CHAPTER 12

Individual Differences

ROBERT C. TRYON
University of California

Introduction

INDIVIDUALS are classed together as belonging to a single species when they possess common characteristics and when the "average individual" of the species differs significantly in these characteristics from the "average individuals" of other groups. The intensive study of the average behavior of a species, however, generally leads the comparative psychologist to ignore the more interesting and important differences between individuals from whom the "average individual" is abstracted. The "average individual" is, in fact, a man-made fiction, and the behavior of a species can properly be understood only by considering the variations in behavior of all (or of a random sample of) the individuals who are classed in it. Indeed, the very origin of a new species presupposes wide differences between individuals produced in overabundant quantities who struggle and compete for existence, the consequence being a selection of the more successful. The peak of mental evolution represented by man presupposes the existence of wide behavior differences among individuals of lower species.

It would thus seem natural that one of the main interests of the comparative psychologist would be individual differences in behavior. Yet adequate scientific studies of individual differences among men began only about three decades ago, with the origin of the mental test movement; and such studies among subhuman forms have been undertaken only within the last ten years. The reasons for this long delay are the fact that the problems to be attacked were not clearly envisaged and that adequate experimental-statistical techniques were not available. The problems and the techniques are now, however, quite apparent, with the consequence that in recent years a rapid development of research in individual differences has taken place. The purpose of this chapter is to acquaint the student with the problems, techniques, and evidence collected to date. We shall confine our study to the evidence on subhuman forms, but the problems and techniques are truly comparative; they are as pertinent to the human being as to lower species.

The psychological and quantitative principles employed in an adequate study of individual differences

Psychologists classify the dynamic behavior adjustments of a species into rather arbitrary categories (learning, sense-acuity, drive, and so forth) to which we give the label "behavior-domains." Each of these domains is an abstraction referring to some aspect of adjustment and can be further re-analyzed into "sub-domains." Thus, the behavior-domain "learning" refers to the propensity of the individual to improve in adjustment to the same situation apart from the effects of maturation; and it can be subdivided further into maze learning, problem-box learning, sensory-sign learning, and so forth. To avoid confusion due to differences in terminology, one should think of behavior not in terms of the more broadly defined abstractions but in terms of the actual situation in which it is manifest. With these preliminary cautions in mind, we may examine certain principles employed in the experimental study of individual differences.

(1) *The behavior-domain to be studied should be defined as a specific measure of behavior in a given situation.* Thus, instead of labelling performance in a maze "maze ability," an abstraction which implies that what is being measured is *general* capacity to learn all kinds of mazes, it is best to define the behavior specifically, for example, "total blind entrances in a given 10-unit T-maze during 30 trials under experimental conditions, *K*," *K* being fully described. For the sake of brevity, one may, of course, call the behavior "maze learning," *provided* one retains the mental reservation that only this particular maze behavior is meant.

(2) *The "validity" of a measure depends upon whether the behavior measured satisfies the broad definition of the domain.* Thus, an experimenter may contend that he is measuring differences in "visual acuity," but his measure can be considered valid only if by an *a priori* psychological analysis he shows that the situation elicits differences in acuity *per se*. Later we

shall see, for instance, that what is measured in a discrimination-box seems, on analysis, to be visual sign *learning* rather than visual acuity. It appears, therefore, that upon the analytical acumen of the experimenter the proper estimation of the "validity" of a measure of behavior depends.

(3) *The situation that elicits the measured behavior should be adapted to the sensory-motor equipment and "natural" behavior-patterns of the species.* All the available experimental and observational data on the species should be brought to bear on the devising of suitable "test" situations. Fowls have good vision and live in open spaces, but rats have relatively poor vision and live in closed-in spaces; each species has its idiosyncrasies, and test situations devised to study individual differences in the sundry behavior-domains should be adapted to these idiosyncrasies.

(4) *The "universe" of subjects and the experimental group of individuals drawn from it should be defined and the nature of the selection made known.* Ideally, one would wish to study a random sample of the whole species, but to do so is ordinarily impossible. Usually, one has to use the laboratory stock available, and whether this stock is a random sample or is inbred or selected for certain characters is rarely known. Lack of knowledge on this score is a crucial deficiency, for obviously, if the stock derives from an inbred strain, all the individuals tend genetically to be the same, and hence, individual differences may not appear. A *definition* of the *stock* from which the observed sample is drawn should include a statement of its origin and the degree to which it has been inbred. Regarding the *sample* of individuals studied, a statement should be made as to the nature of selection from the stock; that is, if it is a random selection, it should be so described—or the number of litter-mates used should be given; and the age of individuals, their previous experience, and the number of individuals should be stated.

(5) *Two comparable measures of the behavior-domain should be secured for each individual in order to ascertain the extent and consistency of individual differences.* The importance of this requirement will be made apparent by a concrete illustration. Suppose our problem were to study individual differences in the domain "blind-alley entrances in a given 10-unit T-maze during 30 trials." We have chosen our sample of rats and have run them on the maze. Rat *A* turns out to be a poorer learner than Rat *B*, making considerably more errors than *B*. Is this differ-

ence a consistent, that is, a reliable, difference? To answer this question, we need two comparable measures of this domain for both A and B. The method ordinarily used is to add up the errors made by each on odd trials, 1, 3, 5, . . . 29, and note in the totals the difference between A and B. Then for each rat, we add up the total errors made on even trials, 2, 4, 6, . . . 30, and note the difference. Thus, we obtain two comparable measures for both A and B, and if A is equally poor in both measures as compared with B, we know that the difference is consistent and reliable. Of course, in practice, we would secure the total odd and total even scores for all rats in the group and calculate the correlation coefficient between the two series of scores. If r (the coefficient of correlation) is 1.00, we know that individual differences are perfectly consistent and reliable; if r is 0, we know there is no consistency and that reliable differences between the animals are utterly absent. The magnitude of the correlation between the comparable measures is thus a measure of the degree to which consistent individual differences *exist* under these conditions of measurement. Until we find this degree, few of the problems of individual differences can be attacked, for, it should be apparent, the degree to which individual differences are correlated on two comparable measures of the *same* domain will radically affect the correlation between this domain and other different variables.

(6) *The analysis of the results should be succinctly stated by means of adequate statistical formulae devised for this purpose.*[1] A concise statement of the *spread,* or variation, among individuals is the *standard deviation* (sigma) of their scores. The measure of the degree of reliability of individual differences in a behavior variable X is the *reliability coefficient* r_x, which is defined as the correlation coefficient between scores in the given domain and those in an exactly comparable domain.[2]

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[1] Limitations of space will not permit of our reviewing the elementary statistical formulae mentioned here. If the student has forgotten the meaning and uses of standard deviation and the correlation coefficient, it is suggested that he refer to any standard statistics text, such as Garrett (10). For a brief account of methods pertaining to the reliability of individual measurements, see reference 10 in the bibliography, Chap. VI, pp. 266–274.

[2] According to this definition, the correlation between errors on *odd* and on *even* trials, r_{oe}, is not the reliability coefficient of errors on *all* trials but only of those on a sample of half the total trials. The reliability coefficient of total trials can be estimated from r_{oe} by the Spearman-Brown formula, $r = 2\ r_{oe} \div (1 + r_{oe})$. (Garrett (10, p. 271).)

The problems to be attacked in the study of individual differences

There are four major problems to be solved in any complete attack on individual differences in any given behavior-domain. These are: (1) To what extent are individuals *consistently* different from each other, and how *constant* are these differences throughout their lives? (2) To what exent are these differences related to physiological and morphological differences? (3) To what extent are these differences caused by differences in hereditary constitution rather than by differences in experience? (4) To what extent are individual differences in the one behavior-domain related to (that is, correlated with) individual differences in other behavior-domains?

We turn now to a consideration of the experimental evidence bearing on these problems.

