ON THE INFLUENCE OF PREVIOUS EXPERIENCE ON PERSONAL EQUATION AND STEADINESS OF JUDGMENT IN THE ESTIMATION OF THE NUMBER OF OBJECTS IN MODERATELY LARGE SAMPLES

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I. INTRODUCTORY REMARKS

In much of the work in which personal equation is a factor the observer is not able to compare his estimates with the true value, and so attempt at each successive observation to profit by his previous experience. If experiments be arranged in which this can be done, the influence of experience upon both personal equation and steadiness of judgment can be studied.

Highly satisfactory materials for such a study are furnished by the data of an earlier paper in which I have shown that there is a pronounced personal equation in the estimation of the numbers of objects in moderately large samples, and have given measures of personal equation and of steadiness of judgment based on the massed statistics of twenty-eight experiments, comprising altogether 15,200 estimates.¹

In these experiments the errors of observation were recorded in sequence. A group of fifty consecutive estimates with the accompanying determinations of the errors constituted a 'period.' With the exception of a single experiment in which the number of objects was so large that the amount of time required for the counting rendered more than 50 estimates per day undesirable, record sheets for a morning and an afternoon period were filled by each observer.

¹ Harris, J. Arthur, 'Experimental Data on Errors of Judgment in the Estimation of the Number of Objects in Moderately Large Samples, with Special Reference to Personal Equation,' this journal, November 1915, 22, pp. 490-511.

Each 'period' is for convenience divided into five 'trials' of ten successive estimates each.

In making these estimates each observer made a persistent effort to improve. This was based on a knowledge of the immediately preceding errors and consisted in a constant effort to lay out the desired number of seeds. The constants from the distributions of errors made in the individual experiments were calculated from time to time in the same laboratory, so that the observers had some knowledge of the results of preceding experiments taken as a whole. This knowledge did not, I am quite sure, have any influence upon subsequent experiments.

The main problems involved in the question of experience are two: Is there a change in personal bias as a result of constant effort to improve and opportunity for improvement? Does the judgment become steadier, *i. e.*, does the observer make less erratic estimates, as a result of experience?

Both of these questions are really twofold. Is there an improvement from period to period? Is there an improvement within the period? In short, does the worker improve both from estimate to estimate in the same half daily period and also from period to period?

II. ANALYSIS OF DATA

Consider first the problem of improvement from period to period.

To test the matter most simply one may merely split an experiment, say our first 700 estimates, into the first and second half, and determine the difference between the constants of the first and second 350 estimates. For personal equation the constants are:

Observer	First 350	Second 350	Difference
Observer B.....	+ .120±.164	+ .223±.136	+ .103±.213
Observer C.....	+1.331±.159	+ .520±.125	-.811±.202
Observer D.....	+2.691±.210	+1.649±.160	-1.043±.264

Observer C's and observer D's personal equations have dropped by an amount four times their probable errors in

passing from the first half to the second half of the experiment. Observer *B*'s has increased by an amount only half its probable error.¹

For steadiness of judgment the results are:

	First 350	Second 350	Difference
Observer <i>B</i>	4.552±.116	3.771±.096	— .781±.151
Observer <i>C</i>	4.408±.112	3.474±.089	— .934±.143
Observer <i>D</i>	5.837±.149	4.438±.113	— 1.399±.187

In all cases there is a distinct and statistically significant decrease in the standard deviation—the judgments becoming less erratic as experience becomes greater.

Instead of contenting oneself with so crude a method as a comparison of the constants for the two halves of an experiment, one may obtain a quantitative expression for the influence of experience by correlating between the number of previous experiences and the measures of personal equation or of steadiness of judgment.

In doing this one must deal with a number of subgroups for each period. It is most convenient to divide each half daily period of 50 estimates into five consecutive 'trials,' each of 10 estimates. For each of these 'trials' the mean personal equation and the standard deviation of the errors must be computed. Thus in obtaining the constants presented here it was first necessary to compute 1,520 means and 1,520 standard deviations, which were then treated as units in computing the correlations.

