The
PSYCHOLOGICAL
RECORD

MAY, 1938
Vol. II 3 No 8

FACTORS IN THE FLUCTUATION OF FIFTEEN AMBIGUOUS PHENOMENA

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THE PRINCIPIA PRESS, INC.
BLOOMINGTON, INDIANA

Price of this number, 50 cents

FACTORS IN THE FLUCTUATION OF FIFTEEN AMBIGUOUS PHENOMENA*†

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INTRODUCTION

Figures of reversible perspective are those in which the spatial relations appear now to form one pattern and again to form another pattern while the physical stimulus remains constant. "A projection becomes a hollow, a protuberance, a depression, a solid, a cavity, a near side or angle, one more remote, or vice versa."[1] The reversals may likewise exist as an interchange of figure and ground so that what once appeared as the ground is now considered figure and what formerly appeared as figure is now ground.

The older literature was confined to descriptions of the manner of reversal and proposals of theories of reversal generalizing from a few observers' fluctuations of one figure. The more recent studies are concerned with the individual rate of reversal and its possible implications, differences of rate of various figures, change in rate by altering the figure or the individual's method of viewing it, eye-movements, and the like. Careful review of the literature led us to believe in the necessity and value of a study based on repeated observations of a series of figures by a number of persons.

PROCEDURE

Fourteen figures of reversible perspective and a near-liminal visual stimulus have been used in the study. The reversible figures were selected because they were considered representative of the large number found in the literature on the subject. The following are the names of the figures and the letters used to designate them in tables and discussion. They are illustrated in Figure 1.

* Parts of this article were read under the same title at the 1935 meetings of the American Psychological Association in Ann Arbor, Michigan. The research was carried on at the University of Nebraska under the direction of Dr. J. P. Guilford to whom I am glad to acknowledge my gratitude for his continued help in developing the problem. A thesis embodying the research was submitted in partial fulfillment of requirements for the degree of Doctor of Philosophy.

† Accepted for publication by Dr. J. P. Guilford, April 9, 1938.

[1] J. E. W. Wallin, *Optical Illusions of Reversible Perspective*, Author, 1905, 1.

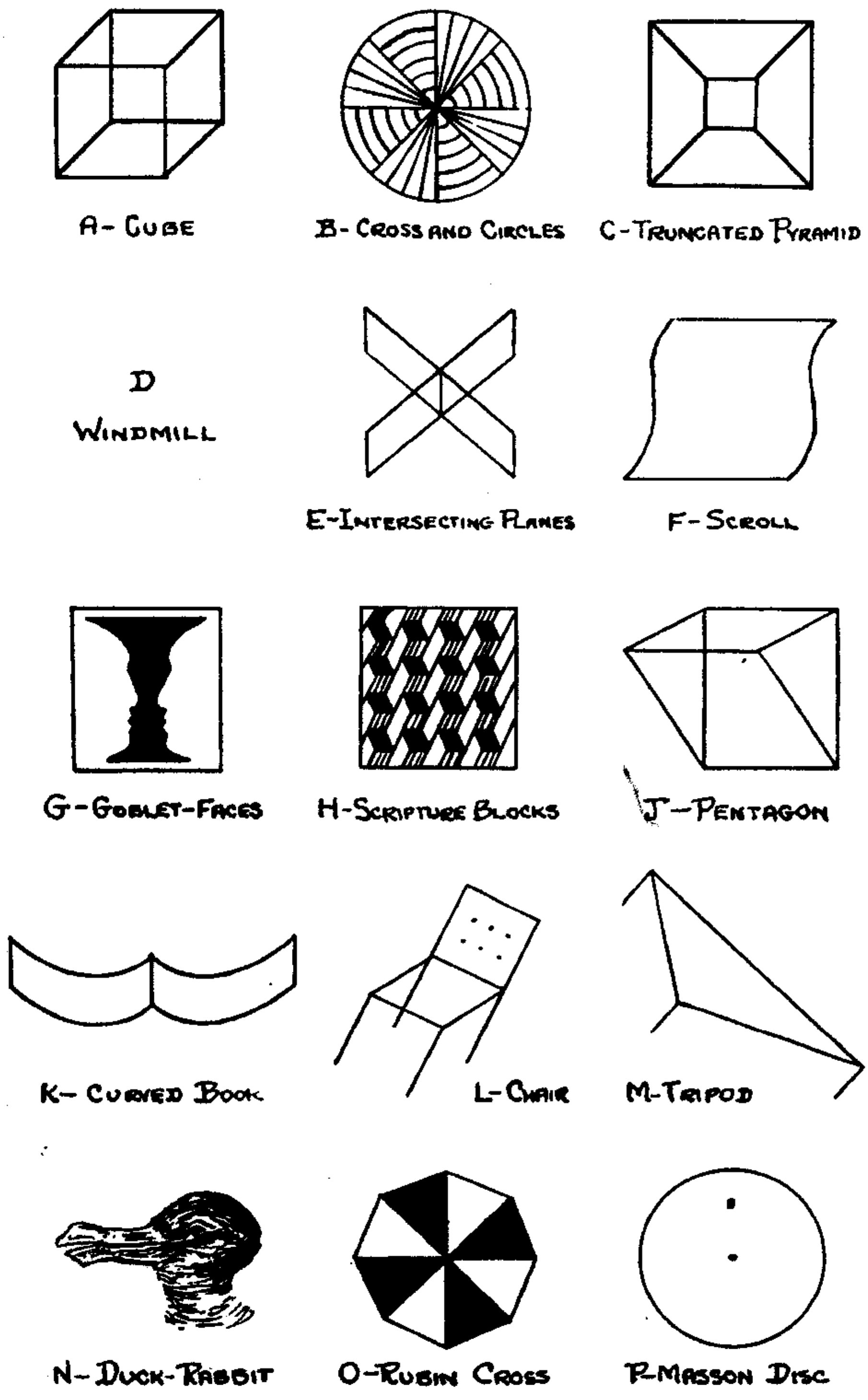

Figure 1 - Fifteen fluctuating phenomena

A—Neck
B—Rubi
C—Mach
D—Wind
E—Sanf
F—Mach
G—Rubi
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A—Necker cube
B—Rubin cross and circles
C—Mach truncated pyramid
D—Windmill model
E—Sanford intersecting planes
F—Mach curved book
G—Rubin goblet and faces (adapted)
H—Scripture blocks
J—Pentagon[2]
K—Curved book[2]
L—Chair[2]
M—Tripod[2]
N—Duck-rabbit
O—Rubin iron cross
P—Masson disc (adapted)

