STUDIES IN INDIVIDUAL DIFFERENCES IN MAZE ABILITY

II. THE DETERMINATION OF INDIVIDUAL DIFFERENCES BY AGE, WEIGHT, SEX AND PIGMENTATION [1]

ROBERT CHOATE TRYON

National Research Council Fellow, University of California

I. THE PROBLEM

The previous study (6) described the principles and methods utilized in the measuring of individual differences between rats in ability to learn two mazes, called X and Y. The evidence cited there proved conclusively, it appears, that the factors which caused individuals to differ from each other in ability to eliminate cul-de-sacs in 18 successive trials on each maze were not chance, indeed, they were so potently systematic that, for an unselected sample of 141 rats, the reliability coefficients for the two mazes were between .96 and .99. The question which one immediately raises is this: What are the causes of this marked systematic variation between rats in learning ability? Already the writer has reported (4) the preliminary work and results of an experiment which aims to ascertain the degree to which hereditary or genetic factors contributes to this systematic variance between individuals. In the present paper, it is proposed to investigate for these same animals the degree to which causes of differences in

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ability on both maze X and maze Y may reside in other known variables, namely, *age, weight, sex and pigmentation*. Such variables as these are irrelevant sources of variation, and if any of them correlates with maze performance, it will be a disturbing factor both in our inheritance problem and in our other investigations on the *generality* of the systematic factors causing differences in ability. Our problem here, then, is that of determining the degree to which each of these factors causes variation in performance, with the end in view of controlling it if it plays a significant rôle, or neglecting it if it does not.

II. THE METHODS OF ANALYSIS

The problem is complicated by the fact that two types of variables are involved: *continuous* variables, such as age and weight, and *discontinuous* dichotomous variables, such as sex (male vs. female), and pigmentation (albino vs. pigmented). The difficulty lies in translating the determination of maze ability by sex and pigmentation into statistical measures which are comparable to the determination of ability by age and weight.

For the determination by continuous variables, statistical method provides:

Method A. Determination as evidenced by simple (first order) correlation.

The correlation of maze score with age and with weight tells us in a general way of the determination of maze ability by these two factors. Trouble arises, however, in affixing definite meaning to the coefficients. A reliable r of .10 between maze score and age does not necessarily mean, as everyone knows, that 10 per cent of the variance in maze ability is determined by age. In fact, in the absence of any *à priori* knowledge of the structure of the variables involved, a given correlation possesses, as the writer has shown elsewhere (3, 5) a very elastic meaning.

For the determination by dichotomous variables, statistical method provides:

Method B. Determination as evidenced by difference between means.

This method consists in ascertaining whether the difference

between mean maze scores of males and females, and likewise the difference between mean maze scores of albino and pigmented animals, are reliably different from zero in the light of their probable errors. If each difference is reliable, then we deem sex and pigmentation to be sources of variation in ability.

Now, it is obvious that a significant difference *per se* is difficult to interpret. What one wishes to know primarily is not that a difference is or is not four times its probable error but rather the degree to which a reliable difference indicates that the independent variable determines variation in the dependent mental variable. Knowledge of the single fact that the difference between means is four times its probable error does not give us this information in any satisfactory way.[2]

There exists, however, another method which will lead us to just those degrees of determination which we desire. The writer has discussed it elsewhere (3, 5). Properly speaking, it is not coördinate with methods A and B, since it makes use of the values calculated under those methods and translates the values into certain meaningful and comparable measures. But for convenience of classification we may term this method:

Method C. Determination as evidenced by percentage degree of determination.

The differences between individuals in maze scores result from variation in numerous component variables or factors. Our particular problem is that of discovering the per cent by which this variation in maze learning is due to variation in certain assigned variables, sex (S), pigmentation (P), age (W), and weight (Z). We will call the ability on the first maze, the X ability, and denote as the most suitable measure of individual differences in the X ability, the variance, or σ_x^2. We shall make *one assumption*, namely, that if these four factors affect variation,

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[2] Vast quantities of research in psychology which are daily being reported in the literature indicate that investigators have as their sole objective, it appears, the proving that the difference between mean scores in a given mental variable of a "control" group as against an "experimental" group is four times its P.E. In the light of what is said above, such results in themselves, appear relatively sterile.

in maze ability they do so in the relation of element to composite, that is, we shall assume, for instance, that age influences maze ability, and maze ability not age. Specifically, if there is any correlation between ability and age, we shall assume that the variance in maze ability is due to variance in age plus variance in other factors than age. This variance in X scores due to other factors than age has the meaning of the variance in performance of animals of the same age, whereas the variance in X scores due to age is the additional variance in performance among animals when their age is permitted to vary through a defined region of variation. We shall consider this assumption more fully when we take up each factor later.

