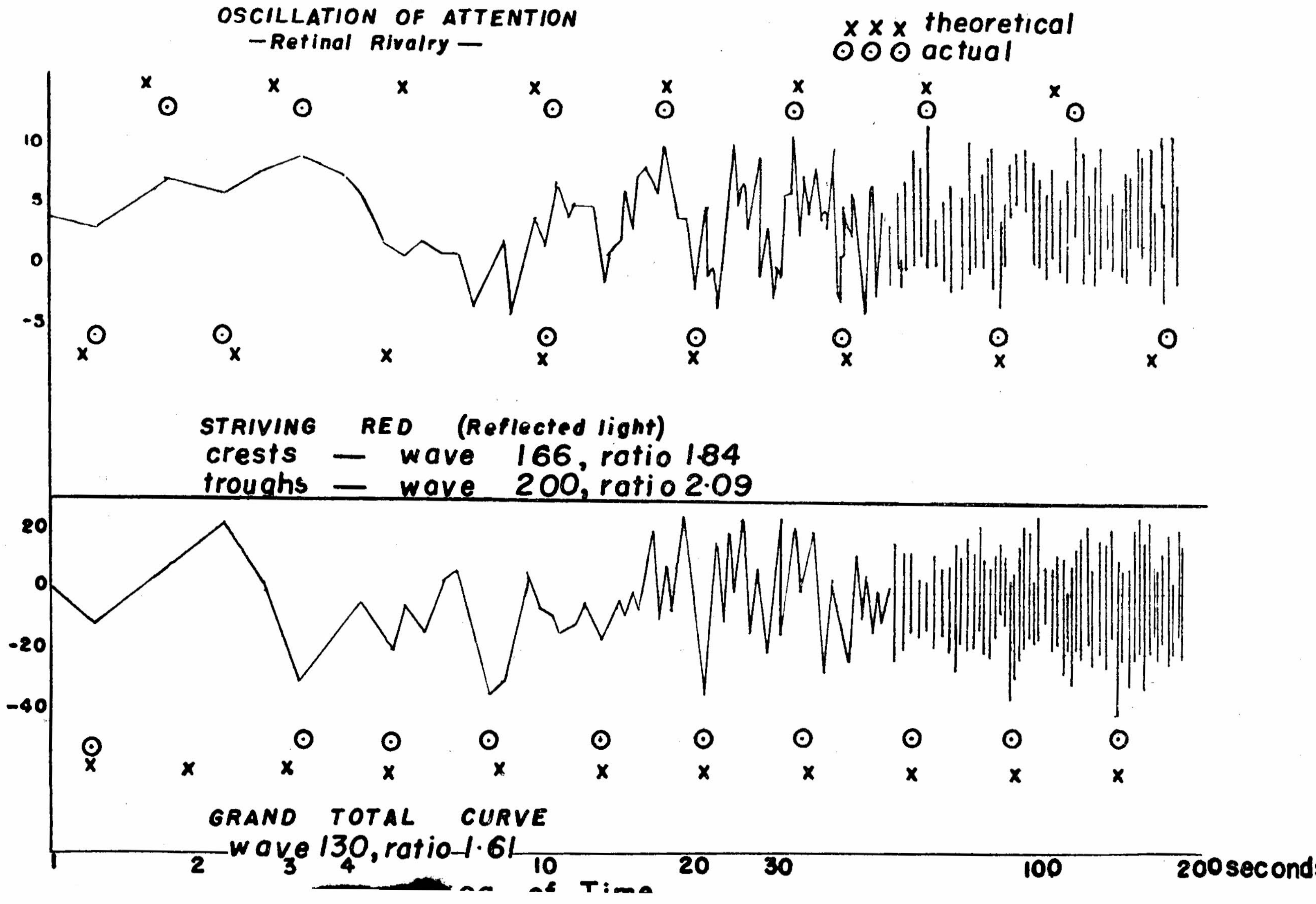

OSCILLATION OF ATTENTION
—Retinal Rivalry—
x x x theoretical
⊙ ⊙ ⊙ actual
10
5
0
-5
STRIVING RED (Reflected light)
crests — wave 166, ratio 1·84
troughs — wave 200, ratio 2·09
20
0
-20
-40
GRAND TOTAL CURVE
wave 130, ratio 1·61
1
2
3
4
10
20
30
100
200 seconds