All figures except the windmill and Masson disc were drawn in black ink on light grey cards, all lines being as uniformly even as possible so as to have no accentuation of parts. Two of the figures (O and G) required black paper as well as ink. The areas of the figures varied slightly, ranging from 16 to 19.5 square inches. Of square and rectangular forms, the grey cards were adapted in size and shape to the area of the figure, allowing a normal margin around the edge.

The windmill was copied from Miles,[3] and was made of 4 small wooden blades hung in a position 45° from the vertical behind a frosted glass window, 4"x9". A 60W lamp was placed behind the windmill providing the sharpest shadow possible. The blades were kept in motion by the air from an electric fan and varied somewhat around a mean speed of 80 r.p.m.

The usual Masson disc was simplified by placing on a white cardboard disc only one black rectangle, 3x4 mm. in size and 5 cm. from the center. This was rotated rapidly on a color mixer yielding a faint line which would seem to disappear and return as it was watched. Because of the tendency for the eyes to follow around the disc when the line disappeared, a white shield screened all but a 30° sector in the center of the upper half of the field. This stimulus offers the difficulty of not being equally bright for all observers since it is not an equal distance from the limen of each.

The observer, O, was seated at the end of a table the top of which was covered with cardboard, the same grey as that on which the figures were drawn. Perpendicular to the end of the table opposite O and 48" from him was a wall of grey cardboard, 22" high, 25" wide, which served as a background for the stimulus cards. Along the sides of the table, cardboards of the same height extended 28" toward O, restricting his range of vision. Since the wall space above the background was covered with grey, O's field of view had no color differences. The background was lighted for the 13 cards

[2] Invented by Wallin, *op. cit.*, 59-95.
[3] W. Miles, Figure for "windmill illusion," *J. Gen. Psychol.*, 1929, 2:143.

by two 60W daylight bulbs hid from O's view. The window shade was drawn so that the room as a whole was only dimly lighted. The cards were hooked with no visible means of attachment to the center of the background about 6 inches from the top, thus placing the center of the figure slightly above or below O's eye level. The distance from O to the cards varied from 48" to 52", according to his sitting posture, but remained approximately constant for each O. Allen[4] showed that a change in size of figure made some difference, though inconsistent, in the fluctuation. The size of the figures we used would not be changed enough in this variation in distance to cause an appreciable difference in fluctuation.

The windmill was observed in the same physical set-up. The surface surrounding the glass was covered with grey and the only illumination was that behind the blades. The adapted Masson disc was viewed against the grey background and illuminated by two 60W bulbs placed 2.5 feet above and slightly behind the O's head.

A telegraphic key on a movable base was placed on the table in the most convenient position for the O to use in recording the fluctuations. The key was connected to a stylus that marked on a kymograph drum the length of time O depressed or released the key. Just beside this key line was one on which seconds were marked by a stylus connected to a Marietta stroboscopic timing device. The kymograph and motor drive were in a room adjoining the observation room with the communicating door closed during observation.

The following directions were read by the O:

> All the figures you will be shown have at least two phases which fluctuate as you watch the figure. You are to hold down the key during one phase and let it remain up during the other. Specific instructions will be given for each figure as it is shown.
>
> If at any time the figure goes flat (loses depth) or assumes a form other than those described in the directions, you are to tap the key as rapidly as possible until a change in the figure is apparent.
>
> Sit comfortably close to the table and assume a *passive* attitude. Keep your eyes on the figure as a whole and do not stare. Let the phases come and go freely without trying to hold or hurry them.

[4] E. C. Allen, Conditions influencing the fluctuations of the Necker-Wheatstone cube, University of Nebraska thesis, 1934, 36-41.

A figure was presented and O tried to explain to the experimenter, E, what he saw. O watched the figure until the second phase appeared or until E pointed it out. After exact agreement on the phases was reached by O and E, a card bearing the directions for recording the two phases by the use of the telegraphic key was given to O.

The phases called "up" and "down" were selected by E so as to fit in most easily with the movement of the figure and thus become more expediently habituated for recording. Although other phases could appear in a few figures, the ones selected for report were chosen on the basis of their relative ease and frequency of appearance and their being in apposition with one another. If other phases appeared during the observation O described the tap phases before proceeding to the next figure. A rest interval of approximately one minute was allowed between stimuli.

Special directions were given for the liminal stimulus:

> On the whirling disc behind the shield you will notice a grey arc about half way up from the center. Watch this arc without staring and it may disappear and return. Report these fluctuations by pressing the key *down* when you *see the arc* and holding it down until the arc disappears, when you release the key.
>
> Allow yourself no indecision—so far as that is possible. The arc is either there or not there. Assume a passive attitude, letting the arc disappear and return as it will.

Observations were made on four separate days over a period of ten days or less and at approximately the same time of day. Each observational sitting was about one hour in length. On the first day the figures were presented to all Os in the same order, A to P. The changes of each figure were indicated on the key for 1.5 minutes for purposes of acclimitization without kymograph recording. On each of the next three days O observed every stimulus for 2 minutes. The figures were presented in haphazard order, no two orders being the same for any observation of any O. Records were timed from the appearance of the first change and in most cases continued until the end of the phase in which the 2-minute interval was concluded, in order that all phases be complete. We obtained then a minimum of 6 minutes of observation for each figure from each O. Remarks on the ease or difficulty of reversal, the similarity of phases, etc. made by the

Os throughout the observations were recorded by E unknown to O.