In equational terms, we assume that

$$\sigma^2_x = \sigma^2_{x_w} + \sigma^2_{x_{ow}} \tag{1}$$

in which σ^2_x represents the variance among individuals in maze scores, $\sigma^2_{x_w}$ is the portion contributed by age variance, and $\sigma^2_{x_{ow}}$ is the remainder of the variance due to other factors than age. The percentage determination of the X ability by W is *defined* as the fraction, $\sigma^2_{x_w}/\sigma^2_x$, and the percentage determination of X by factors other than age is the remaining fraction, $\sigma^2_{x_{ow}}/\sigma^2_x$, which equals $1 - (\sigma^2_{x_w}/\sigma^2_x)$. These percentages have thus a simple meaning, for the per cent of maze variance due to age variation plus the per cent of maze variance due to variation in other factors than age equals 100 per cent. The determinations may be calculated from the variances if such are available, but more simply they are derivable, as I have proved elsewhere [3, formula (13)], from the correlation coefficient between X and W, namely from the equalities:

$$\sigma^2_{x_w}/\sigma^2_x = r^2_{xw} \quad \textit{Percentage determination of X by W} \tag{2}$$

$$\sigma^2_{x_{ow}}/\sigma^2_x = 1 - r^2_{xw} \quad \textit{Percentage determination of X by other factors than W} \tag{3}$$

The percentage determinations of X by Z (body weight) may be calculated by the formulae above where Z is substituted for W.

But with sex and pigmentation the matter is more complicated. Take the case of sex. We wish to know the degree to which

variation in sex causes variation in maze performance. The evidence we possess is the difference between M_1, mean of males in X scores, and M_2, mean of females in X scores, the reliability of which we test by the probable error of a difference formula. These statistics we shall translate into a percentage determination of X by S by means of the following reasoning:

Let the variance of X among the N_1 males be $\sigma^2_{x.1}$, among the N_2 females be $\sigma^2_{x.2}$. From these values, the variance among individuals in ability *due to other factors than sex*, that is, variations between individuals of the same sex, may be considered to be approximately the following weighted average value:

$$\sigma^2_{x_{os}} = \sigma^2_{x \cdot s} = \frac{N_1\, \sigma^2_{x \cdot 1} + N_2 \sigma^2_{x \cdot 2}}{N_1 + N_2} \tag{4}$$

The full variance of X *due to all factors* (sex + other factors) causing individual differences in the population in question is σ^2_x and may be calculated from the partial sigmas by sex from the Yulean formula (7, p. 142, formula 5) which gives the composite sigma from components:

$$\sigma^2_x = \frac{N_1\, [\sigma^2_{x \cdot 1} + (M_1 - M_x)^2] + N_2\, [\sigma^2_{x \cdot 2} + (M_2 - M_x)^2]}{N_1 + N_2} \tag{5}$$

where M_x is the composite weighted mean, $M_x = (N_1 M_1 + N_2 M_2)/(N_1 + N_2)$. In accordance with our definition that percentage determination is the variance of maze ability due to a given factor divided by the full variance in ability due to all factors at work in the population, then (4) over (5) is the percentage determination of X by factors other than sex, to wit:

$$\frac{\sigma^2_{x_{os}}}{\sigma_x} = \frac{\sigma^2_{x \cdot s}}{\sigma^2_x} = \text{\textit{Per cent of X variance due to other factors than sex}} \tag{6}$$

and

$$1 - \frac{\sigma^2_{x_{os}}}{\sigma^2_x} = \text{\textit{Per cent of X variance due to sex difference}} \tag{7}$$

Analogous percentage determinations of X by P (pigmentation) may be calculated from (6) and (7) where P may be substituted for S.

It has elsewhere been shown that for variables as constituted here, the square root of these percentage determinations is the correlation coefficient between the resultant mental variable and the respective contributing factor (3, pp. 420–426), that is, for example, the square root of (7) is the coefficient, r_{xs}, and the square root of (6) is $r_{x \text{ (other factors than } x)}$.[3]

To sum up, then, it may be said that we possess three methods by means of which we may ascertain the dependence of individual variation in maze ability upon the four factors, age, weight, sex, and pigmentation. The first two methods, A and B, tell us only in a crude way of this dependence; method C, however, enables us to ascertain the *percentage* determination of maze ability differences by these several factors. And what we have said for the X ability holds of course for the Y ability.

Our next problem, then, is actually to examine the experimental results and to calculate the percentage determinations of both the X and Y ability by the irrelevant factors.

III. RESULTS

In the discussion so far, we have considered only fallible measures of maze ability. But the fallible differences between individuals are not ordinarily entirely a function of systematic factors. There usually exists a variance due to chance factors. Since this chance variance has no systematic origin, we must eliminate it from any consideration and deal primarily with the variance of scores which arises *solely* from systematic factors.

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[3] As a general method of calculating r, the method used above would require cautious handling. If one were to ascertain r_{xk} from the values of the variances of X in two extreme classes K_1, K_n of the contributing factor, K, which runs normally through classes K_1, K_2, K_3, . ., K_n, then the total variance of X calculated from (5) would be greater than that which would have obtained had the classes intervening between K_1 and K_n been present. Hence, the percentage determinations and correlation coefficients calculated form (7) would be smaller if intervening classes in K were present. One must therefore interpret the values from (6) and (7) relative to the degree of selection in the contributing variable and one should not expect the same values to appear if another type of selection exists. With the dichotomous variables with which we deal in this paper, *no other degree of selection can exist* than the one present, for there exists no intervening degrees of sex or pigmentation than the ones here considered. Hence, the values for the determinations which we calculated would not be affected by selection.