TABLE I A

BY EXPERIMENTS — GEOMETRIC RATIOS

	Transmitted Light		Reflected Light	Transmitted Light	
Levels	Intensities	Striving	Striving	Total	
Emphasis on Red	(*a*) 2.42 (*b*) 2.61	2.53	(1) 1.59 (2) (*a*) 2.09 (*b*) 1.84	Red all levels	1.61
Free Series	unidentified	unidentified	(1) 2.42 (2) 1.87	Green all levels	1.57
Emphasis on Green	2.61	unidentified	(1) 1.71[2] (2) 2.04	Total for Expp.	1.80
Total	1.63	3.35	1.50	Total for Research	1.61

TABLE I B

BY SUBJECTS — GEOMETRIC RATIOS

Ejw.	Par.	Alc.	Laf.	Mag.	Gwn.	Gal.	McK.	Dux.	Eys.
(*a*) 1.53 (*b*) 1.60	1.70	1.49	2.87	2.15	1.82	2.15	?	1.49[2]	(*a*) 1.50[2] (*b*) 1.82

Note : In Tables I A and B when ratios are given as $\frac{(a)}{(b)}$ we imply that two dominant waves were found in the same curve ; while numbers (1) and (2) are used to distinguish two different curves.

TABLE II A

BY EXPERIMENTS — LOG. WAVE LENGTHS

	Transmitted Light		Reflected Light	Transmitted Light	
Levels	Intensities	Striving	Striving	Total	
Emphasis on Red	(*a*) 120 x 2 (*b*) 130 x 2	126 x 2	(1) (126) (2) (*a*) 200 (*b*) 166	Red all levels	(130)
Free	unidentified	unidentified	(1) 120 (2) 170	Green all levels	(122)
Emphasis on Green	130 x 2	unidentified	(1) 146 x 2 (2) 194	Total for Expp.	160
Total	(132)	(164 x 2)	(110)	Total for Research	130

TABLE II B

BY SUBJECTS — LOG. WAVE LENGTHS

Ejw.	Par.	Alc.	Laf.	Mag.	Gwn.	Gal.	McK.	Dux.	Eys.
(*a*) 116	144	108	143 x 2	104 x 2	162	104 x 2	?	108 x 2	(*a*) 110 x 2
(*b*) 128									(*b*) 162

NOTE : In Tables II A and B where trough sequences are not in phase, wave-lengths are enclosed in brackets.

A few further remarks may be made with regard to the data presented in the above Tables.

(1) A number of log. waves have been identified and a good proportion of them are in phase.

(2) Log. waves have sometimes been identified on the basis of troughs and at other times on the basis of crests.

(3) Occasionally two different waves have been identified in the same curve.

(4) Sometimes the same waves have been found (*a*) in curves obtained at two levels of stimulation, or (*b*) in curves obtained from two different subjects. e.g. (*a*) waves 120, 126, and 130.
(*b*) waves 104, 108, and 162.

(5) In nine out of ten 'subject' curves a dominant log. wave (true in phase) has been identified. It seems as though most individuals have cut through some of the same waves at each level of stimulation.

(6) It is surprising that log. wave 130 should have been found so frequently. It occurs in four curves (including the Total Curve for the Research), while three times it is in phase. The chances of this wave appearing are not heavily weighted in its favour. Comparing it with log. wave 120, which in itself has only a reasonable chance of appearing, proportionally speaking the chances of finding log. wave 130 are 68 as against 1,000 chances of finding log. wave 120. There are other multiples of log. wave 13, namely log. waves 143 and 104 ; the latter appearing twice.

Should log. wave 130 or at least log. wave 13 be regarded as specfiic to retinal rivalry ? Specificity in that sense has not been found in other curves of oscillation, and that must therefore, be left an open question.

Summarising. The evidence points to geometric periodicity in curves of retinal rivalry. Periodicity is not upset by altering the level of stimulation by subjective or objective means. Nor does it matter if stimulation is effected by reflected or transmitted light.