Each O answered the Nebraska Personality Inventory from which we obtained scores for social introversion and emotionality. Response is made to this questionnaire by encircling the "Yes," "?," or "No" appearing after the question.

The Os were 12 men and 12 women: 1 faculty member, 9 graduate students, and 14 undergraduates. Equal numbers of men and women were chosen, not to show sex differences, but to balance the factor of sex if it might have weight. The cube had been observed by 6 of the Os in previous experiments. No other figure was more familiar to any O than would have resulted from his seeing it in text-books or when it was displayed for class discussion of reversible figures. The Os are designated by number, 1 to 24.

Criticism can be made justly against the small number of cases. This number was a necessity, however, due to the great number of hours required in reading the records. Conclusions will be drawn in light of this number.

The author acted as experimenter throughout all the observations and read all the records.

RESULTS

With the aid of an ordinary reading glass the kymograph records were read to a tenth of a second to ascertain the length of the appearance of each phase of the figure. Utilizing the three observations of one figure, we calculated for each O the average length of the down, up, and tap phases as well as a general average of both up and down. The number of changes per minute is the rate of fluctuation and considering all three observations, the average fluctuation rate was calculated.

The tap phase appeared in only 98 of the 1077 observations (we lack 3 because of the O's inability to see the figure in perspective on the day tested). Using the method of critical ratio, we found that chances were 987 out of 1,000 that the average length of tap phase was likely to exceed the general average of the up and down phases. We had then in our results a constant error in one direction which was eliminated by diminishing the rate of fluctuation in those 98 observations by the number of times the tap appeared. The average rates of fluctuation of each observer for each figure appear in Table I.[5]

[5] The much longer table of average phase lengths is not reproduced here. It can be found in the original thesis along with the phase readings of the individual figures for each 0 on each day.

TABLE I

AVERAGE RATE OF FLUCTUATION (CHANGES PER MINUTE)

Figure

"O"	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P
1	16.33	9.67	5.17	9.00	8.17	6.00	12.83	9.00	9.50	7.33	8.33	8.50	9.17	10.33	15.50
2	23.83	11.00	23.83	15.67	17.17	16.67	29.83	20.67	30.17	11.17	11.67	21.50	21.50	19.83	18.33
3	32.50	7.00	12.00	11.33	6.83	8.17	9.00	15.83	11.00	7.00	6.67	6.50	9.50	5.67	9.83
4	30.17	23.83	26.83	19.83	18.67	20.17	20.00	19.33	22.83	24.67	23.50	25.17	24.83	23.50	8.83
5	28.50	23.50	23.50	10.00	24.33	16.00	31.83	14.00	28.83	18.00	21.67	22.00	48.83	25.67	18.33
6	30.33	23.33	31.17	10.17	23.67	49.50	43.50	35.33	31.50	32.17	35.33	36.33	48.67	27.33	19.33
7	178.33	91.67	57.83	15.00	80.50	48.17	154.50	60.00	73.33	76.17	63.17	78.17	101.67	132.33	28.33
8	123.33	78.17	106.50	17.83	43.67	117.00	76.33	15.33	43.67	78.83	68.00	88.67	157.00	144.33	15.67
9	20.33	24.67	20.00	17.67	18.33	24.83	35.67	15.17	12.67	21.00	18.00	18.17	35.50	29.17	14.67
10	10.67	3.83	6.50	8.83	5.50	7.00	5.17	8.00	7.00	7.00	6.33	5.00	6.50	7.33	5.83
11	9.83	9.17	12.83	14.83	11.83	9.17	10.33	15.00	13.33	12.33	12.83	6.83	14.83	9.67	7.50
12	33.83	19.17	22.00	26.67	24.00	21.67	33.00	23.83	38.83	19.50	33.17	31.67	28.00	17.67	9.83
13	11.67	8.83	11.50	11.00	12.00	9.83	7.83	13.33	14.33	10.17	18.00	10.17	8.17	9.33	12.17
14	8.83	10.83	21.67	8.33	8.17	14.83	16.17	13.00	11.50	11.50	13.83	14.00	21.50	7.67	13.50
15	2.67	2.67	3.00	6.17	3.00	2.33	2.00	4.17	2.33	2.67	3.83	1.83	3.33	5.83	2.67
16	38.67	15.33	35.67	24.67	11.33	12.67	25.33	35.00	39.00	27.83	38.83	48.67	33.00	16.33	10.17
17	21.17	18.50	8.00	14.67	17.83	10.00	26.17	~~16.67~~	22.00	19.50	16.00	15.33	12.67	26.33	15.67
18	51.50	27.33	65.50	10.17	21.33	79.67	60.83	26.33	45.67	39.83	41.17	69.33	49.00	47.83	12.83
19	16.00	10.67	20.00	10.83	4.67	11.50	12.50	7.50	11.33	12.83	24.50	6.33	18.33	12.00	9.17
20	25.33	17.00	21.50	18.67	10.50	17.17	22.33	10.83	18.83	19.83	18.00	18.83	15.00	20.83	12.83
21	20.83	25.00	16.67	8.17	17.33	12.00	29.50	16.00	20.83	19.17	12.00	14.00	22.83	30.00	18.00
22	18.17	21.50	16.17	22.67	10.67	11.17	7.33	12.00	22.17	20.50	25.00	31.33	6.50	16.33	8.17
23	19.83	10.33	13.83	10.33	14.17	9.50	17.00	10.67	12.83	13.00	17.67	13.17	16.17	13.33	8.50
24	21.50	14.17	18.50	29.83	18.50	10.00	43.00	9.50	27.17	22.50	27.33	26.33	37.00	22.83	17.00

RELIABILITIES

Day-to-day reliabilities in which rate of fluctuation of one day was correlated with that for another were of the "split-third" type. These coefficients with their PE values range from $.517 \pm .11$ to $.988 \pm .004$, with the median at $.866 \pm .04$. When they are raised to show the effect of a test three times as long, i.e., the length of one on which our study is made, we find the reliabilities in most cases well above .85.