In particular, we desire to ascertain the degree to which individual differences in true scores, X_∞ and Y_∞ are caused by the irrelevant systematic factors with which we are dealing in this paper. The removal from the variance of fallible scores of that portion due to attenuating errors of measurement is generally effected by sundry statistical corrections. Fortunately, we have already experimentally reduced such attenuation almost to a negligible quantity (6). In the following text, therefore, corrections for attenuation may safely be neglected. They will be given, however, in a summary table at the end of the paper. In order to prove that we may neglect corrections and that we are dealing with determinations of systematic differences between individuals, I shall indicate as percentage determinations the degree to which errors of measurement and true systematic factors affect fallible differences between individuals.

a. Determination of fallible maze scores by errors of measurement,
E_x and E_y

In another place, the writer has shown (5) that the percentage determination of the variance of individuals in the fallible measures, such as X, by errors of measurement, E_x, is unity less the reliability coefficient, r_x. Thus,

Percentage determination of maze score, X, by errors, $E_x = \sigma^2_{e_x}/\sigma^2_x = r^2_{e_x x} =$
$1 - r_x = 1 - .9876 = .0124.$

Percentage determination of maze score, Y, by errors, $E_y = \sigma^2_{e_y}/\sigma^2_y = r^2_{e_y y} =$
$1 - r_y = 1 - .9682 = .0318.$

The rôle of unsystematic errors of measurement in the causation of individual differences in fallible X, is approximately 1 per cent, that in fallible Y, not more than 4 per cent.

b. Determination of fallible maze scores by true systematic factors,
X_∞ and Y_∞

Since errors of measurement constitute the unsystematic factors, then true systematic factors produce the remaining per cents, to wit:

Percentage determination of maze score, X, by systematic factors, X_∞ =
$\sigma^2{}_{x_\infty}/\sigma^2{}_x = r^2{}_{x_\infty x} = r_x = .9876$.

Percentage determination of maze score, Y, by systematic factors, Y_∞ =
$\sigma^2{}_{y_\infty}/\sigma^2{}_y = r^2{}_{y_\infty y} = r_y = .9682$.

Thus it is evident that close to 100 per cent of the fallible variation between individuals is due to the systematic true variance. The *correlation* between the fallible and true scores is virtually unity, for $r_{x_\infty x} = .9938$, and $r_{y_\infty y} = .9840$.

c. Determination of maze ability by the irrelevant factors

In this section we will ascertain the percentage determination of variance in maze ability by the variance occasioned by spread in age, weight, sex and pigmentation. Variation in each of these irrelevant factors was purposely permitted at the outset of the inheritance experiment. The customary procedure in many maze experiments has been to control such factors. But such control puts severe practical limitations on an investigation and is, in fact, unnecessary if it can be shown that variation in the irrelevant factor does not affect performance. But if it *does* affect the score, then control introduces *selection* in the mental variable—a dangerous situation if the *degree* of the selection remains unknown. But unfortunately it cannot be known unless one permits the irrelevant factor to vary and the correlation discovered. The proper procedure in escaping from this dilemma would be, it seems, to let such a factor vary over a designated region of variation, then calculate the percentage degree to which such variation determines performance. If the determination is negligible, then no limitations need be put on the experiment regarding this factor. If it prove significant, then control should be introduced only down to the limits of variation of the factor within which the correlation of this factor with performance is negligible. To illustrate this point, if one control age by using, say, only 60-day-old animals and no others, this is a needless limitation if there is no correlation of age with performance. If there is a significant correlation, then the use of 300-day-old instead of 60-day-old animals (such selection is arbitrarily

determined by the experimenter) would have resulted in a materially *different* performance. What age should one select? The sensible procedure is to permit age to vary, say, from 60 to 300 days, calculate the correlation, and then select that region of age variation within which the correlation of age with score was zero.

1. Determination of maze ability by age (W).

The variable, age, represents a factor which has as many values as there are ages. It is a homogeneous variable having one degree of freedom. That is, the hypothesis seems untenable that an age of 125 days, for instance, may be considered an expression of numerous component factors, or sub-ages, part of which may determine variation in maze ability, the other part specific to age and not related to maze variance.[4] In determining a portion of the variance in maze ability, age may only be considered as an elementary systematic factor in maze ability, provided it influences maze ability at all.

The data. The ages of 98 animals were known exactly, of 42 animals within a week. The age of one animal was unknown. The age variables involved are:

W_1 = Age in days from birth to first day of running maze X proper

W_2 = Age in days from birth to first day of running maze Y proper

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[4] Such an hypothesis would be legitimate if age of maze-running extended over such a long range that the oldest animals chosen to run were a selected group and furthermore, the somatic expression of multiple genetic factors determining longevity. One could then argue as follows: the age at which each body tissue (nervous, glandular, muscular, etc.) wears out, and thus results in the death of the animal, may be determined by independent genetic factors. Suppose that the quality or efficiency of the nervous tissue was correlated with the longevity of it, that is, the more excellent the tissue the longer would it last. Now, since maze ability would depend *in part* upon nervous excellence, which we have said may be correlated with neural longevity, then the older animals would tend to be the better maze runners. Since death of animals results from wearing out of other tissues than nervous, as well as from adventitious causes, age of running (a function of longevity of the animals if the age at running is permitted to spread over such a wide range that a selective death rate ensues) and maze ability would be determined by common neural factors as well as unique residual factors specific to each. This hypothesis cannot be tendered here, however, because age covered a period during which the number of deaths was negligible, and thus no selective death rate occurred.

For references to the age factor and the learning of rats, see 1 and 2.