Since the constant desired is the correlation between the number of previous experiences (or of 'trials') and personal equation and steadiness of judgment, the first period (or 'trial') must be designated as 0 (no previous experience) and the subsequent ones numbered consecutively, beginning with 1.

I consider first the results for the correlation between the number of previous periods of experience and personal equation.

¹The logical conclusion seems to be that Observer *B*, who at the beginning had practically no personal equation has not changed throughout the work, while Observer *C* and Observer *D* who had distinct personal equations at the beginning have been able to reduce theirs as the result of their experience.

Table I¹ gives the correlation coefficients, r_{pe} , with their probable errors and the ratios to their probable errors. The results may also be expressed in terms of the regression of personal equation on periods of previous experience as shown by the straight line equations in Table II., calculated from the formula

$$e = \left(\bar{e} - r_{pe} \frac{\sigma_e}{\sigma_p} \bar{p} \right) + r_{pe} \frac{\sigma_e}{\sigma_p} p,$$

TABLE I
PERIODS OF EXPERIENCE AND PERSONAL EQUATION

Experiment	Observer B	r/E_r	Observer C	r/E_r	Observer D	r/E_r
I.	-.053±.080	-0.66	-.237±.076	-3.12	-.189±.078	-2.42
II.	-.161±.085	-1.89	-.108±.086	-1.25	-.433±.071	-6.10
III.	-.344±.077	-4.47	-.050±.087	-0.57	-.388±.074	-5.24
II.+III.	-.122±.060	-2.03	-.186±.059	-3.15	-.369±.053	-6.96
IV.	+.002±.087	+0.02	+.260±.081	+3.21	-.073±.087	-0.84
V.	-.025±.087	-0.29	-.057±.087	-.66	+.037±.087	+0.43
IV.+V.	-.089±.061	-1.46	+.027±.061	+.44	+.144±.060	+2.40
VI.	-.017±.151	-0.11	+.353±.132	+2.67	+.078±.150	+0.52
VII.	.....	.....	-.251±.094	-2.67	-.588±.066	-8.91
VIII.	.....	.....	.....	.....	+.114±.086	+1.33
IX.	-.440±.073	-6.02	-.524±.066	-7.94	.....	.....
X.	+.070±.100	+0.70	-.230±.095	-2.42	.....	.....
IX.+X.	-.307±.061	-5.03	-.034±.061	-.55	.....	.....
XI.	-.280±.080	-3.50	-.006±.087	-0.07	+.275±.080	+3.44

TABLE II
REGRESSION OF PERSONAL EQUATION ON PERIODS OF PREVIOUS EXPERIENCE

Experiment	Observer B	Observer C	Observer D
I.	$e = +0.350 - .028 p$	$e = +1.441 - .079 p$	$e = +2.741 - .088 p$
II.	$e = +0.863 - .064 p$	$e = +1.279 - .046 p$	$e = +2.099 - .274 p$
III.	$e = +1.159 - .118 p$	$e = +0.655 - .017 p$	$e = +1.234 - .291 p$
II.+III.	$e = +0.771 - .023 p$	$e = +1.217 - .037 p$	$e = +1.611 - .130 p$
IV.	$e = +0.778 + .001 p$	$e = +0.096 + .172 p$	$e = +0.182 - .072 p$
V.	$e = +0.366 - .016 p$	$e = +1.063 - .031 p$	$e = +0.740 + .027 p$
IV.+V.	$e = +0.917 - .033 p$	$e = +0.874 + .008 p$	$e = -0.391 + .063 p$
VI.	$e = +0.904 - .066 p$	$e = +0.082 + 1.252 p$	$e = +2.404 + .434 p$
VII.	.....	$e = +0.623 - .086 p$	$e = +2.194 - .361 p$
VIII.	.....	.....	$e = +0.011 + .035 p$
IX.	$e = +1.450 - .129 p$	$e = +0.737 - .159 p$	.....
X.	$e = +0.348 + .021 p$	$e = +0.411 - .061 p$	.....
IX.+X.	$e = +1.085 - .047 p$	$e = +0.090 - .005 p$	.....
XI.	$e = +0.791 - .111 p$	$e = +0.232 - .002 p$	$e = -0.617 + .174 p$