Minute-to-minute reliabilities are "split-half," obtained by correlating the average of each O's three first-minute observations with his three second-minute observations. Raised by the Spearman-Brown prophecy formula, since such reliabilities are required in later statistics, the coefficients and PE values[6] appear in Table II.

TABLE II

MINUTE-TO-MINUTE RELIABILITY OF OBSERVATIONS

Figure	r	PEr	Figure	r	PEr	Figure	r	PEr
A	.994	.001	F	.987	.002	L	.972	.004
B	.982	.003	G	.998	.0003	M	.980	.003
C	.994	.001	H	.960	.006	N	.993	.001
D	.894	.015	J	.940	.009	O	.996	.001
E	.986	.002	K	.991	.001	P	.878	.018

These reliabilities are exceptionally high and show our test to be adequate for measuring the rate of fluctuation. Criticism against the small number of individuals involved in the study must be greatly lessened when the reliabilities of the observations stand at such high figures. Our results here corroborate the opinions of other investigators that the fluctuation rate of ambiguous figures is a constant attribute of personality.

RELATIONSHIP BETWEEN THE RATE OF FLUCTUATION OF A FIGURE AND THE EQUALITY OF ITS AVERAGE PHASE LENGTHS

Individual differences in rate of fluctuation among the figures as brought out by our 24 Os are shown in Table III. Rates of fluctuation differ as shown by the means but over-

[6] The probable errors of these reliabilities raised by the prophecy formula are found by the formula: $PEr = \frac{1.349\ (1-r^2)}{\sqrt{N}\ (1+r)^2}$, found in: E. Shen, The standard error of certain estimated coefficients of correlation, *J. Educ. Psychol.*, 1924, 15:462-465.

TABLE III

MEAN RATE, MEAN VARIATION, COEFFICIENT OF VARIATION, RANGE OF RATES, AND RANK OF EACH FIGURE FOR MEAN RATE

Figure	Mean	MV	CV	Range	Rank
A	33.05	21.70	65.7	2.67—178.33	1
B	21.13	12.48	59.1	2.67— 91.67	11
C	25.01	14.46	57.8	3.00—106.50	6
D	14.68	5.15	35.1	6.17— 29.83	14
E	18.01	9.25	51.4	3.00— 80.50	12
F	22.71	17.14	75.5	2.33—117.00	9
G	30.50	11.22	36.8	2.00—154.50	3
H	17.77	8.01	45.1	4.17— 60.00	13
J	23.78	12.01	50.5	2.33— 73.33	7
K	22.27	12.17	54.6	2.67— 78.83	10
L	23.53	12.06	51.3	3.83— 68.00	8
M	25.74	17.05	66.2	1.83— 88.67	5
N	31.21	21.75	69.7	3.33—157.00	2
O	28.39	20.05	70.6	5.67—144.33	4
P	13.03	4.25	32.6	2.67— 28.33	15
Average	23.39	13.25	54.8		

lap as shown by the mean variations. The coefficients of variation, $\frac{100\ MV}{M}$, indicate the amount of variation with respect to the size of the mean, the larger coefficients showing greater variability.

The possibility that the rate of fluctuation may bear a relation to the balance between average phase lengths was suggested by Guilford's results.[7] Using a very dim spot of light, he found that the fluctuation is more rapid at the limen for brightness, i.e., when the phases are nearly equal. He suggests in explanation of his results, "for any given stimulus there are in the organism a set of factors favoring perceptibility and a set of factors against perceptibility. . . . It is conceivable that precisely at the limen, where the balance of factors is best (or worst, as one wishes), a slight change, a shift of but one factor on one side or the other tips the balance in the opposite direction."[8] Just such a balance could conceivably be present in these reversible figures. Were that so, the fast rates would appear when the phases are almost equal in average length and the slow rates when the phases are most unequal. The phase length then, would have

[7] J. P. Guilford, "Fluctuations of attention" with weak visual stimuli, *Amer. J. Psychol.*, 1927, 38:534-583.
[8] J. P. Guilford, *op. cit.*, 552-553.

to be partialled out when correlation between rates of the figures is made. If this factor were allowed to remain uncontrolled, individual differences would not appear in their true light and the intercorrelations would be changed because of the common relationship between the rates and phase length.

To test this we need to know the ratio between the average length of the two phases. We chose to use, however, a ratio between a part and the whole—between one phase and the average of both up and down phases. For the numerator of the ratio we used the lesser of the two values, down and up, in order that all ratios be less than one. Neither phase is inherently an "up" or "down" and the identity of the dominant phase is of no importance here.

The ratios for each observer range from .130 to .999. Coefficients of correlation found between these ratios and the rates of the same figure appearing in Table I will provide an answer to our problem. Machine correlation yields the coefficients appearing in Table IV. The data were plotted on a scatter diagram to investigate the possibility of a non-linear correlation, but none existed.

These coefficients ranging from —.20 to +.20 are of no

TABLE IV

COEFFICIENTS OF CORRELATION BETWEEN RATIO OF PHASE LENGTHS AND RATE OF FLUCTUATION FOR EACH FIGURE

Figure	r	PEr	Figure	r	PEr	Figure	r	PEr
A	—.198	.13	F	.139	.14	L	.199	.13
B	.160	.14	G	.111	.14	M	.109	.14
C	.104	.14	H	—.028	.14	N	.083	.14
D	—.024	.14	J	—.129	.14	O	—.091	.14
E	.160	.14	K	—.017	.14	P	—.073	.14

statistical significance. Their probable errors are in most cases larger than the coefficients. Even P (Masson disc), a stimulus comparable to that of Guilford's, shows no indication of the relationship. The stimulus varied from the individual limens for brightness so as to yield a wide range of ratios, .130 to .968, and offered ample opportunity for testing the hypothesis. From the results on these Os we find that there is no relationship between the individual differences in the rapidity of fluctuation and the individual differences in equality of phase length.