The Evidence Bearing on the Problems of Individual Differences

Evidence relating to the stability of individual differences

In evaluating the experimental evidence on consistency, certain factors must be kept in mind. First, the spread and the reliability coefficient will be greater the more nearly the experimental group approximates a random sample of the whole species. Second, a higher reliability will result from a more thorough measure of each individual: for example, in maze measures, from more blinds, a more complex pattern, and more trials; in sensory discrimination measures, from more trials or discrimination points, and so forth.[3]

In the following treatment, we shall review the evidence as it bears on the two subproblems (1) extent and consistency of individual differences in various behavior-domains and (2) constancy of the differences over varying intervals of time. Most of the evidence is drawn from a single species, the rat; but this is due to the unfortunate fact that no adequate work has as yet been done on other species (except man).

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[3] This principle is embodied in the Spearman-Brown formula, which is really a law of individual measurement. There are other important factors affecting consistency; for a more extended account, see references (40)(50) and (54) in the bibliography.

1. Learning. (a) *Maze learning.* For experiment, the writer chose a random sample of 141 pied and albino rats from two large heterogeneous laboratory colonies, neither of which had histories of inbreeding. These animals were run on two long, difficult T-mazes, the first (Maze *X*) having 17 blinds, and the second (Maze *Y*) having 20 blinds. The procedure consisted in an initial run of 11 trials on a "practice path" involving no choice points, 19 trials on Maze *X*, a week's rest, 5 practice runs, and then 19 trials on Maze *Y*. The reward was food, and one trial a day was given (54).

Marked and consistent individual differences were discovered. The reliability coefficients for errors on trials 2 to 19 were .99 for Maze *X* and .97 for Maze *Y*. For a sample of 45 animals who relearned Maze *X* (13 trials) some months later, the reliability coefficients of successive periods of only 6 trials each were .94, .98, and .98 for original learning, and .95 and .97 for relearning (57). At the end of relearning, the last two periods of only 4 trials each gave coefficients of .95 and .97 (58). Here is evidence of as consistent individual differences in these domains as are found in human "intelligence" domains.

TABLE 16

AVERAGE r's BETWEEN A GIVEN PERIOD (TRIALS AND STAGES) AND ADJACENT PERIODS OF LEARNING FOR THE CONSECUTIVE PERIODS IN THE LEARNING OF TWO MAZES

	Single Trials				*Stages Consisting of 3 Trials*					
Trials	1*	2	3	4	(2, 3, 4)[1]	(5, 6, 7)	(8, 9, 10)	(11, 12, 13)	(14, 15, 16)	(17, 18, 19)†
Maze *X*	.14	.36	.64	.75	.72	.81	.91	.92	.92	.93
Maze *Y*	.05	.31	.59	.65	.71	.78	.81	.75	.78	.83

* In the case of Trial 1 and Stage (2, 3, 4), there was no preceding period present, so that the *r* given is the correlation with the following period.

† For Stage (17, 18, 19), the *r* is the correlation with the preceding stage only.

The *constancy* of individual differences throughout the whole experimental period is indicated by the correlation between *different* trial periods. On a random sample of 107 rats, trials 2 to 19 were divided into stages of 3 trials each, and intercorrelations between total errors on these 6 stages calculated (52). All these coefficients cannot be given here, but in Table 16 are given the average of correlations between each stage and its preceding and following stages of learning, and similar coefficients for the first 4 single trials. Note that as time proceeds during the experimental period, the coefficients rise and reach very high magnitudes. This means that with practice individual differences become stable. This emergence and stabilizing of individual differences is shown very clearly in the coefficients of even the first 4 single trials.

But how constant are these differences throughout the lives of the animals? This question is analogous to the problem of the constancy of the I. Q. in human beings. Three different groups of animals were used to investigate this matter (57). The procedure was to run them 19 trials on Maze *X*, and then after a long interval of time to run them again 13 trials. During this interval, all the animals experienced breeding conditions; furthermore, Group 1 ran another maze, and Group III changed quarters from one building to another, relearning under the new conditions. Statistical evidence indicated that the three groups had dispersions in original learning similar to a random sample. Full data are presented in Table 17, *L* (learning) being total errors on the first 19 trials, and *R* (relearning) being the total on the second 13. The correlations between learning and relearning are .80 or higher, indicating a very high degree of constancy over an interval of from 6 to 8 months, which is more than a

TABLE 17

THE CORRELATIONS BETWEEN LEARNING AND RELEARNING OF A MAZE FOR THREE GROUPS OF RATS EXPERIENCING DIFFERENT INTERPOLATED CONDITIONS

Group	*N*	*Interval between Learning, L, and Relearning, R*			*Reliability Coefficients*		*Correlation between L and R**	
		No. of days		*Conditions*	*L*	*R*	*Raw*	*True*
		M	*S.D*					
I	46	232	19	Breeding, Maze Y	.99	.98	.79	.81
II	25	196	28	" "	.99	.98	.79	.81
III	36	196	51	" New quarters	.98	.96	.85	.88

* The raw correlation is simply r_{LR}; the true correlation is r_{LR} corrected for attenuation. See reference 10 in the bibliography, p. 211 *ff*.

third of the rat's life span. Even between scores on the *first* 6 trials of *L* and the *last* 6 trials of *R*, the raw correlation was found to be .81 (true .85), and this was the correlation between two periods each involving less than 15 minutes of running but separated by a considerable portion of the rat's life.

The above facts are corroborated by experiments on Stone's 12-blind T-maze. Stone and Nyswander (45) ran 205 rats from Slonaker's *inbred* stock[4] 30 trials through the maze. The reliability coefficients were .95 both for total errors and for total time. Even for successive 10-trial stages, the reliability coefficients were .78, .94, and .94 for errors, and .91, .97, and .87 for time. Using the same type of maze and the Wistar inbred stock, Leeper (23) ran 34 rats (Group *C*) 30 trials, and for errors found a coefficient of .94. These experimenters used food as the reward, but Ruch (30), who used escape-from-water as a drive, found (with 19 inbred animals) a coefficient of .95. Had these animals been more definitely a random sample of rats, the reliability coefficients would doubtless have been even higher. Using more representative samples, Tolman and Honzik (48) ran several groups of rats on a modified Stone maze and found wide differences even when *no reward* was given. For two such groups, one hungry and the other slightly hungry, the reliability coefficients for 17 trials were, respectively, .97 and .86 for errors and .97 and .88 for time; and for two analogous groups rewarded by food at the maze-end the coefficients were .96 and .85 for errors and .99 and .95 for time. Even for a group that received reward during certain trials and then had it withdrawn during others (49), the coefficients for the nonreward period were of the order of .92 and, for the reward period, .96. Thus, under quite extensive variations in motivation, consistent differences in performance appear.[5]

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[4] In this experiment and in other experiments reported below, the group of animals is frequently reported as being drawn from an "inbred" stock. Whether this means that all the animals were from the *same* inbred line or consisted of different subsamples from each of *different* inbred lines is rarely reported. The existence of such marked differences between individuals suggests that the latter condition obtained.

[5] We cannot go into the details of other experiments on consistency in maze learning, but below is a brief survey of the reliability coefficients found by other workers: On the 10-blind Carr maze, Stone found .75 on 20 trials (44). On a 2-blind maze, Alm found .92, .93, and .93 for three groups (1). Miles used two 15-blind T-mazes, one on the floor and the other elevated, and found coefficients of .86 and .84 (28). Corey's group on an 8-blind elevated maze gave coefficients of .89, .96, and .92 for errors, total time, and active time, respectively

Stone and Nyswander (45) found also a high degree of constancy throughout the experimental period, the raw *r* between total errors on Trials 1 to 10 and total errors on Trials 11 to 20 being .75, and the true *r*, .86. McNemar and Stone (27) found as high a degree of constancy of individual differences as this over intervals of from one and one-half to four months. Their procedure was to run the animals 30 trials on the maze, and then after an interval of time during which the animals worked on other apparatuses, to run them again 15 trials. A number of groups were run, but for our purposes, we shall consider only those that showed the greatest spread in original learning. Two groups (*C* and *F*) that experienced a problem box and a visual discrimination box during the 45-day interval between the two maze series both gave *r*'s of .80 between learning and relearning error scores; two other groups (*H* and *K*) that experienced only the problem box during a 125-day interval gave, respectively, coefficients of .89 and .75. Here, again, is evidence of the high constancy of individual differences over a fairly long interval of time.