¹ On general principles I feel that it is highly desirable to publish the original data from which all statistical constants are deduced. In the present case, however, it seems quite out of the question to print the 128 correlation tables upon which the conclusions of this paper are based.

where e = personal equation, p = periods of previous experience, the bars denote the means of the two characters and the sigmas their standard deviations. In these equations

DIAGRAM I. Mean Personal Equation for the Successive Periods of an Experiment. The position of the circles indicates on the scale to the left the mean personal equation for the period. The solid lines represent the regression equations for the individual experiments. The broken lines represent the straight line equations for the combinations of the two successive experiments.

the second term shows the actual amount of change in personal equation per period of previous experience.

The empirical means (personal equations) for each period

DIAGRAM 2. Explanation as in Diagram 1. Note that personal equation sometimes increases and sometimes decreases with experience. Note that in both cases the means are very irregular but that there is a great preponderance of those on the positive side of the zero bar—*i. e.*, of cases in which the persistence of personal equation is shown in the individual periods.

have already been shown graphically for the first experiment in Fig. 4 of the preceding paper. The lines superimposed upon these are those representing the regression straight line equations. The lines for twelve additional series are shown in Fig. 1-2. These are for the experiments belonging to sets II.-III. and IV.-V., which were made in consecutive weeks. Hence they are so drawn that the regression line (dotted) for the combined experiment may be drawn through the same set of empirical means.

These diagrams may suggest that personal equation tends to become somewhat less pronounced with experience. There are, however, conspicuous exceptions. They show great irregularity in the distribution of the means of the personal equation of individual periods. There is no evidence that taken as a whole these irregular means could be better represented by a curve of a higher order than by a straight line.

The diagrams further show not only that the individuals differ in their mean personal equation from period to period, but that in the case of consecutive experiments the whole trend of the experiments may differ sensibly.

Turning to the numerical values as a means to finer analysis, it appears that in 20 cases the correlation is negative as compared with 8 cases in which it is positive in sign. Of the 8 correlations involving the data of two consecutive experiments 6 are negative and 2 are positive in sign. Experience tends generally, therefore, to change personal equation in the negative direction. Since the personal equations of the observers who took part in these experiments were for the most part of the positive sort, experience leads on the whole to an improvement of the estimates in so far as personal equation is concerned.

In the case of Experiment C IX. both personal equation and correlation are negative. The tendency is therefore for the observer to become worse by experience. The same is true in the case of D III. and D IV.

Thus in so far as the constants may be classified by the signs of the personal equations and of the correlations, there are $8+3 = 11$ cases in which the personal equation tends to

grow worse with experience to $20 - 3 = 17$ cases in which it tends to become better. This means that if one calculated the personal equation at the *beginning* and at the *end* of the whole experiment from a straight line equation fitted to the means of the whole experiment he would find that in 17 cases the calculated personal equation at the end of the periods of experience would be nearer zero than that at the beginning, whereas in 11 cases the reverse would be true. This point may be easily verified from the equations given.

Averaging the constants for the three individual observers I find, regarding signs,

	Mean Correlation.
Observer B.....	-.136
Observer C.....	-.085
Observer D.....	-.130

For the whole 28 experiments the results are:

	Mean Correlation.
Eight positive coefficients.....	+.151
Twenty negative coefficients.....	-.223
All twenty-eight determinations.....	-.116

If one considers that the three cases in which a negative correlation is associated with a negative personal equation should be classed with the cases in which personal equation tends to become larger with experience the results are:

For 17 cases with tendency to decrease personal equation.....	-.204
For 11 cases with tendency to increase personal equation.....	+.199

An examination of these coefficients in their relation to their probable error shows that only 14 out of the 28 are at least twice as large as their criterion of trustworthiness. Of these, 3 are positive and 11 are negative. In two of these cases, however, *i. e.*, C IX. and D III., the negative sign of the correlation coefficient indicates an increase in the numerical magnitude of personal equation as a result of experience. Hence the statistically significant coefficients—where by statistically significant one means a coefficient at least twice as large as its probable error—stand in the ratio of $11 - 2 = 9$ to $3 + 2 = 5$ in evidence of a modification in the direction of betterment of personal equation by experience. Thus taken as a whole these data perhaps show a slight but distinct

tendency for the observers to reduce their personal equation by a persistent effort to improve and the constant opportunity for improvement afforded by a knowledge of the amount of error of each estimate made. Improvement by modification of personal equation is however, if it exists at all, very slight.