The range[5] of the W_1 ages was from 100 days to 339 days, of the W_2 ages from 135 days to 390 days.   The means and sigmas were:

$$M_{w_1} = 224 \text{ days} \qquad \sigma_{w_1} = 72 \text{ days}$$

$$M_{w_2} = 263 \text{ days} \qquad \sigma_{w_2} = 69 \text{ days}$$

Correlations were computed between X and W_1 and between Y and W_2. The scatter diagrams of these correlations are given in figures 1 and 2, respectively. The plots show that just no relation between age and score exists throughout. Lest it be thought that the 42 animals, whose ages were in possible error of a week might have "destroyed" a real correlation among the others, the entries of these 42 animals have been marked by a dash in the plot of figure 1. It must be apparent that the deletion of these would negligibly have altered the relation.

The correlations computed from these scatter diagrams were:

Correlation between maze X score and age, $W_1 = r_{xw_1} = .05$

Correlation between maze Y score and age, $W_2 = r_{xw_2} = -.05$

The percentage degrees of determination as calculated from these r's are, by formulae (2 and 3):

Percentage determination of maze X scores by age, $W_1 = r^2_{xw_1} = .0025$

Percentage determination of maze Y scores by age, $W_2 = r^2_{yw_2} = .0025$

The decision that these determinations are not significantly different from zero lies in the fact that the r's upon which they are based are insignificantly different from zero, for $P.E._{r's} = \pm.05$.

Thus we may conclude that individual differences in these maze abilities are not affected by differences in the systematic factor, age, at least, for the range considered here.

2. Determination of maze ability by weight (Z).

The evidence as to the weight-performance relationship is important in that it sheds light on the *incentive to learn*. At the end of each run on maze X, all of the males were given the same

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[5] For a distribution of the ages, see the preceding paper (6).
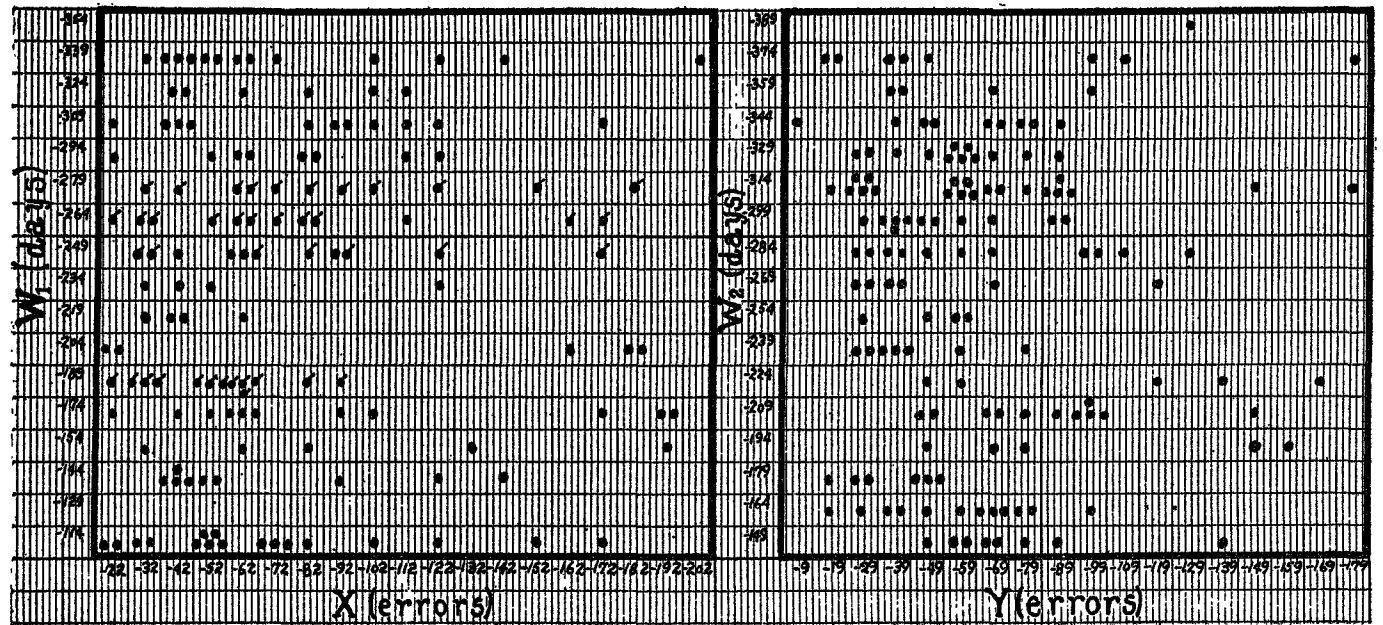
FIG. 1   FIG. 2

FIG. 1. SCATTER DIAGRAM SHOWING THE CORRELATION BETWEEN X (ERROR SCORE ON MAZE X) AND W_1 (AGE ON FIRST TRIAL ON MAZE X)

The dashed entries represent rats whose ages have a possible error of a week

FIG. 2. SCATTER DIAGRAM SHOWING THE CORRELATION BETWEEN Y (ERROR SCORE ON MAZE Y) AND W_2 (AGE ON FIRST TRIAL ON MAZE Y)

amount of food regardless of their initial weight. The females were likewise given the same amount, but being less heavy than the males the quantity given was less.[6] If this constant reward penalized the heavy rats, and over-fed the lighter ones, or had any differential effect, then one would expect the *drive* to vary in a systematic way among the animals and to be correlated with their weights. If this variation in drive affected maze performance, then a significant correlation would appear between maze score and weight.

Conditions were somewhat different on maze Y. At the end of each run, the animals were permitted to eat as much as they chose, that is, until they first showed lack of interest in the food. Their final weights, taken on their last Y run, were therefore not affected by such arbitrary feeding conditions as obtained on maze X.