This is a fortunate result, for had there been such a relationship, the intercorrelations of the rates of the various figures would be accordingly contaminated by an outside factor. There is, then, no necessity for partialling out phase inequality in the intercorrelations.

This problem was originally the main purpose of our obtaining kymograph records and reading them, an exacting, time-consuming task. Had we been able to foretell this result—but experiment is the only method!—we could have obtained rate records with many more observers.

DEPENDENCE OF RATE OF FLUCTUATION OF THE FIGURE ON CHARACTERISTICS OF THE FIGURE

Since individual differences in rate do not depend on the balance existing between the average lengths of the two phases, we should consider the characteristics of the figures themselves in an effort to account for the differences in the speed of fluctuation. The rank order of the figures appears in the last column of Table III, the order which we must consider when trying to assign a reason for the varying rates.

After considering in vain many causes suggested in the literature, we noted that the three most rapid figures, A (cube), N (duck-rabbit), and G (goblet-faces), are rather simple figures in their fluctuations while the three slowest figures, D (windmill), H (Scripture blocks), and E (intersecting planes), are most assuredly complex in their fluctuations. The middle figures are arranged in no observable order; among them are figures which might be considered more simple than the three fastest ones, but none more complex than the slowest. We may exclude P (Masson disc) from this discussion because of the fact that its fluctuation differs completely from that of the others, changing as it does from presence to absence.

These results agree with Gordon's conclusions that the simple figure has a faster rate than the complex.[9] We cannot divide all our figures, however, into these two categories.

RELATIONSHIP BETWEEN THE OBSERVER'S RATE AND PERSONALITY TRAITS

The individual differences in mean fluctuation rates for all figures among our Os are shown in Table V. The spread in means from 3.23 to 82.61 is extremely wide and the mean variations change accordingly. Size of the mean variations with respect to their means is shown by the coefficient of

[9] K. Gordon, Meaning in memory and attention, *Psychol. Rev.*, 1903, 10: 280-283.

TABLE V

MEAN AND MEAN VARIATION OF FLUCTUATION RATES, COEFFICIENT OF VARIATION AND RANGE OF RATES FOR EACH OBSERVER

"O"	Mean	MV	CV	Range
1	9.58	2.09	21.8	5.17— 15.50
2	19.52	4.66	23.8	11.00— 30.17
3	10.58	3.97	37.5	6.50— 32.50
4	22.11	3.45	15.6	8.83— 30.17
5	23.66	6.13	25.9	10.00— 48.83
6	31.84	7.72	24.2	10.17— 49.50
7	82.61	32.74	39.6	15.00—178.33
8	78.28	35.68	45.6	15.33—123.33
9	21.72	5.49	25.3	14.67— 35.67
10	6.70	1.19	17.8	3.83— 10.67
11	11.28	1.67	14.8	6.83— 15.00
12	25.52	6.19	24.2	9.83— 38.83
13	11.22	1.93	17.2	7.83— 14.33
14	13.02	3.27	25.1	7.67— 21.67
15	3.23	.95	29.4	1.83— 6.17
16	27.50	9.55	34.8	10.17— 39.00
17	17.36	3.90	22.5	8.00— 26.33
18	43.22	16.47	38.1	10.17— 79.67
19	12.54	4.99	39.8	6.33— 24.50
20	17.83	3.22	18.1	10.50— 25.33
21	18.82	4.85	25.8	8.17— 30.00
22	16.64	5.98	35.9	6.50— 31.33
23	13.35	2.48	18.6	8.50— 19.83
24	23.01	7.02	30.5	9.50— 43.00
Aver.	23.38	7.32	27.2	

variation, $\frac{100\ MV}{M}$, the greater the value, the more the variation in the individual rate of fluctuation. These coefficients range from 14.8 to 45.6 with a mean of 27.2 and with only one O, 8, deviating markedly from the group. This indicates that in general the individual has a rate of fluctuation around which the rates for each of the figures group with a moderate amount of variation. We have here another demonstration of the evidence of a trait of an individual, rate of fluctuation of ambiguous figures.

By comparing Table III with Table V we can obtain information on the characteristics of the individual differences in figures and individuals. We note that the means for the Os (3.23-78.28) have a much wider range than do the means for the figures (13.03-33.05). The average mean variation for the Os is 7.32 while that for the figures is 13.25. A difference still more striking is the averages of the coefficients of variation: for the Os it is 27.2 and for the figures, 54.8. The figures show a greater variability in rate than do the individuals. These results indicate that for rate of fluctuation the individual is a more powerful organization than the figure, for the latter is amenable to the former. All figures, however, are not equally amenable, a fact which is indicated by the differences in the maximum rate for the figures, shown in the range. The "figural rate" has a certain amount of influence which the individual rate does not entirely overcome.

The presence of a comparatively constant fluctuation rate in an individual immediately suggests an inquiry into its implication for the personality of the observer. In 1920 McDougall[10] presented evidence that the individual whom he judged more introverted had a faster rate of fluctuation of a model windmill viewed directly. With the cube as the figure, attempts to test his suggestion, measuring introversion by means of various questionnaires, have yielded correlations of no significance.[11] However, in 1936, George reports correlations between introversion measured by a rating scale developed for the experiment and passively viewed figures as follows: adapted Jastrow cube, .36; windmill shadow, .44; Rubin cross, .48.[12]

To test McDougall's suggestion further we chose to measure our Os with the Nebraska Personality Inventory, a testform not yet used for the purpose. Weights for the two traits measured by this questionnaire were derived following an application of Thurstone's method of factor analysis

[10] W. McDougall and M. Smith, The effects of alcohol and some other drugs during normal and fatigued conditions, *Med. Res. Council Report*, 1920, 24-29.