(b) *Problem-box solution.* The measure of efficiency in problem-box solution is time. Heron found, with his simple inclined-plane box, a reliability coefficient of about .8 for total time for trials beyond the first 8 (17). Using 98 inbred animals, who worked on a single-treadle box, Stone found, excluding the first 5 trials, a coefficient of .76 (42), and, when a box in which the animal had to consider three treadles before getting out to food was used, a coefficent as high as .83 (7).

(c) *Sensory cue learning.* Before we can present problems that legitimately measure the behavior of animals, it is desirable to know the animals' sensory-motor capacities. It is of paramount importance to know the classes of stimuli or stimulus-patterns to which the animals are sensitive—and especially we want to measure individual differences in their sense acuities. But the typical discrimination-box does not measure such indi-

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(8). Liggett's group, which ran a 4-unit linear maze, gave .92 and .90 for time and errors, respectively (24). Using 6 Warner Y-units, Jackson found coefficients of .76 and .95 for a simple- and a double-alternation pattern, respectively (21). Husband (20) used 10 Warden U-units and found a reliability coefficient of .88. This array of high coefficients proves conclusively the universality of consistent individual differences in maze ability among rats.

Some of the coefficients given above and throughout the text are not those reported by the authors, who in certain instances failed to apply the Spearman-Brown correction and in other instances applied it wrongly. Throughout this chapter, the writer has made the proper corrections.

vidual differences. In a visual discrimination-box, for instance, the animal is presented with a light path and a dark one, and he must learn to go through one and not the other. Here, the stimulus difference is within the threshold of all animals, and, therefore, what is measured by total errors is capacity *to learn* to follow one stimulus and avoid the other. This is sensory sign *learning*. To measure acuity differences, it is necessary to wait until all the animals have learned the first difference in intensities, and then on later trials gradually to reduce the difference between the two stimulus intensities until the learning breaks down. Individual differences in visual acuity will then be defined as the stimulus difference at which the animal's learning breaks down.

The notable work on visual sign learning is that of Stone (41). Seventy-one rats ran a 5-chamber light-dark box for 40 trials. The reliability coefficient of errors from Trials 11 to 40 was .94, and the coefficients of successive stages of 10 trials each were .51, .87, .82, and .93. Similarly, Williams (71) found, on a one-chamber box and with two groups of rats, a coefficient of .96 for errors on 24 trials. In kinaesthetic cue learning (requiring the discriminating of different inclined paths), Ruch's 24 animals gave a coefficient for errors on 40 trials of .79 (31). As to the constancy of such differences, Stone (41) discovered that between the last three stages of 10 trials each, the raw *r*'s were .71, .75, and .85, the true *r*'s being .79, .89, and .98. From these and the above data, it appears that individual differences are both consistent and constant in these domains of learning.

2. Capacity to discriminate stimuli or stimulus-patterns. The conditions for measuring acuity have been indicated above. To the writer's knowledge, no analyses relative to the problems of *individual differences* have been carried on under these conditions. Yoshioka's work on the discrimination of distance (74) is, nevertheless, relevant here. He ran rats in a box in which food was reached by a long or a short path, where the ratio of long to short was the value *R*. The score was the number of choices of the short path, and the reliability coefficients of the total scores on 54 trials for five different groups (of 40 rats each) with different *R*'s are shown in Table 18. High consistency of individual performance is apparent in these domains. In Group V, where the short path was almost equal to the long path, Yoshioka found that the mean of short choices was about equal to that of long choices, indicating no discrimination. Why

TABLE 18

RELIABILITY COEFFICIENTS OF RATS' CHOICES IN A DISTANCE DISCRIMINATION APPARATUS

Group	I	II	III	IV	V
R	1.44	1.33	1.23	1.14	1.07
Reliability coefficient *	.82	.93	.82	.92	.83

* These *r*'s are mean *r*'s of animals running to the same *R* on Yoshioka's mazes I and II.

is there such high consistency here, where one would think that the rats were running by chance? The reason is that they tended to form *position-habits*, and since the short path was always on the same side for each rat, if he had a position-habit for this side, he consistently secured a high score; if to the long side, he consistently earned a low score. Thus, the coefficient for Group V indicates the high consistency with which the animals *form* a position-habit in a nondiscriminable situation. But the rats of Group I showed a marked learning of the short path, so that here we have evidence of high consistency of learning "shortness" as a means-end relation involving least effort in reaching food. Just how to get a measure of individual differences in distance discrimination out of such data is not apparent. In an analogous experiment where the animals were faced with the problem of discriminating kinaesthetic *patterns* of equal length, that is, a 1-triangle path and another path of equal length but made up of a number of triangles, Yoshioka found high consistency as indicated by reliability coefficients for different groups of .95, .83, .85, and .94, though here again, the differences may have been largely due to position-habits rather than discrimination capacity (72).

3. **Drive.** Little work has been done on individual differences in the strength of the various types of biological drives.[6] One interesting approach is that of Washburn (70), who measured the degree to which mice were hunger-driven by correlating for each mouse the amount of food eaten at the end of a maze (Watson's circular maze) with his velocity of running. The *r*'s for different mice ranged from .76 to zero. Those whose *r*'s were high were called "hunger-driven," those whose *r*'s were low, "activity-driven." This is an ingenious motivation scale, and all the problems of individual differences in this domain should

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[6] See Chapter 4, for the data collected by Stone.

be attacked by its use, though on better mazes and with more animals. Differential studies should also be advanced by the use of the obstruction-box, which has been shown to have considerable value in the measurement of different types of drives (69).

The most complete work on individual differences in gross energy has been done by the measurement of it in rats according to the number of revolutions they make in circular revolving cages. Using, apparently, a fairly random sample of animals, Shirley found great differences between individuals (36). Over a period of days, some rats showed a median distance traveled per day of about 8 *miles;* others of as little as 180 *feet.* For periods of 5, 10, and 20 days, the reliability coefficients of revolutions were .97, .98, and .99, respectively. The constancy of these individual differences was also quite marked. Over a period of 15 days, the correlations between *different* 5-day periods were .89, .88, and .95. Even when a considerably greater interval elapsed between measures of activity, the correlations were very high (37). Thus, with rats who were given a 10-day run at the sixth, seventh, eighth, and ninth months of life, the *r*'s between the sixth month's record and the records of the seventh, eighth, and ninth, respectively, were .88, .81, and .72; between the records of the eighth and ninth months, .86. It was also apparent that as the rats grew older, the differences between them became more stabilized. Another measure of activity that showed the same fact of consistency was that obtained by Hall (12), who placed the rat in a circular laboratory field where the food was in the middle but enclosed by a barrier. For 26 males and 26 females running 14 two-minute periods, the reliability coefficients of total distance traveled were .89 and .96, respectively; with the barrier removed, the coefficients were .93 and .93. Another interesting discovery was that rats differed consistently in "appetite": the reliability coefficients for "amounts of food eaten" were .99 and .93, respectively.

4. Emotional expression. How to provide standard stimulus situations in which directly to measure differences in anger, fear, and other emotional reactions has been a problem. One adequate quantitative analysis is that of Hall, mentioned above, who measured differences in certain correlated by-products of the fear reaction. When rats show marked fear, this state is usually accompanied by urination and defaecation. Hall kept counts of the defaecations and the urinations per rat during the first trials and found very marked, consistent differences, as indicated by the following reliability coefficients for males and females respectively; defaecations, .83 and .96; urinations, .86 and .96. Whether differences in elimination frequencies represent accurately differences in degree of emotional upset is not as yet definitely known.

Evidence bearing on the relation between behavior differences and physiological differences

Little work has been done with animals on the relation between normal behavior differences and differences in somatic structures or functions, although this is obviously a problem of great interest and importance. The numerous experiments on the effect of cerebral insult on behavior (by Lashley, and others) do not bear directly on this problem. What we want to know here is the correlation of behavior differences among *intact* animals with their differences in physiological and morphological make-up. Work already done has been with reference to obvious morphological differences.