These findings are in good accord with the results for personal equation presented in the preceding paper, *i. e.*, the demonstration of its persistence in each of the three observers throughout a period of two years.

Turn now from the question of improvement as a result of experience from period to period to the problem of improvement within the period.

Each period of 50 estimates has been split up into 5 trials of 10 errors each, and the personal equation (*i. e.*, the mean deviation) and the standard deviation for each of these computed. These trials are now classified not by the sequence of the periods of experimentation but by first to fifth trial within the periods. In determining the correlation between the number of previous trials and personal equation the first must be ranked as 0 (no previous trials) and the subsequent ones as 1 to 4.

TABLE III
TRIALS WITHIN THE PERIOD AND PERSONAL EQUATION

Experiment	Observer B	r/E_r	Observer C	r/E_r	Observer D	r/E_r
I.	$+ .370 \pm .070$	$+ 5.29$	$- .073 \pm .080$	$- 0.90$	$- .002 \pm .081$	$- 0.03$
II.	$+ .214 \pm .083$	$+ 2.58$	$+ .234 \pm .082$	$+ 2.85$	$- .329 \pm .078$	$- 4.21$
III.	$+ .193 \pm .084$	$+ 2.30$	$- .074 \pm .087$	$- 0.85$	$- .150 \pm .085$	$- 1.76$
IV.	$+ .252 \pm .082$	$+ 3.07$	$- .103 \pm .086$	$- 1.20$	$- .062 \pm .087$	$- 0.71$
V.	$+ .160 \pm .085$	$+ 1.88$	$- .229 \pm .083$	$- 2.76$	$+ .207 \pm .083$	$+ 2.49$
VI.	$- .093 \pm .150$	$- 0.62$	$- .088 \pm .150$	$- 0.59$	$- .233 \pm .143$	$- 1.63$
VII.	.....	.....	$+ .110 \pm .099$	$+ 1.11$	$- .240 \pm .095$	$- 2.53$
VIII.	.....	.....	.....	.....	$+ .377 \pm .075$	$+ 5.03$
IX.	$+ .140 \pm .089$	$+ 1.57$	$+ .001 \pm .091$	$+ 0.01$	.....	.....
X.	$- .191 \pm .097$	$- 1.97$	$- .025 \pm .101$	$- .25$	.....	.....
XI.	$+ .170 \pm .085$	$+ 2.00$	$- .194 \pm .084$	$- 2.31$	$- .111 \pm .086$	$- 1.29$

The results are given in Table III. Of the 28 constants 12 are positive and 16 negative in sign. In all cases in which personal equation is positive the negative correlations may be looked upon as indicating a tendency to improvement, whereas in all cases in which personal equation is negative the positive correlations may be taken to indicate improvement. Judged

by this standard two of the negative coefficients *D*, III. and *D* IV., indicate (if they may be considered statistically trustworthy) a tendency to become worse with experience. In the third case of negative personal equation, *C* IX., the correlation is positive in sign.¹ Hence, viewed from the standpoint of progress in the direction of the elimination of personal equations as the result of successive trials of ten attempts each within the individual experimentation periods the results stand 15 : 13, in favor of an improvement within the period.

Only 11 of the 28 constants are two or more times as large as their probable errors. Of these 8 are positive and 3 are negative in sign.

The averages, regarding signs, are:

	Mean Correlation.
Observer <i>B</i>	+ .135
Observer <i>C</i>	- .034
Observer <i>D</i>	- .060

The mean of the 12 positive coefficients is + .202, that of the 16 negative ones - .131, that for all the experiments + .012.

The results, extensive as they are, indicate very clearly by the low magnitude of the correlations and their nearly equal distribution into positive and negative values that there is no appreciable change in personal equation as a result of an effort to improve within a period of 50 trials.