As to the relation between the factors determining the weight and performance variables, the situation is doubtless complex. As a variable, gross weight has many degrees of freedom, that is, it is a function of many probably independent factors. It is certainly the summed weights of numerous component weights of separate parts which are themselves probably multi-factorially determined. Now, to the degree, however small, to which gross weight influences maze ability, it is logical to suppose that all the elemental weights contribute their differential share. Suppose, for instance, that the variance of gross weight contributes 1 per cent to the variance of maze ability due to the differential nutritive effect of constant food on rats of different weights. Since each of the organs, the elementary weight of which contributes its share to gross weight, is itself affected in its own weight by the amount of nutrition which it receives, it contributes its proportional share to the total amount of variance which gross weight contributes to maze ability.

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[6] For details, see the previous paper (6). Incidentally, the writer believes that the starvation regimen often imposed upon the rat "to increase the incentive" is bad technique, since it introduces a host of uncontrolled factors. Even with the generous reward given on maze Y, no lethargy was noted in the running of the animals.

There are other theories which one may hold as to the interaction of the factors, but any *à priori* theory which the writer has entertained has always led him to the hypothesis that the variance of gross weight enters in its entirety into maze ability variance, however small this degree of determination may be. Perhaps it is not wise to be too dogmatic in our hypothesis as to the substructure of these variables, in view of the fact that these substructures are not known for either variable. As a matter of fact, however, the total degree of determination of maze ability by gross weight turns out to be so small as not to involve us in serious difficulties even if it be eventually discovered that some elements of gross weight are specific to gross weight and independent of maze ability.

The data. Since we wish to observe the effect of weight variation *per se* upon maze ability, we must hold sex constant, for the males and females differ significantly in weight. The males were of greater number ($N = 88$) and were therefore chosen for this analysis. The variables involved are:

Z_1 = weight in grams on first day of encountering experimental conditions of maze X.

Z_2 = weight in grams on nineteenth day of running on maze Y.

Means and sigmas were as follows:

$$M_{z_1} = 282 \text{ grams} \qquad \sigma_{z_1} = 39 \text{ grams}$$

$$M_{z_2} = 248 \text{ grams} \qquad \sigma_{z_2} = 30 \text{ grams}$$

The decrease in average weights in Z_1 and Z_2 does not mean that the rats as a group lost weight during the experimental period. The times at which the animals were weighed were not comparable. The Z_1 weights were taken at the time the rats were removed from their living colony cages. In the living cages food and water had been before them continually. The Z_2 weights were taken, on the other hand, twenty-four hours after the animals had been fed at the end of their eighteenth run on Y. For the Z_1 and Z_2 means to be comparable, it would have been necessary for *both* weights to have been taken, say, twenty-four hours after being in the presence of food and water.

The correlations between Z_1 and X, and between Z_2 and Y were computed from the scatter diagrams represented in figures 3 and 4. No significant relationship between weights and maze performance is indicated by either plot. The correlations were:

Correlation between maze X score, and weight $Z_1 = r_{z_1 x} = -.09$

Correlation between maze Y score, and weight $Z_2 = r_{z_2 y} = -.11$

The percentage determinations calculated from these correlations are:

Percentage determination of maze X score by weight, $Z_1 = r^2_{z_1 x} = .0081$

Percentage determination of maze Y score by weight, $Z_2 = r^2_{z_2 y} = .0121$

These determinations are doubtless insignificantly different from zero because the correlations upon which they are based are not significantly different from zero (P.E.$_{r's} = \pm.07$).

In conclusion, then, we may say that the evidence indicates that the individual differences in performance on maze X and maze Y are in no significant degree determined by differences in weight, and that differences in drive attendant upon weight differences do not exist.