1. **Age and behavior.** In a previous chapter, the relation between physiological maturity and behavior was discussed, and we will not review it here except briefly to recall that in the researches of Stone on this problem, he found that for rats, in many learning domains, there was no relation between ability and age (from puberty to early senescence) (42)(43).

2. **Sex and behavior.** In human beings, it has appeared to be a universal fact that, other things being equal, there is a negligible difference between males and females in cognitive capacities. And the findings in subhuman species have been similar. In his T-maze studies mentioned earlier, the writer found a slight indication of male superiority in learning, but this difference was negligible with respect to the vast differences between individuals due to other factors (55). Studies from the Stanford laboratory (26)(51) give similar results. Rats were given trials on a T-maze, a Carr maze, a problem box, Warden U-mazes, light-dark discrimination boxes, and two elevated mazes. Either no sex difference was found in these different experiments, or where a slight male superiority was indicated, it was negligible relative to the great overlap of the two sex groups. It seems very probable that if a behavior difference between the sexes exists, it will be in emotional domains. In human beings, measurements of neuroticism by the Thurstone personality inventory and those of annoyance by

Cason indicate that in these domains a very evident difference between the sexes appears, and it is significant that also in the experiments by Hall on emotionality in rats, very evident sex differences appear. Greater activity has been noted in the female (19)(29), the predominance being greatest at the peak of the sexual cycle (68).

3. Other morphological characters. From the very slight amount of work done on the relation between other morphological characters and capacity, no evidence has appeared to indicate that such characters are predictive "signs" of ability. Even when one might have expected some relation, none has appeared. For instance, in the writer's experiments, the animals all received the same amount of food, and since they differed considerably in weight, one might have expected that they were being differently rewarded and that this fact would affect their maze scores. But the correlations between weight and error scores proved to be zero. Again, one might have expected that pied rats with pigmented eyes would have been, by virtue of superior vision, superior to pink-eyed albinos in maze-learning. Yet here also, only a negligible difference in ability appeared (55). In nondiscriminable situations where rats show position-habits, Yoshioka found an *r* of .43 ± .15 (S.D.) between number of right choices and degree of right curvature of the nose, indicating a slight tendency for a rat to "follow his nose" (73). Shirley studied the relation between activity and body weight (38), and found zero correlation. The brains of the animals were weighed and the correlations between activity or maze ability with weight of cerebrum or cerebellum or per cent of brain weight were all unreliably different from zero.

Apparently, the real causes of behavior differences are exceedingly numerous, complex, and fundamentally related to differences in the integrations in the nervous system and its projecting sensory-motor tissues, so that any differences attendant upon simple differences in external gross morphology are readily swamped by these more fundamental sources of variation.

Evidence indicating the degree of causation of individual differences by hereditary and by environmental factors

Since the beginning of the twentieth century, geneticists have accumulated considerable data on the genetic causes of individual differences in morphological characters in plants and animals. Few controlled experiments have been performed on behavior, doubtless because, until recently, no one knew how to measure mental differences accurately. Thanks to the work of the geneticists, the methods of studying hereditary causation are now established. To study hereditary causation of mental differences, it is necessary (1) to choose as the original experimental population, *P*, a random sample of animals from the species, (2) to measure accurately the behavior differences of these on a valid scale and under rigorous conditions of environmental control, and then (3), by sundry systems of mating, to determine the nature of the hereditary factors at work. To

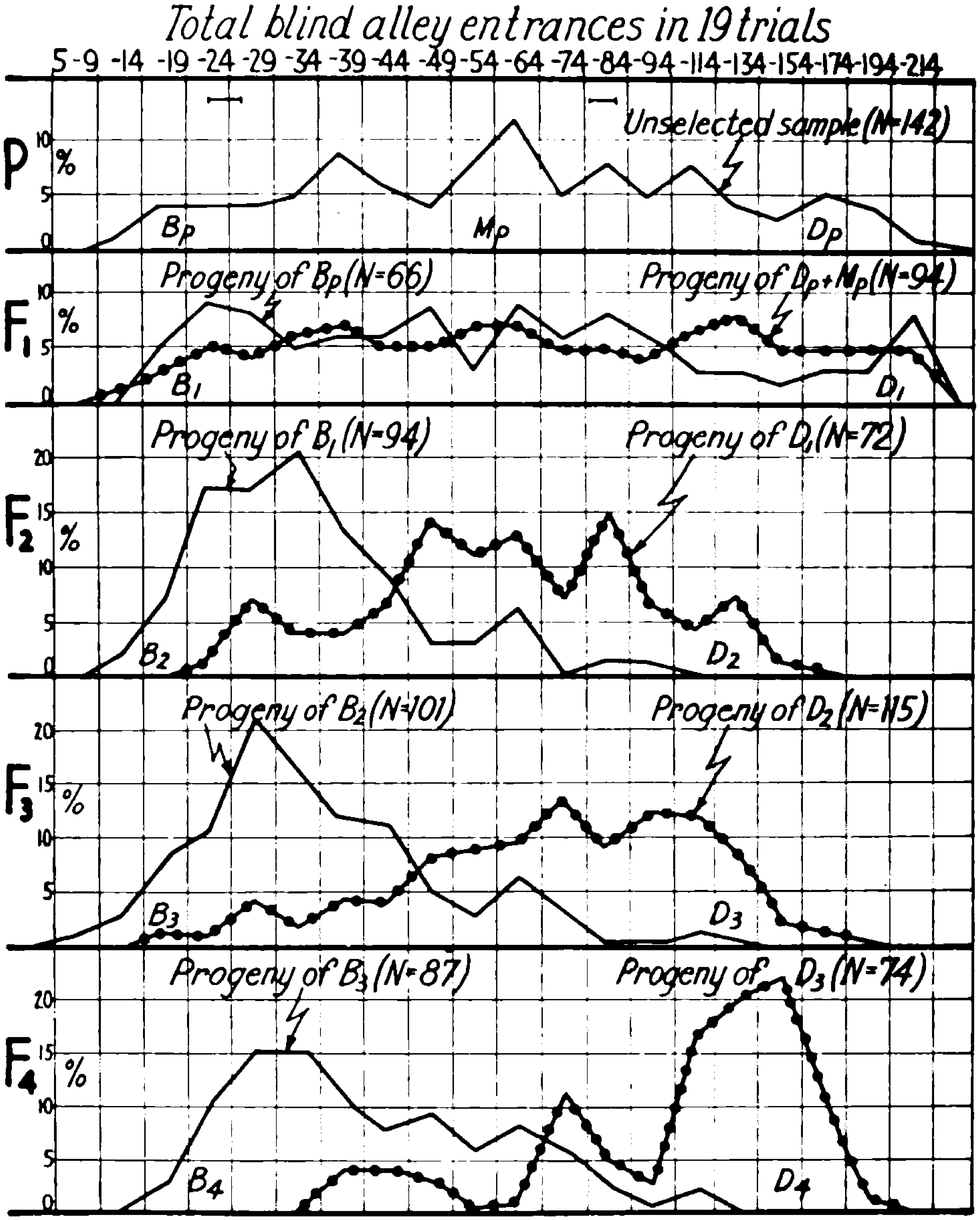

Fig. 68A. Effects of Selective Breeding on Maze Learning.

(Continued on p. 345)

study environmental causation of differences, it is necessary (1) to choose a group of individuals all exactly identical in heredity (a "pure line") and (2) from these to select random subgroups, S_1, S_2, . . . , which are then respectively exposed to different environments, A_1, A_2, . . . , the latter being systematic variations of an environmental condition, A.