I now turn to a consideration of the relationship between the number of periods of previous experience and steadiness of judgment as measured by its standard deviation. The correlation coefficients with the means of estimating their statistical trustworthiness are given in Table IV. The evaluations of

$$s = \left(\bar{s} - r_{ps} \frac{\sigma_s}{\sigma_p} \bar{p} \right) + r_{ps} \frac{\sigma_s}{\sigma_p} p,$$

where *s* = steadiness of judgment as measured by the standard deviation and the other symbols have their usual significance, are given in Table V.

¹ Neither of the three constants, *D* III., *D* IV., nor *C* IX., can safely be regarded as trustworthy in comparison with its probable error.

The straight lines for the first experiment covering 14 periods are shown with their empirical means in Diagram 3. The means and fitted lines for the two sets of experiments which were made in consecutive weeks are shown in Diagrams 4-5.

TABLE IV
FOR PERIODS OF EXPERIENCE AND STEADINESS OF JUDGMENT

Experiment	Observer B	r/E_r	Observer C	r/E_r	Observer D	r/E_r
I.	-.457±.064	-7.14	-.347±.071	-4.89	-.474±.063	-7.52
II.	-.305±.079	-3.86	-.263±.081	-3.25	-.434±.071	-6.11
III.	-.074±.087	-.85	-.013±.087	-0.15	+.022±.087	+.25
II.+III.	-.420±.051	-8.28	-.263±.057	-4.61	-.319±.055	-5.80
IV.	-.340±.077	-4.42	-.290±.080	-3.63	-.240±.082	-2.93
V.	-.068±.087	-0.78	-.411±.072	-5.71	-.084±.087	-.97
IV.+V.	-.431±.050	-8.62	-.468±.048	-9.75	-.265±.057	-4.65
VI.	-.337±.134	-2.51	-.311±.136	-2.29	-.628±.091	-6.90
VII.	.....	.....	-.258±.094	-2.74	-.451±.080	-5.64
VIII.	.....	.....	.....	.....	-.037±.087	-.43
IX.	-.244±.086	-2.84	-.095±.090	-1.06	.....	.....
X.	+.220±.096	+2.29	-.244±.095	-2.57	.....	.....
IX.+X.	-.284±.062	-4.58	-.348±.059	-5.90	.....	.....
XI.	-.086±.086	-1.00	-.160±.085	-1.88	-.247±.082	-3.01

TABLE V
REGRESSION OF STANDARD DEVIATION MEASURING STEADINESS OF JUDGMENT ON PERIODS OF PREVIOUS EXPERIENCE

Experiment	Observer B	Observer C	Observer D
I.	$s = 4.190 - .106 p$	$s = 4.350 - .087 p$	$s = 5.770 - .175 p$
II.	$s = 3.577 - .076 p$	$s = 3.743 - .078 p$	$s = 4.480 - .157 p$
III.	$s = 2.609 - .014 p$	$s = 2.927 - .003 p$	$s = 3.069 + .006 p$
II.+III.	$s = 3.424 - .050 p$	$s = 3.518 - .035 p$	$s = 3.948 - .051 p$
IV.	$s = 6.784 - .140 p$	$s = 7.402 - .164 p$	$s = 7.325 - .170 p$
V.	$s = 5.027 - .025 p$	$s = 6.059 - .153 p$	$s = 5.721 - .039 p$
IV.+V.	$s = 6.500 - .091 p$	$s = 7.237 - .120 p$	$s = 6.883 - .081 p$
VI.	$s = 14.755 - .959 p$	$s = 13.808 - .951 p$	$s = 17.770 - 2.278 p$
VII.	.....	$s = 1.836 - .039 p$	$s = 3.109 - .161 p$
VIII.	.....	.....	$s = 2.008 - .006 p$
IX.	$s = 2.275 - .038 p$	$s = 1.817 - .010 p$	.....
X.	$s = 1.666 + .035 p$	$s = 1.663 - .034 p$	.....
IX.+X.	$s = 2.184 - .024 p$	$s = 1.872 - .023 p$	.....
XI.	$s = 2.959 - .019 p$	$s = 3.010 - .037 p$	$s = 4.565 - .079 p$