[11] M. F. Washburn, K. Wheeler, K. B. New, F. M. Parshall, Experiments on the relation between reaction time, cube fluctuation, and mirror drawing to temperamental differences, *Amer. J. Psychol.*, 1929, 41: 112-117. J. P. Guilford & K. W. Braly, An experimental test of McDougall's theory of introversion-extroversion, *J. Abn. Soc. Psychol.*, 1930, 25:382-389. J. P. Guilford and J. M. Hunt, Some further experimental tests of McDougall's theory of introversion-extroversion, *J. Abn. Soc. Psychol.*, 1931, 26:324-332. N. O. Frederiksen and J. P. Guilford, Personality traits and fluctuations of the outline cube, *Amer. J. Psychol.*, 1934, 64:470-474.

[12] R. W. George, The significance of the fluctuations experienced in observing ambiguous figures and in binocular rivalry, *J. Gen. Psychol.*, 1936, 15:39-61.

which yielded evidence of two well-defined traits: social introversion (S) and emotionality (E).[13] Scores on the Inventory appear in Table VI. The higher scores indicate the greater amount of the trait.

TABLE VI

SCORES ON NEBRASKA PERSONALITY INVENTORY[14]

"O"	S	E	"O"	S	E	"O"	S	E
1	353	287	9	270	354	17	337	287
2	349	320	10	251	297	18	387	349
3	364	386	11	299	354	19	295	392
4	397	373	12	228	260	20	277	257
5	300	347	13	264	287	21	360	344
6	264	318	14	328	333	22	308	278
7	433	344	15	267	276	23	260	283
8	417	324	16	352	339	24	355	327

These scores show a wide range of differences on each of the traits examined and thus present very acceptable material for comparison with fluctuation rates. The scores and rates were correlated in the usual manner, yielding the results which appear in Table VII.

TABLE VII

CORRELATION COEFFICIENTS BETWEEN RATES OF FLUCTUATION AND SCORES ON THE NEBRASKA PERSONALITY INVENTORY

Figure	S	E	Figure	S	E	Figure	S	E
A	.632	.178	F	.469	.148	L	.491	.137
B	.608	.159	G	.577	.183	M	.599	.112
C	.594	.231	H	.422	.207	N	.549	.213
D	.109	—.110	J	.551	.117	O	.621	.139
E	.525	.125	K	.615	.164	P	.487	.425
			Mean Rate	.619	.177			

[13] J. P. Guilford and R. B. Guilford, Personality factors S, E, and M, and their measurement, *J. Psychol.*, 1936, 2:109-127.

[14] To facilitate interpretation we present the quartile scores for each trait, based on 660 cases:

	Q_1	Q_2	Q_3
S	307	340	372
E	318	340	369

The significance of the coefficients can be judged most advantageously by use of a table prepared by Wallace and Snedecor.[15] Significance depends on the size of the r and the number of observations in the sample from which it is calculated. When $N = 24$ a significant r is .404 and a highly significant r is .515. Ten of the correlations between rate and social introversion (S) are highly significant: A, B, C, E, G, J, K, M, N, O. Of the remaining figures four, F, H, L, P, are significant, while D (windmill) shows no relation. The correlation with mean rate of fluctuation is also highly significant. We have then a personality trait, social introversion, which bears a consistently positive relation to rate of fluctuation. This relationship is most strongly marked with the cube (A), according to our data. We find that the windmill (D), a variation of McDougall's figure, is of no value in indicating the kind of introversion the Nebraska Personality Inventory measures.

Emotionality (E) has no significant r with the fluctuation rate except with P (Masson disc). This indicates that the rate of this stimulus is related to another identified personality factor as well as with social introversion, while no other figure here used is related to it. The disc depends for its fluctuations on brightness while the other figures do not. This fact may be some clue to the reason for the relationship.

When the correlations of the Inventory and rate of fluctuation are corrected for attenuation, they are raised several points to a degree that may be considered nearer their theoretical relationship than is designated in Table VII. Using the reliabilities for the figures given in Table II and the following reliabilities for the trait scores based on 660 cases: $r_{ss} = .85$, $r_{ee} = .86$, we calculated the corrected correlations. All of the coefficients are raised and although we cannot judge their exact significance by the criterion applied to the uncorrected coefficients, we may conclude that they are of greater significance. The correction only serves to strengthen our former results on the relation of rate to social introversion (S) and does not add enough value to the correlations with emotionality (E) so that we need qualify our conclusions on the lack of relationship between that trait and fluctuation rate.

We are of the opinion that former investigators, with one exception, did not find these relations because the weights

[15] H. A. Wallace and G. W. Snedecor, *Correlation and Machine Calculation*, Iowa State College, 1931, 62-63.

for the personality traits were not derived by a statistical method which isolated one trait. George, whose results follow the general trend of ours, emphasizes the fact that he believes his rating scale to measure more nearly one trait than do other scales. McDougall's opinion, which we corroborate, was based on subjective judgment of introversion and we cannot repeat the test as originally performed. The introversion here correlated may or may not agree with his definition of the term.

PRESENCE OF FACTORS TO ACCOUNT FOR THE INTERCORRELATIONS AMONG FIGURES

The fluctuation rate of each figure for different individuals, presented in Table I, can be assumed to result from the operation of various factors. An isolation of such factors would tell us what amount of each rate is dependent on each factor present in the other figures and what amount is operating in control of that figure alone.

From Table I we calculated the intercorrelation of rate for all figures. These appear in Table VIII, which is to be known as the correlational matrix.[16] All of these coefficients are positive and most of them highly significant, indicating that there exists a strong relationship between rate of one figure and that of another. Two figures, D (windmill) and P (Masson disc), stand out, however, because of their low correlations with most other figures and with each other. These figures do not have as much in common with the others as those others have with one another. They are physically different from the others in that they are not geometric figures.