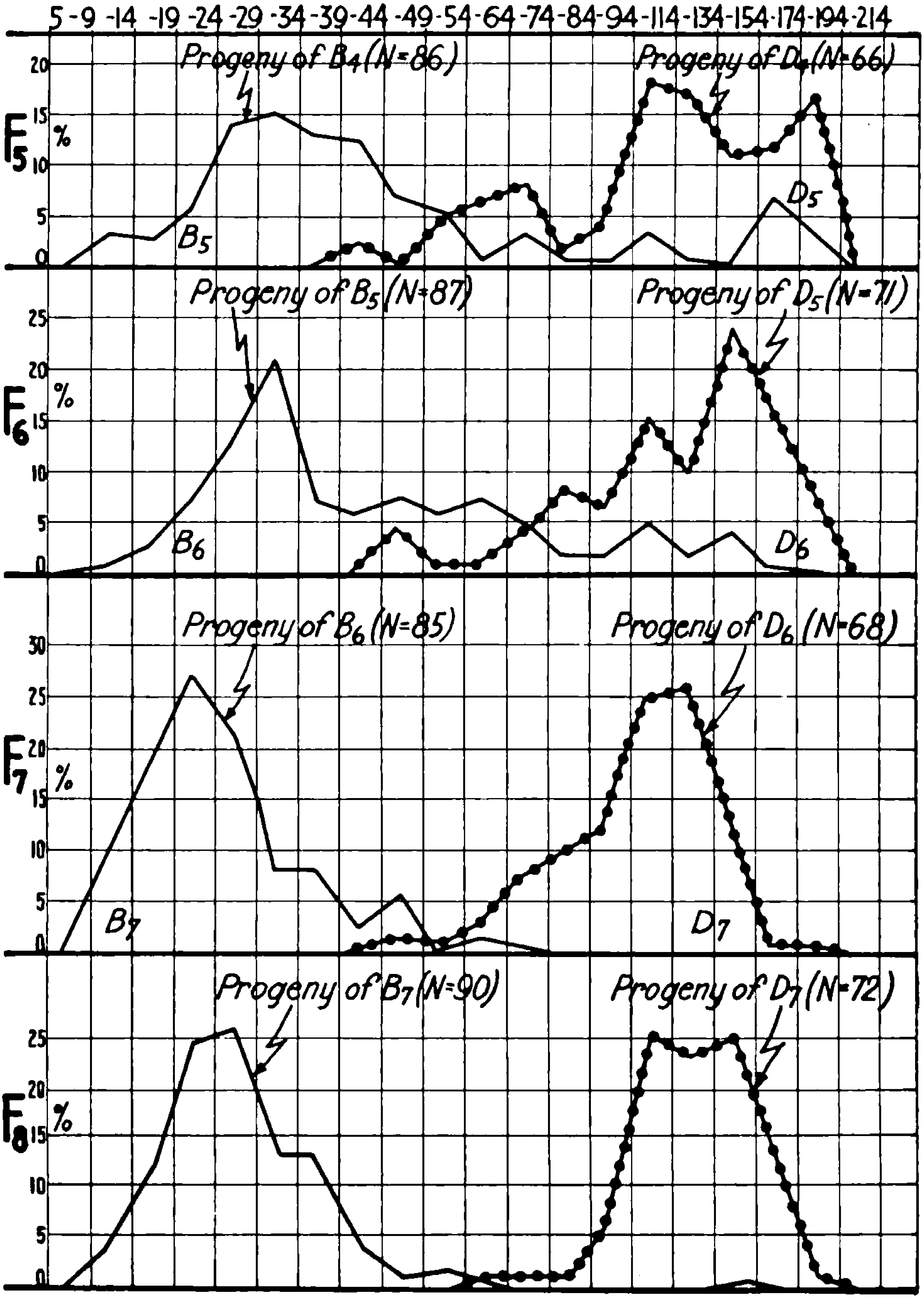

Fig. 68B. Effects of Selective Breeding on Maze Learning.

(Continued)

1. The objective facts from controlled experiments. (a) *Selective breeding studies.* To what extent are individual differences in maze learning due to hereditary determiners? Using the method described just above, the writer endeavored to establish, through selective breeding by assortative mating, two races of rats, a "bright" and a "dull" (59)(60)(61). A random, unselected sample of 142 rats was chosen and then run for 19 trials on Maze X, described earlier in this chapter. The measure of learning capacity was the total errors on all trials. Fig. 68 shows the results of selective breeding for brightness and dullness. The error scale across the top refers to all generations below it, the extreme left end being the "bright" end of the scale (few errors) and the extreme right end being the "dull" end. The frequency distribution of the original P group is just below the scale. Note the extreme dispersion of individuals and the unimodal distribution. Extremely bright (B_p) individuals were bred together, and their progeny are shown below—indicated as the F_1 (first filial) generation. The F_1 progeny of extremely dull and median ($D_p + M_p$) are also shown. Not much difference appeared in this generation. The assortative mating of extreme bright and of extreme dull was continued, and the results show a gradual appearance of a bright race and a dull one. In the F_8, there is practically no overlap between them. This difference remains to the present F_{22} generation. It appears that we now approximate two pure lines, one which "breeds true" for brightness and one which "breeds true" for dullness. It is apparent, therefore, that differences in this maze ability are markedly determined by differences in hereditary constitution.

It is to be recalled that Shirley found differences in the activity of rats to be wide and consistent. That such differences are markedly due to hereditary differences is now apparent from the experiments of Rundquist, who after 12 generations of selective breeding established a race of active and one of inactive rats (32). Other experiments on behavior inheritance have been performed, but in these no evidence as to the consistency of individual differences has first been secured.[7]

(b) *Family resemblance studies.* A common method of studying inheritance is that of determining the correlation between groups of individuals of different degrees of relationship, such as identical twins, fraternal twins, siblings, and parents

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[7] See references (5)(34)(35)(47) and (67) in the bibliography.

and progeny. Such methods are relatively inconclusive, since the coefficients are delicately affected by the degree of assortative mating and selective breeding in the populations. For example, it is apparent from the facts of Fig. 68 that the correlation between parents and offspring depends on the *degree* of selective breeding: for example, between P and F_1, the r would be low; between F_7 and F_8, it would be very high.

(c) *Effects of varying environments on individual differences.* Another method of approach is to raise a group of individuals in a constant environment, then measure differences between them in a given behavior; next, expose them to variations in environment, and then re-measure them in the given behavior. If the correlation between the two measurements is very high, it indicates that the environmental variations are relatively unimportant in affecting behavior differences, and that the differences are therefore primarily determined by heredity. Experiments of this type by Stone and the writer were reported earlier under the heading, "Evidence relating to the stability of individual differences," where it was shown that the correlation between the learning and the relearning of a maze by rats was very high even though great environmental changes were introduced[8] during the interval between the two measurements.

(d) *Studies relating to the Lamarckian hypothesis.* The Lamarckian view that differences in behavior may be due to differences in the experience of the parents which are transmitted to the offspring in the form of "biological memory" has been experimentally tested—generally, with negative results. In testing this theory, the following technique is mandatory: (1) the task to be learned must be important to the animal and must be tackled by him under strong motivation; (2) all animals of the initial population should be exactly the same genetically (a homozygous, inbred stock); (3) successive generations must be put through the task under exactly the same experimental controls. When this technique is followed, if "biological memory" is a fact, later generations should perform better than earlier ones. The second condition, genetic identity, is crucial, for without it, the improvement in later generations may result from selective breeding. McDougall's experiment is a *behavior* study

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[8] With this method there are numerous difficulties, which space limitations prevent us from discussing here. For an account of these, see reference (57) in the bibliography.

testing this theory (25). Using animals from the inbred Wistar stock, he put them through a water discrimination-box in which, in the lighted alley, the rat had to climb over an electric grill of sufficient shock to tetanize the muscles, whereas through the dark alley it could escape without shock. McDougall found in later generations marked improvement in learning to avoid the lighted alley where the shock was given. One explanation of these results on grounds other than the Lamarckian hypothesis is as follows: the rats may not have been identical genetically, but rather, may have varied widely in innate learning capacity (in one group, the learning scores varied from 90 to 229); the electric shock may have constituted a selective agent by its severity[9] and frequent repetition, either eliminating the stupid animals or occasioning full or partial sterility among them. Thus, the results may have been due to the selection of bright learners. It is of interest to note that in the writer's experiments (see Fig. 68), no Lamarckian effects are to be discerned in the dull race, for the dull F_8 are as dull as the dull P animals.[10] A final difficulty with this hypothesis is that no mechanism has as yet been conceived whereby the *specific ideas* of parents can be transmitted through the germ plasm to the offspring, whereas the mechanism of Mendelian factors or genes is quite adequate to explain selection, as the next section will indicate.