In all of these diagrams the straight lines are fitted to the mean standard deviations for the individual trials of which 5, comprising 10 observations each, constitute a period. These means are represented by circles, connected by solid lines. As a check, and to show the influence of differentiation among

DIAGRAM 3. Means of Five Standard Deviations in the Fourteen Periods of the First Experiments, Circles and Solid Lines, with the Fitted Regression Straight Lines. The solid dots connected by broken lines show the standard deviations for the fifty errors in each period.

the individual trials of a period the standard deviations of the 50 estimates of each period are shown by solid dots connected by broken lines in the first two of these diagrams.

In all cases the constant based on the 50 observations is higher than the mean of that of the 5 sub-groups of 10 constituting the period. This is to be expected from the fact that

DIAGRAM 4. Explanation as in Diagram 3. The dotted regression lines show the rate of change, if considered linear, for the two consecutive experiments.

the individual trials of a period differ somewhat among themselves. These differences naturally contribute to the period standard deviation when the data of all the trials are thrown together.

These diagrams show something of the amount of change

occurring in steadiness of judgment as a consequence of previous experience. There is perhaps a slight suggestion of non-linearity. At first the standard deviation of the estimates

DIAGRAM 5. Explanation as in Diagrams 3-4. The Mean Standard Deviations only are shown.

perhaps falls slightly more rapidly than later. There are, however, cases in which this is not at all apparent. Con-

sidering the irregularity in the empirical means the equation to a straight line represents the change in steadiness of judgment fairly well.

From the table of correlation constants, it appears that *26 out of 28 coefficients are negative in sign*. Thus while personal equation decreases very little with experience as shown by the fact that both positive and negative correlations are found in not widely different numbers, steadiness of judgment unquestionably becomes greater as is indicated by the fact that in practically every experiment the mean standard deviation of the estimates made in the trials of the individual periods decreased as experience increased.

The same point is shown by an examination of the constants in comparison with their probable errors. In the case of the correlation between periods of previous experience and personal equation only 9 constants indicating an improvement in personal equations were at least twice as large as their probable errors. In the relationship here under consideration no less than 18 constants must by the same standards be considered statistically trustworthy. All eight of the correlations covering the range of previous experience afforded by a two weeks' test are *at least* 4.5 times as large as their probable errors, and so unquestionably show an improvement in steadiness of judgment.

The mean correlation for the individual observers are:

	Mean Correlation.
Observer B.....	-.188
Observer C.....	-.239
Observer D.....	-.286

For all observers the averages are:

	Mean Correlation.
Positive values, 2.....	+.131
Negative values, 26.....	-.265
All values, 28.....	-.238

From the problem of the relationship between the number of periods of previous experience and steadiness of judgment one naturally turns to the question of improvement within the individual periods, irrespective of their temporal position in the experiment. Table VI gives the correlation between the

number of trials, each of 10 estimates, and the standard deviation of the errors in the individual trials.

TABLE VI
TRIALS WITHIN THE PERIOD AND STEADINESS OF JUDGMENT

Experiment	Observer B	r/E_r	Observer C	r/E_r	Observer D	r/E_r
I.	-.210±.077	-2.73	-.253±.076	-3.33	-.349±.071	-4.92
II.	-.109±.086	-1.27	-.422±.072	-5.86	-.128±.086	-1.49
III.	-.176±.084	-2.10	-.450±.069	-6.52	+.060±.087	+0.69
IV.	-.319±.078	-4.09	-.408±.073	-5.59	-.005±.087	-0.06
V.	-.234±.082	-2.85	-.294±.080	-3.68	+.013±.087	+0.15
VI.	-.051±.150	-0.34	-.566±.103	-5.50	-.324±.135	-2.40
VII.	.....	.....	+.219±.096	-2.28	-.308±.091	-3.38
VIII.	.....	.....	.....	.....	-.032±.087	-0.37
IX.	-.159±.089	-1.79	-.473±.071	-6.66	.....	.....
X.	-.036±.100	-0.36	-.276±.093	-2.97	.....	.....
XI.	-.125±.086	-1.45	-.385±.074	-5.20	-.013±.087	-0.15

The predominance of negative signs indicates that within the individual periods there is a decrease in the scatter of estimates, or an *increase* in steadiness of judgment. Of the 28 constants all but 3 have the negative sign. The averages are:

	Mean Correlation
Observer B	-.158
Observer C	-.331
Observer D	-.121
All observers	-.208

Of the 28 coefficients 17 are at least twice as large as their probable errors. One of these is positive, the remainder are negative in sign.