There is a remarkable agreement between the curves of this research and those theoretically postulated, in the matter of trough sequences. Where the evidence on this point is weak (e.g. in total curves), there is general conformity to the theoretical pattern.

Arithmetic Waves. To carry further conviction the method of Periodogram Analysis or Serial Correlation should be used in the search for periodicity. The Periodogram Method consists essentially in finding the amplitude of a large number of trial periods. The trial periods which yield the greatest amplitudes will yield approximations to the most probable periodicities. But to search for geometric periods by this method the curves of the research are not long enough.

The curves were, however, examined for possible arithmetic periods by the method of Serial Correlation. In this method two copies of a series are made and the two sets of figures are correlated for varying degrees of shift of one copy relative to the other. If there is a true period when a shift corresponding to exactly one period is made $r = 1.00$. If the shifts are of half-periods then $r = -1.00$. When the r values are plotted against a scale of possible wave-lengths the curve obtained shows crests at points of high positive correlation and troughs at points of high negative correlation. The crests are indicative of true periods, and analogously the troughs are indicative of half periods.

In 20 curves which were examined there was clear evidence of—

a period of 10 seconds in one curve,
a period of 12 seconds in 4 curves,
a period of 15 seconds in 12 curves,
a period of 20 seconds in 2 curves,
a period of 30 seconds in one curve.

What do we make of these findings ?

The serial correlations clearly indicate that arithmetic waves too cut through the curves with a clear accent on the 15 second period. This rhythm cannot be explained away as the manifestation of an imposed rhythm, arising from experimental conditions.

In complicated curves such as we have it is quite possible for several patterns to intermingle. If we admit that the dominant pattern is one of geometric periodicity, it is no contradiction to observe that arithmetic cycles are present as well.

(B) Rate of Oscillation

By the Rate of Oscillation in a Rivalry Experiment we mean the number of times a subject moves from one percept to another in a given period of time.

In the present experiment there is a wide range of individual differences. The rate varies from subject to subject, but each subject tends to be consistent from one experimental situation to another, as may be seen from the Table below—

TABLE III

RATE OF OSCILLATION PER 100 SECONDS

Experiments	1	2	3	4	5	Total	Average
Subjects							
Ejw.	46	41	49	47	52	235	47.0
Par.	62	64	53	66	75	320	64.0
Alc.	95	80	86	104	83	448	89.6
Laf.	30	29	27	29	24	139	27.8
Mag.	27	34	24	20	18	123	24.6
Gwn.	87	93	90	78	91	439	87.8
Gal.	97	96	89	89	84	455	91.0
McK.	90	85	94	78	84	431	86.2
Dux	78	75	81	71	63	368	73.6
Eys.	73	68	63	62	65	331	66.2
Total	685	665	656	644	639	3289	
Average	68.5	66.5	65.6	64.4	63.9		65.78

Note : Experiment 1 is the Free Series.
Experiments 2 and 3 stressing Red and Green respectively by increasing intensities.
Experiments 4 and 5 stressing Red and Green respectively by exercising preference.

Similar findings are reported from a related field, namely the Perception of Ambiguous Figures, such as the Rubin's Vase, the Neckar Cube and the Truncated Pyramid. The rate of oscillation is slower in the Perception of Ambiguous Figures than in Retinal Rivalry, but consistent from one testing to another.

Denton[10] used 5 different tests of Ambiguous Figures and obtained reliability coefficients between two sittings of the order of 0.86, 0.73, 0.94, 0.76, and 0.93 for five tests, and an average inter-correlation of 0.53 for the first sitting and 0.68 for the second sitting. Using the method of Factor Analysis she established a general factor of oscillation. Whether that same factor spreads over the oscillations of Retinal Rivalry is yet to be discovered. Again, what is its relationship to Flugel's factor of oscillation in Work Curves ? That question too is yet unanswered.