2. Factor explanations of the objective facts. (a) *Genetic (hereditary) factors: the Mendelian factor theory.*[11] It is to be recalled that the theory of mental evolution demands wide inherited differences in behavior between individuals, and that the above experimentally determined objective facts indicate that such differences do exist. And it is to be noted that individuals exist in all degrees of capacity, forming, in fact, a continuous unimodal distribution. What biological mechanisms exist to explain these objective facts? The most adequate theory, supported by many genetic investigations of plant and animal

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[9] See the abstract of the work of Dunlap on the physiological effects of electric shock (9).

[10] A thoroughgoing Lamarckian would, however, criticize the writer's task as not being as important to the rat and causative of such striving as McDougall's, where the rats had to avoid near-electrocution.

[11] Space limitations preclude the presenting here of an elementary treatment of Mendelian theory, and the suggestion is offered the student either to read, say, such a brief but adequate account as that by T. H. Morgan in *The Foundations of Experimental Psychology*, pp. 7–22 (edited by Carl Murchison, Clark University Press, 1929) or to skip this section.

structures, is the theory of *independently assorting multiple Mendelian factors (or genes).* We shall describe this theory by showing how it may account for individual differences in maze-learning ability. It is assumed that there is a large number, k, of genes determining this ability. First, consider one of these genes, A, which exists in two degrees of expression, A and a. An individual of homozygous constitution, AA, is brighter than one of aa constitution, and a heterozygous individual, Aa, lies between the two. No dominance is assumed. But there are k such genes, A, B, C, D, . . . , each possessing the same properties as those described for A. Thus, an individual of constitution $AABBCCDD$ . . . would be the brightest possible in maze ability; $aabbccdd$ . . . the dullest; and $AaBbCcDd$ . . . would be average. All degrees of ability would be possible: $aABBCCDD$ . . . next to brightest, $aaBBCCDD$ . . . next, $aabBCCDD$ . . . next, and so on. Thus, the continuity of individual differences is adequately explained. Under random mating, the types of individual that could exist and the frequency of each can be found from the product of $(A + a)^2$ $(B + b)^2$ $(C + c)^2$ $(D + d)^2$. . . . In the resulting series, the terms show the various genotypes, and their coefficients the frequency of their occurrence. The result is a *normal distribution curve*, if k is large enough. Hence, the wide, continuous, and unimodal dispersion of individuals in the P generation (Fig. 68) whose parents were randomly mated is adequately accounted for.

According to this theory, the effects of selective breeding result simply from the gradual sorting into one race of all the large-lettered genes for brightness, and into the other, all the small-lettered genes for dullness. In a final bright pure line, *all* individuals would be $AABBCCDD$ . . . , and their progeny would be exactly like them; analogously, in the dull pure line, all would be $aabbccdd$ . . . and would breed true for dullness.[12] Some modification of this theory is necessary to account for the regression of progeny of bright and of dull. The linkage of different genes in the same chromosomes would also affect the results.

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[12] Final tests of this theory will consist in the crossing of these two pure lines. If the theory is adequate, then all of the new F_1 individuals will show the *same median* capacity, since all will be of constitution $AaBbCcDd$. . . . Selfing these F_1's should give an F_2, in which all the genetic types will appear; that is, the distribution should be similar to that of the P group at the top of Fig. 68. For later experiments of this type, see reference 61.

Later, we shall see that the rank order of individuals in different learning domains is not the same: that the intercorrelations vary from nearly unity to zero. These facts in no way jeopardize the view that individual differences are inherited, for they may mean only that individual differences in different behavior-domains are determined by different gene-complexes. If two behavior-domains are determined by the same gene-complex, they will correlate unity (the environment being constant); if they are determined by different complexes, they will, under random mating, correlate zero. In brief, the degree of correlation will thus be determined, under random mating, by the proportion of common genes entering into the two behavior-domains.

Apart from this cause of intercorrelation, two behaviors may show positive correlation without there being common genetic factors. If, for example, behavior *X* is determined by genes A, B, C, and D and behavior *Y* by genes H, I, J, and K, no correlation between *X* and *Y* would appear from common genes, since there are none. But if some selective agency is at work to produce assortative mating in such a fashion that the superior individuals (represented by large letters) in *X* and in *Y* tended to breed together, and if, likewise, the inferior ones (represented by small letters) mated, the individuals in later generations would show a positive correlation between *X* and *Y*, since the two extreme types of individuals would be of constitution *AABBCCDDHHIIJJKK* and *aabbccddhhiijjkk*, and the types of individuals throughout the intermediate range would have the same genes in corresponding degrees of expression. Thus, positive correlation between behavior-domains may mean either common gene-complexes, or independent gene-complexes correlated by virtue of assortative mating.

(b) *Environmental and maturational factors.* It cannot be denied that differential training may exert considerable influence in determining individual mental differences. Extreme environmentalists assert quite unreservedly that behavior differences derive primarily from differences in conditioning, especially during early development. There may not, however, be an issue here, for even when learning proceeds by conditioning (or by any other means), differences in *capacity* to form conditioned responses may be wide and, furthermore, inherited. The laws of learning attempt to describe the process through which the individual goes from inefficiency to efficiency, whereas the laws of inheritance attempt to describe the nature of the forces which account for inherited differences in capacity to go through the learning process. The best means of studying the process of individual development is to get rid of variation due to heredity by working with individuals of the same heredity.

There are, indeed, two very different types of developmental process: learning and maturation. Innumerable experiments have been performed on the effects of learning in one situation upon that in another (transfer), of varying the situation, the motivation of learning, and so forth; but since these have been discussed in other chapters, we need not consider them here. Likewise, the nature of maturation and the factors that affect it have been treated elsewhere.

Evidence bearing on the relation between individual differences in one behavior-domain and individual differences in other domains

To what extent is the behavior of the individual in one situation generally *characteristic* of him in all situations? If we discover that an individual manifests superior learning ability when confronted by one task, can we predict that he will be superior in all tasks? Is superior learning associated with superior sense acuity, with strong motivation, and so on? If we should find no such correspondence, may there not, nevertheless, be some *congruence* between an individual's several behaviors, or is behavior, on the contrary, highly specific, seeming to indicate that adjustment in one situation is exclusively characteristic of the individual in that situation and in no other? Our method is to calculate the intercorrelations between performance in divers behavior-domains, and then to study the magnitude and significance of such correlations.

Intercorrelational evidence may also shed light on *the psychological nature* of the causes of the individual differences that appear in one behavior-domain. Such evidence is, of course, secondary, our main information coming from an *a priori* analysis of the situation and of the behavior *in situ*. Thus, on *a priori* analytical ground, we must present a psychological rationale that differences in maze errors are differences in *learning*, that differences in breakdown when the light intensities of alternate paths in the discrimination-box are gradually brought to equality are differences in *visual acuity*. But the correlation between these behavior-domains and other domains may occasionally shed some light on the matter. Whereas such evidence does not invalidate an *a priori* psychological analysis, it may divulge some of the conditioning psychological features of the behavior. Thus, if maze-learning scores correlate highly with degree of hunger-drive, with gross activity, with visual acuity, and so forth, these facts would inform us of some of the causes (or associated conditions) of learning.

1. Evidences from temporal subdivision of the same behavior-domain. We noted earlier that high intercorrelations were found between the performance of rats on different trials in maze learning, even when such trials were separated by a considerable interval of time, and we noted that this was also true of gross activity. It was further apparent that as the animals became more inured to the situation, the intercorrelations were higher. From these scant data, we may tentatively conclude that ability, especially after inurement, is temporally a stable characteristic of the individual in a single, defined behavior-domain.

2. Evidence from component subdivisions of the same behavior-domain. This is the problem of "internal consistency" or of so-called "validity of a behavior item," one of the common problems to be considered in mental-test construction. Some data of this sort have been collected on maze-learning. Stone and Nyswander (45) found with the T-maze that for 30 trials, the r between total errors on the first 6 *blinds* and those on the last 6 was .82. Since the reliability coefficients for each group of 6 were probably in no case greater than .85, the true r must have been nearly unity. Corey found similar results with an elevated maze (8). Here is evidence of general characteristic differences within spatial divisions of the *same* general domain.