For the present it has hardly seemed worth while to calculate the regression equations for this entire series of relationships. For experiment I. they are:

	Regression Straight Line Equations
Observer B	$s = 3.779 - .138 t$
Observer C	$s = 4.144 - .181 t$
Observer D	$s = 5.367 - .367 t$

Diagram 6 shows clearly how great the decrease in scatter of estimates as the result of a few 'trials' is. Apparently too the decrease cannot be satisfactorily represented by the slope of a straight line. The improvement is apparently more rapid at first than later, and some curves of a higher order are required to describe the rate of change.

DIAGRAM 6. Mean Standard Deviations and Regression Straight Lines Showing Change in Steadiness of Judgment within the Individual Periods of Experiment I.

To carry this matter one step farther I have calculated the correlation ratios, η , as well as r . They are:

	Coefficient of Correlation	Correlation Ratio
Observer B.....	-.210	.337
Observer C.....	-.253	.364
Observer D.....	-.349	.398

Both of these constants for all of the three observers agree in indicating a real interdependence between the number of previous trials in a period and steadiness of judgment. The signs of the coefficients of correlation show that the estimates become less erratic, or the judgment steadier. The correlation ratio is necessarily positive. Applying Blakeman's test for linearity of regression¹,

	$\xi/E\xi$
For Observer B.....	1.75
For Observer C.....	1.74
For Observer D.....	1.88

Thus these mathematical tests furnish no *proof* that the change in steadiness of judgment as the result of experience within the period can be regarded as other than linear. Sometime a detailed investigation of this question for the whole material may be in order, but there seems no advantage in going into it in greater detail at present.

III. CONCLUDING REMARKS

The purpose of this paper is the presentation of the results of a statistical analysis of extensive series of experimental data on the influence of previous experience upon errors of judgment in the estimation of the numbers of objects in moderately large samples.

The experiments comprised from 200 to 700 estimates each. These have been grouped for purposes of calculation into ultimate units of ten consecutive estimates each. These are designated as trials. The statistical constants of the errors of the ten estimations constituting a trial are the units of calculation in the present investigation. Five of these units constitute a period of the experiment.

The problems to be solved in a study of the influence of

¹ Blakemann, J., *Biometrika*, Vol. 4, pp. 332-350, 1905.

previous experience are two. Is there a modification of the characters of the estimates as a result of experience from period to period? Is there a modification of the characteristics of the estimates as a result of experience from trial to trial within the period?

The answers to these questions have been expressed in terms of the correlation between the number of previous trials within the period of the number of previous periods of experience within the experiment and personal equation or steadiness of judgment as the case may be.

Personal equation seems to be remarkably little influenced by experience. In some experiments it increases, in others it decreases. Taken as a whole the results indicate a slight reduction in personal equation as a result of experience from period to period. Within the period there is no demonstrable influence of experience upon personal equation.

Steadiness of judgment is in rather conspicuous contrast with personal equation, in that it is unmistakably influenced by previous experience. The correlations between the number of previous trials within the period and steadiness of judgment and between the number of previous periods within the experiment and steadiness of judgment are numerically low, but almost without exception indicate that as experience becomes greater the scatter of the individual estimates about their mean value becomes less. Probably the rate of this change is not uniform, but is most rapid at first and then falls off.

There are a number of points concerning these data which might be discussed in greater detail. My purpose, however, has been to present in outline the matters of fact incidentally brought out in the routine of a biologist's experiments. The detailed discussion involved in comparison and interpretation must be left for the psychologist.