Meanwhile, the reliability of the measurement of oscillations has stimulated the interest of workers in the field of personality testing as a possible tool in their investigations. Much earlier in the day Mc Dougall had made a penetrating observation. His experiments had suggested to him the idea that the rate of oscillation in the perception of ambiguous figures might be connected with the 'speed of nervous action', and he concluded that a rapid rate of oscillation was characteristic of introverts, while a low rate was characteristic of extraverts. Since then confirmation of this hypothesis has come from several sources. These studies have been briefly reported by Eysenck in his *Dimensions of Personality*.

As an extension of this field, the capacity to alter the rate of oscillation either (*a*) by trying to accelerate it, or (*b*) by trying to retard it, has been studied with a view to establishing a connection between the degrees of control of oscillations and dimensions of personality. On two points further testing and elucidation are necessary :—

(*a*) whether those whose oscillation rate is higher are better able to control the rate than those who are slower, and

(*b*) whether the capacity to alter the rate is weaker in neurotics than in normals.

The experiments of the present study were not designed to answer those questions, but they may throw some light on the general problem.

Our subjects were not required to attempt to increase or decrease the rate of oscillation, but interference with the stimuli, i.e.by stressing them subjectively or objectively, produced some modification of the basal rate.

This situation gives us the opportunity of studying the limits of variability in the rate of oscillation. There is obviously a close connection between the degree of control and the limits of variability, and what might be said here about 'variability' is likely to have some bearing on the problem of 'control'.

For this section of our inquiry we examine in detail the data collected from ten subjects only. While the data is, on that account, weak for statistical purposes, it gives sufficient insight into the problem of variability. The essential data is presented in Table IV.

TABLE IV

Subjects	Ejw.	Par.	Alc.	Laf.	Mag.	Gwn.	Gal.	McK.	Dux.	Eys.
M, Average Rate of Oscillation	47	64	90	28	25	88	91	86	74	66
σ, Average Variation	3.63	7.07	8.78	2.15	5.66	5.27	4.86	5.46	5.58	3.98
$\frac{100\sigma}{M}$, Coefficient of Variability	7.72	11.04	9.76	7.68	22.64	5.99	5.34	6.35	7.54	6.03

In the Perception of Ambiguous Figures, Petrie[11] obtained correlations of the order of 0.77 and 0.83 between tests in which subjects were asked to assume a passive attitude and those in which they were required to increase the rate of oscillation. The only comparable measures in our work is the correlations between the figures in the various columns of Table III. These correlations are equally high. There is a reduction when the basal rate of oscillation is correlated with the 'average variation' in the rate, as given in Table IV. The correlation then reduces to $\rho = +0.22$.

When the basal rate is correlated with the coefficient of variability, there is a still greater change, $\rho = -0.64$.

What this finding suggests is that there is an inverse relationship between the coefficient of variability and the basal rate. As it happens the subject with the highest basal rate has the lowest coefficient of variability, while the subject with the lowest basal rate has the highest coefficient of variability. The subjects in between are less systematic. The inference we can make from these observations is that the more rapid oscillators are generally more restricted and are not easily driven from their basal rate.

As noticed earlier, our measures are not strictly comparable with the measures in which workers in the field of personality are interested. They instruct their subject to try to speed up oscillations. In our experiments the enforcement of one or other of the stimuli tends to reduce the rate of oscillation. Besides oscillation in retinal rivalry is a high tension phenomenon. The oscillations flow so rapidly that in the case of a very rapid oscillator he has almost reached the limit of his capacity. It should, however, be mentioned that by loading the rival stimuli equally and endowing them with some static quality it is possible to slow down the rate of oscillation at the limen (i.e. where 50% of the time is devoted to each percept). But there are limits. At the same time it is possible to remove weights from the rival stimuli and increase fluctuation. The stability of each percept can be so weakened that oscillations become ' unbearably ' rapid, and the percepts fuse. The ' Red ' and the ' Green ' percepts fuse and yield a ' Yellow ' percept.

One further observation might be made. In personality testing the two measures which are most frequently used are—(*a*) the rate of oscillation, when the subject is asked to assume a passive attitude, and (*b*) the rate of oscillation, where the subject is required to increase it as much as possible. We have suggested a third measure, (*c*) the amount of increase, which is the absolute difference between the two earlier measures. All these measures are parallel measures, judging by the correlation between them. If an independent measure is required it seems better to remove the dimension of speed, as we have done in calculating the coefficient of variability, by dividing the absolute difference by the basal rate. The result may be a better measure of ' control.'