3. Evidence from differently defined aspects of the same domain. Since behavior in the same situation has many aspects, it can be scored in different ways, each defined score having, of course, a different psychological significance. Thus, maze learning can be scored in terms of errors, time, number of trials necessary to achieve a criterion of perfect learning, distance traveled, and so forth. To what extent is one aspect related to the others? Between errors and time in maze learning, the r's have been found to be .6 (Tolman and Nyswander), .9 (Corey), and .93 (Shirley). This relation is of interest as bearing on the question: To what extent is the speedy individual also the most accurate? In maze measures, the r between total time and errors is spuriously high because time is increased by the making of errors. What is needed is velocity-when-no-errors-are-made correlated with number of errors, but no evidence of this sort seems to have been reported. Between errors and trials necessary to achieve a criterion of perfect learning, the *r*'s are of the order .89 (Corey), .78 (Husband), and .90 (Shirley); between time and trials, .57 (Shirley) and .87 (Corey); between time and total distance traveled, about .80 (Alm). Thus, it appears that between different measures of behavior in the *same* domain, individuals tend to take the same rank order.

4. Evidence from studies on the interrelation between behaviors when the situation is experimentally altered in a controlled manner. From studies of this sort, considerable information on the generality and the psychological nature of the causes of individual differences is obtained. In a given situation, the development of individuals is permitted until each individual has reached stability of performance; then certain stimulus features are altered and the relation between individual differences under the new and the old conditions studied. If no change in rank is observed, then differences in behavior are not contingent upon response to the stimulus-features that have been varied. The writer has performed a number of experiments of this type, using his Maze *X*. On this maze, which is well-lighted, the rats run their normal trials without any disturbance of the maze units whatever. At the fourteenth trial, all the animals have about reached their limits of learning, and in these plateau levels, there are marked individual differences. The true inter-*r*'s between the trials from 14 to 19 are approximately unity corrected for attenuation, indicating that whatever the systematic causes of individual differences on these successive trials, they are the same for all these trials. Are behavior differences here due to differences in capacity to discriminate the sundry sensory cues in the pathways and/or to form simple connections between sensory signs and response, or are the differences due to differences in capacity to form "higher" abstracted or generalized direction-distance relational sets that direct the movements? With two groups of rats who had reached a plateau in their learning, the lights were turned off for several trials and the rats run in pitch-darkness. The true *r*'s between the lighted and dark trials were .98 and .93 for the two groups (58). Therefore, visual cues and capacity to sense them apparently do not control individual performances in the later stages of learning. Other experiments of this general type (63, 64) tested other sense modes. Some theorists argue that maze learning is kinaesthetically controlled in the sense that the rats form serial, chained kinaesthetic conditioned responses, previous movements providing stimuli for the later ones. If this is so, then by breaking this serial chain experimentally, the performance after the break should be completely disrupted. For one group of 76 rats, T-units 3, 4, 5, and 6 were taken out of the maze, and the animals were "short-cut" from units 2 to 7. The true *r* between efficiency with the serial chain intact (Trial 19) and efficiency with the serial chain broken (Trial 20) on units 7 to 17 was, for errors, .94; for time, 1.00. Certainly capacity to form serial, chained kinaesthetic responses does not determine individual differences after the rats reach a plateau in learning. In a final crucial experiment on 76 animals, on Trials 20, 21, and 22, great violence was experimentally done to the stimulus situation: the lights were turned off, a blanket was thrown over the top of the units to disrupt general auditory cues, T-units were interchanged, but the maze pattern was kept constant except for the fact that the kinaesthetic sequence was broken by the short-cut. The true *r*'s between efficiency on Trials 17, 18, and 19 with the situation unchanged and Trials 20, 21, and 22 with it altered were, for errors .78; for time, .95. Deleting Trial 20 where emotional upset or distraction might have entered, the *r*'s were, for errors, .85; for time, .94. Deleting both Trial 20 and Trial 21 gave *r*'s of, for errors, .95; for time, 1.00.

These high intercorrelations indicate clearly that differences between individuals are not controlled by sensory stimuli or responses conditioned to them, but apparently by the degree to which the animals have formed higher generalized distance-direction behavior-sets in the given situation.

An analogous experiment by Tolman and Honzik (49) sheds light on the psychological nature of the motive for maze learning. They ran rats 11 trials through a modified Stone maze, giving them *no food* at the end of the maze. Here, differences between rats could not be assigned to differences in reward-value of the food-goal, since it was absent. Then, the rats ran 11 more trials with food in the end-box—the typical maze procedure. The *r* for errors[13] between the two periods was .67, true .73.

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[13] Not reported by the experimenters, but obtained by the writer from them. Another group of animals that had the reward trials first and nonreward trials last gave an *r* of 67, true .71.

Thus, under two quite different sets of motivational conditions, the rank orders in ability were fairly similar. The cause may have been either a drive common to the two periods, say, the drive to get out of the maze proper (amplified by food in the reward situation), or differential capacity to cognize the spatial relations of the maze whatever the motive.

5. Evidence from the intercorrelation of different behavior-domains. The validity and significance of a given behavior-domain hinges upon the way in which it is defined and measured and upon its importance to the species being measured. The correlation of this domain with other "outside criteria" may or may not divulge the psychological nature of the domain. What such inter-r's actually show is the *generality* of individual differences.[14]

To ascertain whether the inherited differences that appeared on Maze X were general characteristics of the rats that could be also observed in other T-mazes, the writer (56) ran 141 animals on another 20-blind maze, Maze Y, and found the raw inter-r to be .77 (true .79) for errors on total trials. Even the errors on 3 trials on one maze, when correlated with total errors on the other, gave a true r of .91. This indicates a fairly general learning ability in two such T-maze domains. Other experimenters have found lower values. The Stanford workers, Commins, McNemar, and Stone (7), report the results on 256 inbred rats who ran 40 trials on a 12-blind floor maze and 20 trials each on two elevated mazes, one with 12 blinds and the other with 20 blinds. The true r's (for total errors) between the floor maze and the two elevated mazes were .65 and .56,

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[14] In addition to this *objective* interpretation, such inter-r's can be analyzed into "underlying factors" by the mathematical methods of Spearman, Kelley, Thurstone, and others. These methods attempt to deduce general, group, and specific factors that are statistically consistent with the observed inter-r's. Though important analytical devices which deserve a prominent part in a systematic treatment of individual differences, these methods have not as yet been used in any problem dealing with subhuman animals, and hence they will not be considered here. Because of the possibility of rigorous experimental control of disturbing irrelevant factors in the case of animals, animal material is excellent for studies in factor-analysis, and doubtless many studies of this type will shortly appear.

Note. Shortly after the above was written, the mail brought the first published paper on factor-analysis in animals: Dunlap, J. W., "The Organization of Learning and Other Traits in Chickens," *Comparative Psychology Monographs*, **1933, Vol. 9, No. 4.**

respectively; between the two elevated mazes, the true *r* was .66. Miles ran 38 heterogeneous rats on two 15-blind T-mazes of the same pattern, one an alley maze and the other elevated, and obtained a raw *r* of .50 (true .59) for errors and one of .67 for time (28). Leeper ran 34 inbred rats 30 trials on a modified Stone maze, waited an interval of 40 days, and then ran them on the mirror image of the maze for 20 trials. The raw *r*'s were .71 (true .76) for errors and .35 (true .40) for time (23). Finally, Alm reports a raw *r* of .52 for total distance traveled in two simple 2-blind mazes and one of .57 for time (1). Since the reliability coefficients were about .90, the true *r*'s would not be much higher. Thus, it appears that between maze-learning domains, the coefficients for errors range from about .50 to .91. Studies should be made to determine the reason for these differences in values.