3. Determination of maze ability by sex (S).

If sex variation bears any relation whatsoever to maze ability, it can do so only in the relation of element to composite. This is true because we know on the basis of genetic evidence that as a variable sex has only one degree of freedom, i.e., it depends upon variation in *one* genetic determiner only. The determination of sex is by the interaction of the X and Y chromosomes, which results in sex being inherited in the simple unifactorial manner, male (XY) and female (XX) progeny always being the result of a cross between the XX female homotype and the XY male heterotype. Since variation in maze ability, on the other hand, behaves in such a way as to indicate that it has n degrees of freedom, i.e., is determined by n multiple genetic and environmental factors, one of the elementary factors may be the sex determiner.
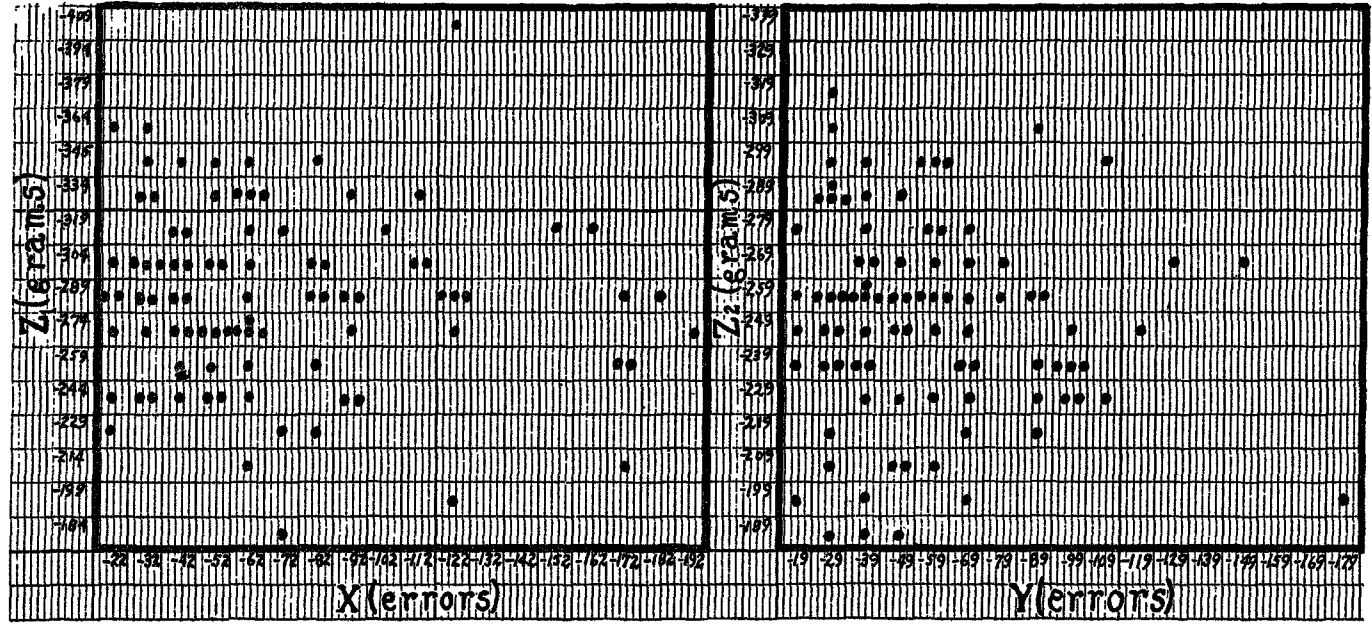
FIG. 3

FIG. 4

FIG. 3. SCATTER DIAGRAM SHOWING THE CORRELATION BETWEEN X (ERROR SCORE ON MAZE X) AND Z_1 (WEIGHT ON FIRST DAY UNDER MAZE X EXPERIMENTAL CONDITIONS)

FIG. 4. SCATTER DIAGRAM SHOWING THE CORRELATION BETWEEN Y (ERROR SCORE ON MAZE Y) AND Z_2 (WEIGHT ON NINE-TEENTH DAY OF RUNNING MAZE Y)

The data. As sex is a discontinuous variable, the calculation of the determination of maze ability by sex differences must be derived, as we have seen, from the significant difference, if one exists, between the mean maze scores of males and females. The 88 males, denoted by *M*, and 53 females, *F*, gave means and standard deviations as follows:

$$M_{m_x} = 67 \text{ errors} \qquad \sigma_{m_x} = 42 \text{ errors}$$

$$M_{f_x} = 83 \text{ errors} \qquad \sigma_{f_x} = 49 \text{ errors}$$

$$M_{m_y} = 53 \text{ errors} \qquad \sigma_{m_y} = 31 \text{ errors}$$

$$M_{f_y} = 74 \text{ errors} \qquad \sigma_{f_y} = 37 \text{ errors}$$

These values indicate that in both maze performances, the females did more poorly and were more variable than males.

The questions to be answered are two:

1. Are these differences between means of males and females significant statistically? The results are:

Difference between means of males and females in X scores 16 errors ±5.54

Difference between means of males and females in Y scores 21 errors ±4.05

The numbers after the differences are probable errors. The values show that the sex difference on X is about 3 times its probable error, that on Y about five times. From the point of view of probable errors, therefore, the X difference is on the border line of significance, that on Y almost surely significant.

On the basis of evidence from the performance of several hundred more animals[7] than those involved above, the writer feels that a real sex difference exists in the X ability, and of about the magnitude shown above. Assuming, then, that a real difference exists between the sexes in our X and Y abilities, the origin of this difference may lie, in the writer's opinion, in purely local features of our experimental technique. It happened that both males and females were run upon the same maze. The males were run first each day, the females followed. The smell of the males may have produced a disturbed performance of the females. The experimenter did observe that the females occasionally

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[7] Nearly 700 animals have already been run in the inheritance problem (2).

sniffed, explored, and showed the characteristic tenseness which indicates awareness of a disturbing cue. Whether the origin of this sex difference in maze ability can be safely assigned to our special maze technique, instead of, on the other hand, to a biologically determined general timidity or inferiority of the females which would have appeared upon a maze of their *own*, cannot, of course, be definitely decided here.

2. Assuming these sex differences to be real, of what degree of importance are they in determining individual differences in maze performance? To answer this question we must calculate the percentage determination by means of formula (7).

Percentage determination of maze X score by sex, $S = (\sigma^2_x$ due to sex$)/\sigma^2_x =$
$1 - (\sigma^2_{x.s}/\sigma_x^2) = .029$

Percentage determination of maze Y score by sex, $S = (\sigma^2_y$ due to sex$)/\sigma^2_y =$
$1 - (\sigma^2_{y.s}/\sigma^2_y) = .085$

The per cents indicate by formula (6) that about 97 per cent of the X variance and about 91 per cent of the Y variance are produced by factors other than sex.