(C) Conventional Mean Periods

In the search for periodicity in Section (A) we examined curves obtained by summing records collected per half second for a total duration of 200 seconds in a series of experiments conducted at several levels of stimulation. The basic assumption was that at each level of stimulation the subject was cutting through an underlying curve of attention. By adding together different records we attempted to obtain a rough approximation to the underlying curve. Although summation curves may not express the underlying curve exactly, they certainly throw up points of maximum and minimum output at the right places, and thereby provide an opportunity of studying the periodicity present in the attention curves.

We now turn to a different aspect of our study : we examine *individual* records of subjects, not summation curves.

In liminal sensory experiments Wiersman[12] and others have observed that the average length of the spells of visibility and invisibility (sometimes called mean-periods positive, and mean-periods negative) and the total-mean period, which is the sum of the previous means, are functions of the intensity of the stimulus.

Does a similar relation hold in retinal rivalry ?

In the present inquiry the ' Red ' aspect is regarded as positive, and the ' Green ' aspect as negative. The conventional mean-periods obtained are the average for ten subjects, collected per experiment in the second group of experiments (viz. with transmitted light). The data is presented in Table V.

TABLE V

Experiment	% of Red Percept	Mean-Periods in Seconds		
		Positive	Negative	Total
R_{-2}	38.5	1.44	2.78	4.22
R_{-1}	45.5	1.76	2.10	3.86
R_0	52.0	1.86	1.75	3.61
R_1	54.5	1.98	1.60	3.58
R_2	63.0	2.69	1.42	4.11

Note : In Experiment R_{-2} and R_{-1} the Green aspect is enforced by subjective and objective means respectively. In Experiment R_2 and R_1 the ' Red ' Aspect is enforced by subjective and objective means respectively. In Experiment R_0 the two aspects are balanced.

From the Table it will be observed that these mean-periods are functions of the intensity of the stimulus. That is to say that when emphasis is laid on one or other of the stimuli, altering the balance between them, the power of the persistence of that stimulus is increased, and consequently the mean-period is increased. It should be noted that when the mean-period positive is increased in this way there is a loss in the mean-period negative ; but the gain in the former is not due to an exact corresponding loss in the mean-period of the latter. If the loss were exact the Total Mean-Period would remain constant irrespective of the stimulus level. In that case the Total Mean-Periods would plot out not as a curve but as a straight line parallel to the X axis.

Guilford argues that such results as ours, where the total mean periods form a curve, are 'hard to explain on the basis of a rhythm of attention'.

If the dominant wave pattern in our curves were of an elementary sine or co-sine pattern, and at each level of stimulation a subject were cutting through a sine or co-sine curve the total mean-period would be constant at each level, as could be easily demonstrated by drawing parallel lines at different levels through a sine or co-sine curve. Then, the total mean-periods would plot out as a straight line as indicated above. But curves of retinal rivalry are complicated and do not conform to such a simple system. We have demonstrated earlier by an independent line of inquiry the presence of both geometric and arithmetic periodicity in the curves of this research.

Mean-periods are usually plotted against stimulus values. In the present case it is difficult to obtain a physical measure of the stimuli, as coloured light and contour are used for stimulation ; besides there are no measures for conative effort.

The percentage values of Table V are measures of the degrees of assimilation, and may therefore be regarded as bearing a logarithmic relation to the stimuli, so that 38.5% (or 0.385) can be regarded as equivalent to log x, where x is a stimulus value. Hence, when log x = 0.385, x = 2.4. The full range of calculated stimulus values is presented in Table VI, together with the values of the total mean-period.

TABLE VI

Experiments		R_{-2}	R_{-1}	R_0	R_1	R_2
Red Aspect, log X	=	.385	.455	.520	.545	.630
Stimulus Values, X	=	2.4	2.9	3.3	3.5	4.3
Total Mean-Period, Y	=	4.22	3.86	3.61	3.58	4.11

NOTE : log X values are really percentages. X values are corrected to one decimal place.