By applying the Thurstone multiple-factor technique[17] to the correlational matrix, we shall attempt to account for the degree of these intercorrelations. We extracted two centroid factors which account for a great amount of each coefficient. This fact is observable from the smallness of the second factor residuals (discrepancies between original coefficients and those calculated by two factors), which range from —.160 to +.120 and have a standard deviation of .047. This standard deviation is comparable with the standard error of the mean correlation coefficient, .002 (calculated from Table VIII), and thus satisfies one test for the number of factors necessary to

[16] The probable errors of these coefficients of correlation are not included here but can readily be obtained from tables designed for the purpose.

[17] L. L. Thurstone, *The Theory of Multiple Factors*, 1933, and *A Simplified Multiple Factor Method*, 1933, The University of Chicago Bookstore.

TABLE VIII

CORRELATIONAL MATRIX

TABLE VIII

CORRELATIONAL MATRIX

Figure	B	C	D	E	F	G	H	J	K	L	M	N	O	P
A	.957	.770	.134	.938	.690	.934	.732	.848	.930	.854	.847	.853	.942	.610
B		.809	.165	.936	.743	.911	.649	.808	.961	.864	.849	.900	.975	.642
C			.175	.662	.953	.707	.467	.734	.912	.891	.930	.926	.870	.394
D				.175	.052	.162	.178	.372	.247	.374	.321	.168	.125	.039
E					.596	.965	.777	.869	.877	.798	.772	.796	.885	.741
F						.643	.388	.635	.846	.813	.866	.878	.818	.362
G							.794	.892	.889	.816	.817	.796	.878	.763
H								.852	.660	.666	.670	.487	.554	.623
J									.847	.872	.893	.729	.765	.658
K										.946	.940	.935	.964	.577
L											.949	.884	.859	.482
M												.869	.861	.488
N													.913	.549
O														.588

describe the original correlational matrix.

The loadings of these two centroid factors in each figure appear in the first two columns of Table IX. The maximum value of a loading is 1.000, the total variance. The first factor has all positive values but the second appears with both positive and negative values. Since these negative quantities may cause difficulty in attempting to name the factor, it is advisable to follow the usual practice and rotate into a positive manifold the pair of orthogonal axes which represent a continuum of each factor and with reference to which each figure can be plotted, using the factor loadings as coordinates. Rotating the axes clockwise 45° will bring all points into the first, or positive quadrant. These new coordinates, or factor loadings, appear in the third and fourth columns of Table IX.

TABLE IX

FACTOR LOADINGS BEFORE AND AFTER ROTATION OF AXES

Figure	Factors before rotation I	II	Factors after rotation I′	II′
A	.943	.101	.595	.738
B	.955	.021	.660	.690
C	.877	—.434	.927	.313
D	.241	—.034	.194	.146
E	.924	.311	.433	.873
F	.805	—.420	.866	.272
G	.938	.299	.451	.875
H	.735	.420	.223	.817
J	.918	.195	.511	.787
K	.983	—.147	.799	.591
L	.945	—.223	.826	.511
M	.945	—.224	.827	.510
N	.914	—.268	.836	.457
O	.942	—.116	.748	.584
P	.651	.448	.144	.777

Graphic representation of the figures with the new factor loadings as coordinates with respect to axes I′ and II′ appears in Figure 2. All but one of the points fall near the edge of a circle with radius 1.00 on whose circumference they would lie were their variance entirely accounted for by the

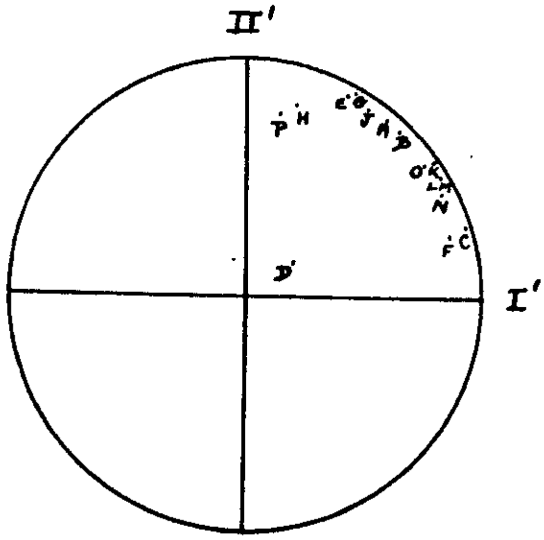

FIGURE 2

Two-factor analysis of the fifteen figures after rotation of axes.

two common factors. Figure D (windmill) is quite removed from the group, while P (Masson disc) and H (Scripture blocks) draw away somewhat noticeably. This arrangement of figures along each axis represents the key to the identity of the two factors.

Considering the figures with respect to axis I′, we find that their order seems to indicate that the factor is concerned with the distinctiveness between the phases, the difficulty of differentiating between one phase and the other. The less the distinction, the farther out on the axis the figure appears. The two phases of both C (truncated pyramid) and F (scroll) are not greatly different, a notion that is corroborated in remarks of the Os recorded by E. They said that it was hard to tell whether the figure was in the up or the down phase. By contrast, the phases of P (Masson disc), D (windmill), and H (Scripture blocks) are very different and distinctive. P might be considered to have a different kind of distinctiveness from the others, in that the differentiation rests on a being there or a not being there. D and H are referred to by many Os as figures in which there is no question about which phase is present. The Os usually liked both figures for just that reason. The figures lying between the extremes become progressively more distinctive in their phases as one proceeds toward the center of the circle along the axis. We might name the factor "lack of phase distinctiveness."

This decision concerning the possible identity of factor I′ has been arrived at after exclusion of numerous possibilities suggested by the literature on the figures and our experience with them. Some, such as type of movement, shape, and familiarity, were excluded because it could well be seen that they were non-applicable. Others, such as balance of the phases and complexity, were excluded because statistical information presented earlier in the discussion make them non-applicable.