The derived correlation coefficients ascertained by taking the square roots of equation (7) were:

$r_{xs} = .17$ $\qquad\qquad\qquad$ $r_{ys} = .29$

or, more intelligibly, the derived correlation coefficients between other factors than sex and maze scores are, by taking the root of equation (6):

$r_{x(\text{other factors})} = .99$ $\qquad\qquad$ $r_{y(\text{other factors})} = .96$

From these data on sex, we may conclude that the determination of individual differences in maze performance, especially on Maze Y are truly but to a negligible extent affected by sex differences.[8]

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[8] For a high correlation to exist between sex and maze score, all of the males would earn low scores in maze performance, all the females high. Pictorial evidence that this is not so is presented in the correlation distributions of figure 3 in the previous paper (4) in which the males are differentiated from females as entries in the scatter diagrams.

4. Determination of maze ability by pigmentation (P).

The pigmentation variable consists of the two categories: presence and absence of pigmented eyes. The pigmented-eyed rats had also pigmented coats which ranged from a small hood to solid, "self" color. The non-pigmented-eyed animals had pink eyes, and white coats (albinos). The reason for investigating this variable is that pigmented eyed animals have better vision than pink-eyed, hence differences in maze performance might possibly arise in part from this differential visual acuity.[9]

The most plausible hypothesis to take regarding the factorial relation of pigmentation to maze ability is the postulation that if pigmentation influences maze ability at all it does so in only two ways, namely, by virtue of the presence of pigmentation and the absence of it. Even though the number of factors which determine pigmentation are complex,[10] so that this variable may have several degrees of freedom, these factors interact to produce only two kinds of pigmentation variation (as far as we are concerned). Since these two kinds by hypothesis are, if causal agents in determining maze ability, components of it, then the sundry factors influencing color heredity are themselves components of maze ability. That is to say, we do not conceive of the pigmentation variable possessing certain factors in common with maze ability but also other residual factors which affect pigmentation but *not* maze ability.

The data. Most of the females were albinos, hence it was thought advisable to compare only pigmented males with albino males. Had we included the females, a difference in mean maze score of the pigmented and albino animals may have appeared because of the slight sex difference already discussed.

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[9] Dr. E. G. Wever and Miss Esther Robinson, working in the California laboratory, performed an experiment to discover if such differential visual acuity attendent upon pigmentation difference really existed. Their results, which I understand are to appear soon in the *Univ. Calif. Publ. Psych.*, indicate that such a differential occurs.

[10] In rodents albinism apparently depends upon the recessive condition of a general color factor. Other independently assorting factors, however, interact in such a way as to complicate the genetic scene, for animals may be heterozygous or homozygous dominant for a given color factor and yet be albino, provided they are homozygous recessive in the general color factor.

Denoting the pigmented animals (N = 40) as C (colored), the non-pigmented (N = 48) as A (albino), the mean maze scores were as follows:

$$M_{a_x} = 64 \text{ errors} \qquad \sigma_{a_x} = 41 \text{ errors}$$

$$M_{c_x} = 70 \text{ errors} \qquad \sigma_{c_x} = 43 \text{ errors}$$

$$M_{a_y} = 47 \text{ errors} \qquad \sigma_{a_y} = 24 \text{ errors}$$

$$M_{c_y} = 61 \text{ errors} \qquad \sigma_{c_y} = 36 \text{ errors}$$

From these figures, it appears that the pigmented or colored animals are slightly poorer and more variable in maze running.

The same two questions queried regarding the sex scores must be answered for pigmentation:

1. Are the differences between the means of pigmented and albinos significant statistically? The results are:

Difference between means of X scores of colored and albino animals = 6 errors ± 6.11

Difference between means of Y scores of colored and albino animals = 14 errors ± 4.45

That the difference between the two groups in the X performance is significantly greater than zero is questionable, for it does not exceed one probable error, but the difference in the Y measures, being more than three times its error may be significant. As with sex, the difference between the pigmented and albino groups is believed to be really greater than zero and of about the magnitude indicated above—this, on the basis of evidence from more animals than are involved here. There are too few cases here, apparently, to demonstrate the statistical significance of this difference. In order to get a fair answer to the second question we shall assume that the differences above are real.

The theory which may be advanced to explain why pigmented animals tend to do slightly more poorly than albinos is that their better vision causes them to be disturbed more easily by extraneous stimuli. By extraneous stimuli, I mean such as arise from movements of curtains and doors initiated by the animals themselves. The better vision of the pigmented animals is apparently

not, on the other hand, an aid to them in learning, for the paths contain curtains placed at such strategic positions as to prevent the animal from discerning, when he comes to the choice point, which is the true path and which the blind alley.

2. Whatever may be the cause of the difference between albinos and pigmented, does it to *any significant degree* affect individual differences in maze ability? The percentage determinations from formula (7) are:

Percentage determination of maze X scores by pigmentation difference, $P = (\sigma^2_x$ due to $p)/\sigma^2_x = 1 - (\sigma^2_{x \cdot p}/\sigma^2_x) = .004$

Percentage determination of maze Y scores by pigmentation difference, $P = (\sigma^2_y$ due to $p)/\sigma^2_y = 1 - (\sigma^2_{y \cdot p}/\sigma^2_y) = .055$

These determinations indicate by formula (6) that .996 and .945 of the X and Y performances respectively, are due to other factors than pigmentation. The derived correlations are:

$$r_{xp} = .06 \qquad\qquad r_{yp} = .23$$

$$r_{x(\text{other factors})} = .998 \qquad\qquad r_{y(\text{other factors})} = .972$$

From these evidences,[11] the conclusion is obvious that as a factor in maze ability pigmentation is negligibly potent in determining individual differences in maze ability.