We are now in a position to plot mean-period curves ; positive, negative and total against stimulus values, using the data tabulated in Tables V and VI. It remains only to explain why the enforcement of a stimulus by subjective means can be regarded as being in a continuous series with objective enforcement.

Both methods of enforcement have a similar influence on the mean-periods. Correlation of the mean-periods for the objective and subjective enforcement are high : for the 'Red' aspect $r=0.956$ and for the 'Green' aspect $r=0.729$. The correlation for the subjective enforcement of the 'Red' and the 'Green' stimuli is again high, $r=0.779$. The grounds for regarding the stimuli as though they belonged to a continuous series are satisfactory.

The Total Mean-Period Curve. Can we find a simple algebraic equation to describe this curve ?

In Table VI we have only the ordinates Y_1, Y_2, Y_3...... and a set of points of the abscissa X_1, X_2, X_3...... which extend over part of the curve, no information being available regarding the rest of the curve. In attempting to fit a regression line we observe that the trend suggests a parabolic curve, defined by the equation—

$$y_1 = a + bx + cx^2$$

The constants *a*, *b* and *c* are determined by the method of least squares. The normal equations we use for this purpose are—

$$\Sigma y = Na + b\Sigma x + c\Sigma x^2$$
$$\Sigma xy = a\Sigma x + b\Sigma x^2 + c\Sigma x^3$$
$$\Sigma x^2 y = a\Sigma x^2 + b\Sigma x^3 + c\Sigma x^4$$

We thus obtain the required equation :—

$$y_1 = 10.66 - 4.125x + 0.604x^2$$

The standard error of this estimate (i.e. the standard deviation of the residuals of the data from the trend) is $S_y = 0.044$, and the coefficient of correlation based on the parabola is given by the equation $\rho^2 = 1 - \frac{S_y^2}{\sigma_y^2}$.

By computation $\rho = 0.98$.

This evidence shows that the parabola fits the data well enough. If a sufficient number of observations could be recorded for each subject, in order to reduce the errors of experimentation, it would be possible to find an equation for each individual subject. Individual differences would then be in respect of the *latus rectum* of the different parabolas obtained.

Measurement of Conation. Another suggestion which arises from this study is that it may be possible to obtain a physical measure of conative effort by building a strong enough curve for the mean-period of (say) the positive aspect. A much longer series of physical intensities should be used in constructing the curve. When the curve is built the conative effort registered in a particular ordinate—y can be placed against the curve and the corresponding x value can be read off. This x value will be in terms of a physical measure—a steady physical measure of a psychological quality which is dependent on many influences.

Mean-Period Curves. For easy reference the empirical values of the mean-periods (y) and the values estimated from the equation :—$y_1 = 10.66 - 4.125\ x + 0.604\ x^2$ are set out in Table VII. In the accompanying graph the empirical values of y are plotted, but the points are not joined up. Continuous lines join up points for the estimated values (y_1), as well as the points for the empirical values of the mean-periods positive and negative respectively—(see Table V for values).

TABLE VII

Stimulus Values, X	=	2.4	2.9	3.3	3.5	4.3
Empirical Values, Y	=	4.22	3.86	3.61	3.58	4.11
Estimated Values Y_1	=	4.24	3.78	3.63	3.62	4.09