Factor II′ presents more difficulty in identification. It has been suggested that the "reality" of the figure, with whatever implication that might have, is the factor present. But although most of the others seem to fit this criterion, D (windmill), coming at the bottom of the scale, does not at all fit into the position expected of it. Statistics show the factor not to be complexity, phase dominance, or a variability as expressed in the probable error of the mean or of the distribution, and inspection shows that unequal perspective, shape, type of movement, and the like are not operative. The significance of this factor (average of the squares of the factor loadings of each figure) is .4035, only slightly less than that of the first factor, .4282. The identity, however, is not obvious since the objects under consideration yield so little in the way of cues because of their very nature. Rather than posit a questionable name for the factor, we prefer to let it go nameless.

We should next consider the figures separately to find how much of the variance of each is dependent on the common factor and how much is dependent on a factor specific to the figure itself. The *communality* of the test, the sum of the squares of the two factor loadings, tells how much each figure has in common with the other figures analyzed and is, therefore, a measure of the common factors present. It is always smaller than the reliability of the test except in those infrequent cases where it is equal to it. The communality measures the variance of a test when both the error factor (errors of measurement) and the specific factor are eliminated. The *reliability* is the variance with only the error factor omitted. We can thus find the *specificity* of each figure by subtracting communality from reliability. We may also find the *error* factor through application of the definitions mentioned above. The *uniqueness* of a test is the sum of the specificity and error factors, two terms which are unique

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VARIANCE OF
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Figure	Co
A	.8
B	.9
C	.9
D	.0
E	.9
F	.8
G	.9
H	.7
J	.8
K	.9
L	.9
M	.9
N	.9
O	.9
P	.6

for one test for one occasion. Uniqueness is, therefore, the difference between communality and total variance. Stated concisely, where *a* represents the variance for the figure under consideration and the subscripts denote that part of the variance due to the factor named, we have:

$$\text{Total variance} = 1$$

$$\text{Reliability} = r_{aa}$$

$$\text{Communality} = h^2$$

$$\text{Specificity} = a_s^2 = r_{aa} - h^2$$

$$\text{Error} = a_e^2 = 1 - r_{aa}$$

$$\text{Uniqueness} = a_o^2 = a_e^2 + a_s^2$$

$$\therefore \text{Communality} = h^2 = 1 - a_o^2$$

These measures can be found for each figure and appear in Table X. The reliability for each figure is that previously given in Table II.

TABLE X

VARIANCE OF EACH FIGURE RATE ANALYZED INTO COMMON, SPECIFIC AND ERROR COMPONENTS

Figure	h^2 Com.	r_{aa} Rel.	a_e^2 Err.	a_s^2 Spec.	a_o^2 Uniq.
A	.899	.994	.006	.095	.101
B	.912	.982	.018	.070	.088
C	.957	.994	.006	.037	.043
D	.059	.894	.106	.735	.841
E	.950	.986	.014	.036	.050
F	.824	.987	.013	.163	.176
G	.969	.998	.002	.029	.031
H	.717	.960	.040	.243	.283
J	.880	.940	.060	.060	.120
K	.988	.991	.009	.003	.012
L	.943	.972	.028	.029	.057
M	.944	.980	.020	.036	.056
N	.908	.993	.007	.085	.092
O	.901	.996	.004	.095	.099
P	.624	.878	.122	.254	.376

We notice here that most of the figures have a very low specificity, indicating that the two factors account for most of the variance of the figure. D (windmill) has an extremely high specific factor which we can feel justified in venturing to say is due to its motion. No other figure contains the motion evident in D. The rather high error factor in D may be partly due to the variation in that motion. P (Masson disc), H (Scripture blocks), and F (scroll) have much higher specificities than do the other figures. That of P seems obviously to be due to its very different nature, as demonstrated by the intercorrelations in Table VIII. No explanation of the others can be seen on the surface. K (curved book) is almost entirely described by the two factors. Its specificity is almost negligible, and its slight variance beyond that due to the factors is caused by chance errors, which are likewise very low.

A clearer picture of these ambiguous figures would probably be obtained if 10 or 15 others were included in the analysis. This would provide the possibility of grouping the figures in constellations, the causes of which might then be identified. A still clearer picture would probably be obtained if the ambiguous figures were analyzed along with other measures of the individual's behavior. They might then, it is true, only group apart from the other, showing their "fluctuatingness." It would be possible, however, that some few of them might differ from the others and appear in other constellations. Likewise, other measures might appear in the constellation composed mainly of ambiguous figures. Through these relations, then, there would be presented a possibility of carrying the analysis of the factors to a more accurate stage.

RELATIVE VALUE OF FIGURES FOR MEASURING INDIVIDUAL DIFFERENCES

Realizing the fact that the figures are not of equal value for measuring individual differences, we considered their relative merits in light of: reliabilities of fluctuation rate, coefficients of variation, mean rates, range of rates, consistency with an O's mean rate, correlation with social introversion scores, and by completeness of their description by the two common factors located in the analysis. It appears that figure A (cube) is the best single figure for measuring individual differences. Though the other figures may be especially useful from one aspect or another, they are inferior when considered in all the aspects. Records of the rate of the cube should be made on three different days in order to obtain the most reliable average fluctuation rate.

CONCLUSIONS

The results of the observations of fifteen ambiguous phenomena by 24 Os on three different days, as discussed above, yield the following conclusions:

1. That rates of fluctuation are highly reliable measures of one attribute of an individual.
2. That an individual has an average rate of fluctuation that characterizes him and that each figure has a sort of characteristic rate which for all figures is not equally amenable to the observer's rate.
3. The individual differences in the rate of fluctuation of a figure are not related to its average phase length for different individuals.
4. That the slowest figures tend to be the most complex and the fastest are among the simplest.
5. That an individual with a more rapid fluctuation rate tends to be more socially introverted, as measured by the Nebraska Personality Inventory.
6. That two factors will account for the amount of intercorrelation existing among the rates of the figures, the first appearing to be "lack of phase distinctiveness," and the second being unidentifiable.
7. That the cube is the best single figure to use for measurement of individual differences.