IV. SUMMARY AND CONCLUSIONS

a. The purpose was to ascertain the degree to which individual differences in maze performance were determined by each of the following factors: age (W), weight (Z), sex (S), and pigmentation (P).

b. Three methods by which such determinations may be made were described and utilized. These were the method of simple correlation, the method of significant differences, and the method of percentage degree of determination.

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[11] The negligibility of the relation between pigmentation variation and maze score is pictorially shown in the correlation scatter diagrams of figure 3 in the previous paper (6), where it is apparent that the pigmented animals (blacked entires) are present in all parts of the performance range, a condition which would reduce the correlation to zero.

c. Two T-mazes were used, X (17 blind alleys) and Y (20 blind alleys). The subjects were 141 adult rats of variable age, weight, sex, and pigmentation.

d. The results may be summarized in tables 1 and 2.

TABLE 1

Means and standard deviations of the sundry variables

	SCORE X (TOTAL ERRORS IN 18 TRIALS)		SCORE Y (TOTAL ERRORS IN 18 TRIALS)	
	Mean	S.D.	Mean	S.D.
Total group, $N = 141$.	72.6737 ± 2.564	45.1362 ± 1.813	60.954 ± 1.963	34.5646 ± 1.388
Males, $N = 88$.......	66.818 ± 3.035	42.206 ± 2.146	53.136 ± 2.206	30.681 ± 1.560
Females, $N = 53$.....	82.783 ± 4.515	48.709 ± 3.193	73.935 ± 3.400	36.680 ± 2.404
Pigmented, $N = 40$..	69.750 ± 4.619	43.330 ± 3.266	61.000 ± 3.788	35.534 ± 2.678
Albino, $N = 48$......	64.375 ± 3.998	41.086 ± 2.827	46.583 ± 2.341	24.064 ± 1.655

	AGE W_1 (DAYS)		AGE W_2 (DAYS)	
Total group, $N = 140$.	223.786 ± 4.127	72.401 ± 2.918	263.290 ± 3.922	68.805 ± 2.773

	WEIGHT Z_1 (GRAMS)		WEIGHT Z_1 (GRAMS)	
Total group, $N = 88$.	282.171 ± 2.837	39.459 ± 2.006	248.023 ± 2.157	30.002 ± 1.525

TABLE 2

Percentage degrees of determination and correlation coefficients

DETERMINATION OF:	PER CENT	r	DETERMINATION OF:	PER CENT	r
X by E_x, $N = 142$......	.0124	.1114	Y by E_y..............	.0318	.1783
X by X_∞, $N = 142$.....	.9876	.9938	Y by Y_∞.............	.9682	.9840
X by W_1, $N = 140$......	.00	.0458	Y by W_2..............	.00	$-.0457$
X by Z_1, $N = 88$........	.00	$-.0879$	Y by Z_2..............	.00	$-.1120$
X by S, $N = 88 + 53$....	.0290	.1703	Y by S...............	.0849	.2914
X_∞ by S, $N = 88 + 53$.	.0294	.1715	Y_∞ by S.............	.0877	.2961
X by P, $N = 40 + 48$...	.0040	.0632	Y by P..............	.0548	.2341
X_∞ by P, $N = 40 + 48$.	.0041	.0640	Y_∞ by P.............	.0566	.2379

N. B.: In the above tables the notation is as follows: fallible maze scores are X or Y, true scores are X_∞ or Y_∞, errors of measurement E_x or E_y, age is W, weight is Z, sex is S, pigmentation is P. The number after $\pm$ is P.E. The P.E. of all r's are in the neighborhood of $\pm.05$ except for the r's around .96, the P.E.'s here being about $\pm.002$. The N for a given row in table 2 is the same for X and Y. The values in these tables are to more places than those cited in the text, where the places were kept only to that indicated by one-half the P.E. For the formulae used in securing the numerical values above see the text and references (1, 3).

e. Under the conditions of measurement in these experiments, the conclusion may be drawn that such factors as age, weight, sex, and pigmentation determine to a negligible degree differences between individuals in the learning abilities measured by maze X and maze Y.

REFERENCES

(1) LIU, S. Y.: The relation of age to the learning ability of the white rat. Jour. Comp. Psychol., 1928, viii, 75–86.

(2) STONE, C. P.: The age factor in animal learning: I. Rats in the problem box and the maze. Genet. Psychol. Monog., 1929, v, No. 1, 1–130. II. Rats in a multiple light discrimination box and a difficult maze. Genet. Psychol. Monog., 1929, vi, No. 2, 125–202.

(3) TRYON, R. C.: The interpretation of the correlation coefficient. Psych. Rev., 1929, xxxvi, 419–445.

(4) TRYON, R. C.: The genetics of learning ability in rats—a preliminary report. Univ. Calif. Publ. Psych., 1929, iv, 71–89.

(5) TRYON, R. C.: The reliability coefficient as a per cent, with application to correlation between abilities. Psych. Rev., 1930, xxxvii, 140–157.

(6) TRYON, R. C.: Studies in individual differences in maze ability: I. The measurement of the reliability of individual differences. Jour. Comp. Psychol., 1930, xi, 145–170.

(7) YULE, G. U.: An introduction to the theory of statistics. London: C. Griffin and Co., Ltd., 1922.