SUMMARY

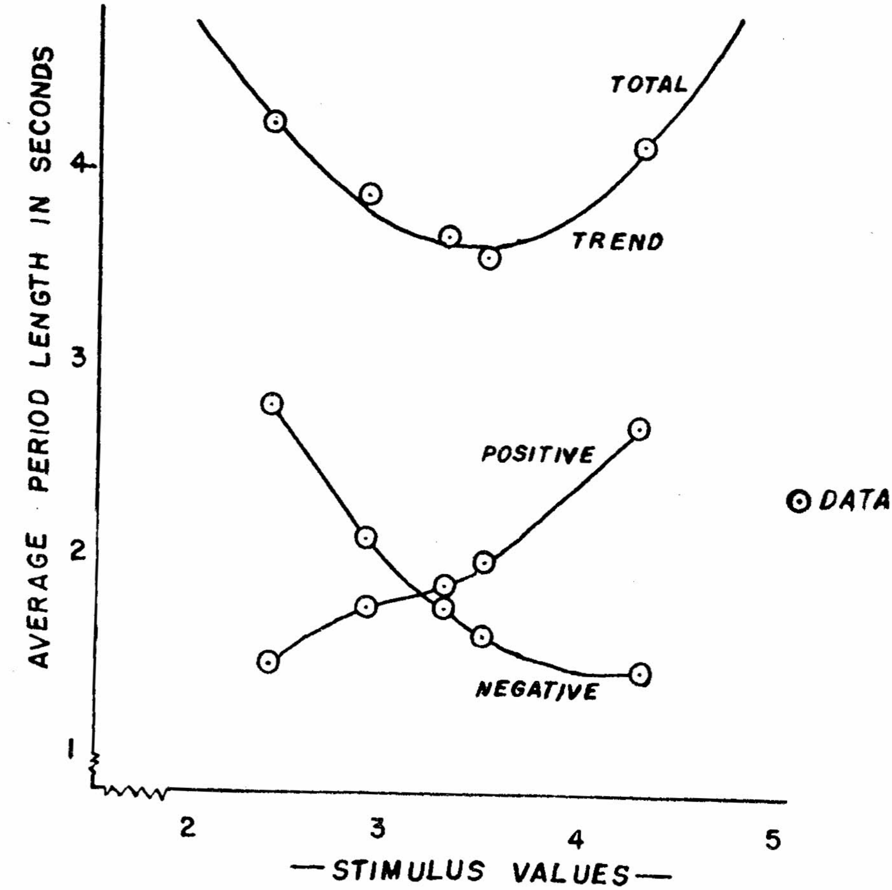
This study of the oscillation of attention is based on retinal rivalry. Stimulation is effected by presenting to the eyes simultaneously two discrepant stimuli by means of a stereoscope, both reflected light and transmitted light being used to study the process.

Experiments are performed at different levels of stimulation by varying the relative intensities of the two stimuli objectively or by requesting the subject to exercise a preference for one or other of them, when the stimuli are balanced.

When individual records are averaged per experiment and expressed in the form of conventional mean-periods (positive, negative and total) the results obtained at different levels of stimulation fall into a pattern similar to that obtained by Wiersma and others in liminal sensory experiments, where they argue that these mean periods are functions of the stimulus.

The curve of the total mean-period is found to be parabolic in shape, fully defined by the equation :—

$$y_1 = 10.66 - 4{\cdot}125x + 0.604x^2$$



MEAN-PERIOD CURVES

OSCILLATION OF ATTENTION

x x x theoretical

Retinal Rivalry

A method of obtaining a physical measure of conative effort by building strong enough individual curves for the mean-period (positive) is suggested.

Summation curves are found to be complex in character : any possible rhythm in them is not easy to explain in terms of elementary sine or co-sine patterns. They are examined for evidence of periodicity with special reference to the Philpott Theory, that in attention curves troughs should appear at geometrically increasing intervals of time. When the curves of the research are plotted against the log. of time, it is not difficult to detect geometric sequences and to identify known wave lengths.

When the material (expressed per five second interval) is examined by the method of serial correlation there is evidence of arithmetic cycles with a clear accent on the 15 second period. While, therefore, the dominant pattern might be one of geometric periodicity, arithmetic cycles are present as well. These periodicities are not upset by altering the level of stimulation.

The rate of oscillation varies from subject to subject, but each subject tends to be consistent from one experiment to another. The effect of altering the balance between the stimuli is generally to reduce the rate of oscillation. The average variation of the rate correlates slightly with the basal rate of oscillation ($\rho = +0.22$), but there is an inverse relation between the degree of control (i.e. the coefficient of variability) and the basal rate ($\rho = -0.64$). A discussion is initiated on the application of oscillation rates to measure dimensions of personality.

(This study is based on some of the data collected by the writer in a thesis on *Fluctuations of Meaning*.[13] The evidence is re-examined and fresh calculations have been made. A few changes of interpretation are the results of re-valuation).

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