An entirely different picture is presented by the relationship between maze learning and other learning domains, such as problem-box and sensory sign learning. The Stanford experimenters reported for different groups zero *r*'s between time on the triple-problem box and errors on the T-maze. And between learning in the light-dark discrimination box and in the maze, the *r's* were also zero—a fact corroborated by Williams (71). All of these measures had high reliability coefficients. The Stanford experimenters discovered zero correlations between sensory sign learning and problem-box learning. These facts are illuminating, for they point to the conclusion that the learning behaviors in these different situations are quite different kinds of learning—that there is no such fact as *general* learning ability, but rather that there are *numerous learning abilities.*

Another investigated relationship is that between activity and maze learning. Is the better learner also the more active and energetic one? Shirley ran two groups of rats in activity cages and then through an 8-blind maze (38). Even though the reliability coefficients of both measures were high, the *r*'s between activity and maze errors and time were very low, giving little support to a postulation of such a marked relationship.

It thus appears that the intercorrelations between such a domain as maze learning and other domains shed little light upon the psychological nature of individual differences in maze learning. Behavior differences seem to be so specifically tied up to the unique situation in which they are measured that analysis should be confined to behavior *in situ.* One study that seems to be an exception is that by Krechevsky on "hypothesis formation" in rats (22). He ran the animals in a light-dark discrimination box, which was made unsolvable for the animal by sometimes having the light alley a blind and sometimes a true path, and by changing the dark alley likewise. The results showed that the animals tended to fall into two groups, those which followed one or the other of the visual cues *consistently*, acting as if it were the proper solution (these rats were classed as having *visual* "hypotheses"), and another group that formed right or left position-habits, disregarding the visual cues (these were classed as rats with spatial or kinaesthetic "hypotheses"). The animals used were 23 bright and 23 dull rats from the writer's inheritance groups, and 80 "stock" rats. Krechevsky reports that the maze-bright animals tended to be kinaesthetic animals, whereas the dulls were preponderantly visual; the "stock" animals were evenly distributed into the two classes. The results of this experiment imply a high positive correlation between propensity for kinaesthetic "hypotheses" and maze ability. However intriguing are the possibilities of such relationships, the results must be checked by running not only, as here, the extremes in maze ability, but rats of all gradations in ability; also, the actual correlations should be worked. If under such conditions the *r*'s were high, we would have evidence as to some of the psychological determinants of the maze ability.

High specificity of performance indicates that psychological analysis of individual performance can best be gained by a study of variables apparent in the situation proper. Correlations with "outside criteria" apparently are of little value. One fruitful approach to analysis is that in which controlled systematic variations in the situation or subjects are introduced, as is illustrated in section (4) above. Another approach is the one in which the experimenter does not attempt to control many variables that might affect individual performance, but lets them vary in the situation, measures them, and attempts to predict performance from them. Hall's work (12) indicates the fruitfulness of this approach. He let rats move at will in an open laboratory field which contained food enclosed in a barrier in the middle. He then tabulated, for each animal, distance traveled, amount of faeces and amount of urine eliminated, weight before and after regular feeding, amount of food eaten, and age, and discovered that certain movements of the rat in the field during some periods correlated (multiple) with a composite of these variables as high as .78. He thus uncovered certain important variables associated with activity of this type.

Recent advances

Since 1934 no studies on individual differences have been published which negate what has been said in the preceding sections. Most psychological study of animals continues to consist of experiments showing the effects of laboratory-induced changes of conditions on the *average* animal. Systematic studies of the psychological nature and causation of individual differences are rare. The few recent contributions are noted below; and these are studies on rats.

Maze ability. The hereditary strains of bright and dull maze learners, as depicted in Fig. 68, have now been perpetuated to the F_{22} generation, but even in these later generations the two lines have become no more distinct than the F_8 of the figure. Though there is little overlap on each other (61), considerable variation still occurs within each line, and continued selective breeding does not reduce it.

One of our major interests has been to describe the psychological nature of the differences between these bright and stupid learners. Our experiments seem rather clearly to indicate that the difference is not one of sense acuity or ability to make stimulus-response connections (62) but rather the capacity to develop abstract spatial orientations as defined by the maze path (63)(64). In addition to this cognitive difference between them, there appear to be obvious personality differences. Bright rats appear to be more emotionally disturbed in non-maze situations, whereas the dulls show more disturbance in the maze proper. Present work in which these animals are being observed in numerous non-maze situations reveals that brightness and dullness turns out dynamically to be an exceedingly complex affair.

Data are beginning to appear on Heron's bright and dull maze learners (18). Though these strains do differ to some degree in performance in another maze than that for which they have been bred, they seem to differ in no other way that has been studied—in activity, hunger drive, reflex time to shock, or in brain weight (11)(33)(39).

Emotional expression. Another systematic attack on problems of individual differences is that of Hall. He has discovered that defecation is an index of emotionality in the rat (13). This finding opens up for scientific study a phenomenon of considerable relevance to human problems. By selective breeding Hall has established strains of emotional and unemotional rats, thus proving an hereditary factor in emotionality. Several investigations on the psychological nature and correlates of this trait have been made (6)(14)(15)(16). It appears that emotional rats tend to have a lower activity level in free situations, yet to be more variable in a psychological situation requiring choice, that is, to less stereotyped. Emotional disturbance seems to be reduced when the rat is impelled by a strong need (for example, hunger), and remains reduced in the situation where the strong need was originally evoked.

Drive. A very significant group of researches on the relationship between individual differences in the strengths of sex, hunger, thirst, exploratory drives, learning, emotionality, activity, and body weight, were performed by Anderson (2)(3)(4). Because of the large number of variables measured, the number of correlations between them are exceedingly numerous. In general the correlations were low between performances in different apparatus situations. The major generalizations would be that the different drives are rather independent, and are not highly related to learning ability. The factors determining individual differences in "motivation" in the rat appear to be utterly complex dynamically.

Organization of behaviors. An increasingly frequent type of study in human individual differences is the attempt to reduce the large number of kinds of performance possible to a few "traits" or "factors." The ambition is to discover a few "primary unities" which determine a great many kinds of behavior. The technique is that of measuring many kinds of activity, calculating the intercorrelations between them, then by a "factor analysis" determining the few underlying factors which allegedly account for all the intercorrelations. Vaughn (66) and Thorndike (46)(65) have conducted such researches with rats, each investigator scoring a large number of performances of the animals in about ten apparatus situations. In general, the findings were like those of Anderson—low correlations except between behaviors in the same apparatus situation, that is, between different aspects of dynamically the same performance. In the light of the aim of such investigations, the results are discouraging, for it appears that the determiners of the rat's performance are numerous, and rather uniquely tied up to specific situations, and that independently scored behaviors in different situations are rather to be characterized by disorganization than by organization.

Conclusion and Prospectus

Comparative psychologists have made the beginning of a systematic attack on the problems of individual differences. While their work has been confined to the rat, the results lead to certain tentative conclusions: (1) In a given domain of behavior, wide and consistent individual differences exist, and in some behavior domains these differences persist throughout a considerable portion of life. (2) These behavior differences are quite unrelated to obvious morphological differences, and their physiological correlates are as yet unknown. (3) In certain domains of maze learning and activity, these differences are markedly determined by hereditary factors. (4) Ability seems to be highly specific: whereas it is consistent and constant in a *given* situation, between quite *different* situations (even though the behaviors in the two are similarly defined—for example, as "learning") it appears to be highly variable. (5) The most promising approaches to an understanding of the psychological nature of the causes of individual differences are (*a*) a thorough *a priori* analysis of the situation in which the behavior is manifest, (*b*) a study of individual differences during a period in which the situation remains unchanged except for systematic variation of stimulus features, and (*c*) a study of the interrelation between sundry behavior variables *in situ*. The experiments in maze ability, emotional expression, drive, and organization of behaviors, discussed in the section above on "Recent Advances," indicate the directions in which work is being done along these lines.

The contents of the preceding pages indicate that the scientific study of individual differences is characterized more by the prospects of future work than by a significant collection of conclusive data. Studies have been made only on the rat (and man)—and investigation of the rest of the phylogenetic scale still lies before us. In the rat, the major problems of individual differences have been attacked in only a few domains, and many other gross domains of behavior (sense acuities, insight-formations, delayed responses, simple conditioned responses, and so forth) remain relatively unexplored. As a consequence, our conclusions are really little better than speculations. We grievously need more complete studies on more behavior-domains in many more species.

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