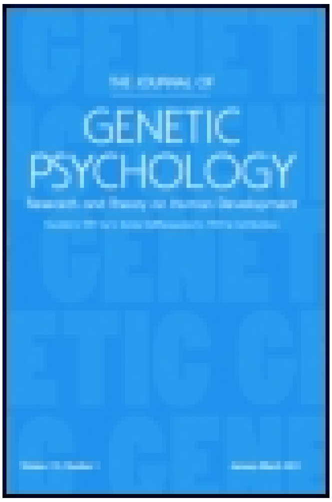

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The Inheritance of Brightness and Dullness in Maze Learning Ability in the Rat

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THE INHERITANCE OF BRIGHTNESS AND DULLNESS IN MAZE LEARNING ABILITY IN THE RAT*

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A. INTRODUCTION

In 1935 I reported the results of an experiment on selective breeding of rats for maze learning ability (3). At that time the results for only four generations and the parents were available. At the present time the 16th generation has completed its training. This report, therefore, will give the additional data together with comments and interpretations based upon the additional experience with the problem.

For the apparatus and technique of running the animals the reader is referred to a paper on the automatic maze (4) and to the previous report on breeding (3). Efforts have been made to keep running conditions as uniform as possible from generation to generation. The only significant deviation from the procedure as previously outlined is that I have paid less attention to litter size, the quickness of breeding, and close inbreeding than previously. The rats have remained healthy, and normal litters have been born. The only unhealthy sign which has been noted is that a number of the bright females develop a blocking of the intestinal tract. It is probably some form of tumor. It usually develops some time after the birth of the litter and is, therefore, not serious so far as the maintenance of the strain is concerned. This disorder occurs in other rats but very infrequently.

B. RESULTS AND DISCUSSION

Figures 1 and 2 show the distributions for the various generations. It will be noted that there has been a certain amount of fluctuation from one generation to another. Other than this, the distributions tell little. A more detailed analysis can be made by a study of Table 1. In this table will be found the means and other

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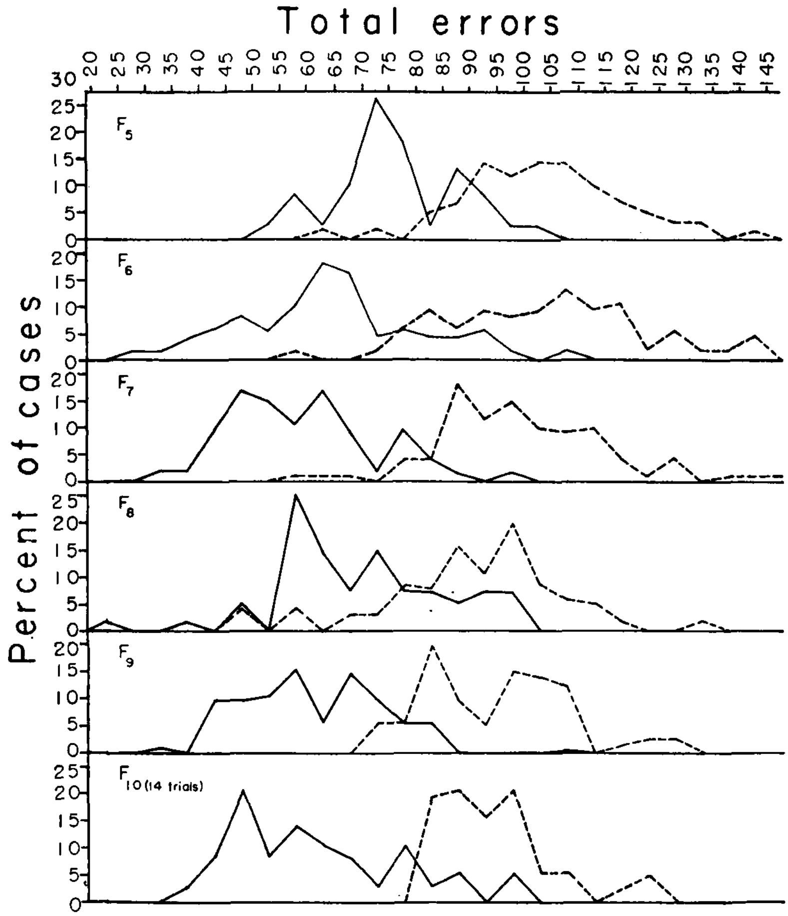

FIGURE 1

DISTRIBUTIONS FROM THE 5TH, 6TH, 7TH, 8TH, 9TH AND 10TH GENERATIONS

The dotted lines represent the dull rats. The distribution for the dull rats of F_7 omits two animals as their inclusion would have extended the figure unduly. One animal made a total of 155 errors, the other 190.

measures for the brights and dulls from the 5th to the 16th generation, inclusive. All generations were run 17 trials save the 15th which was given 32 and the 14th which was run for 16 trials. The means do not include the scores for the first two trials.

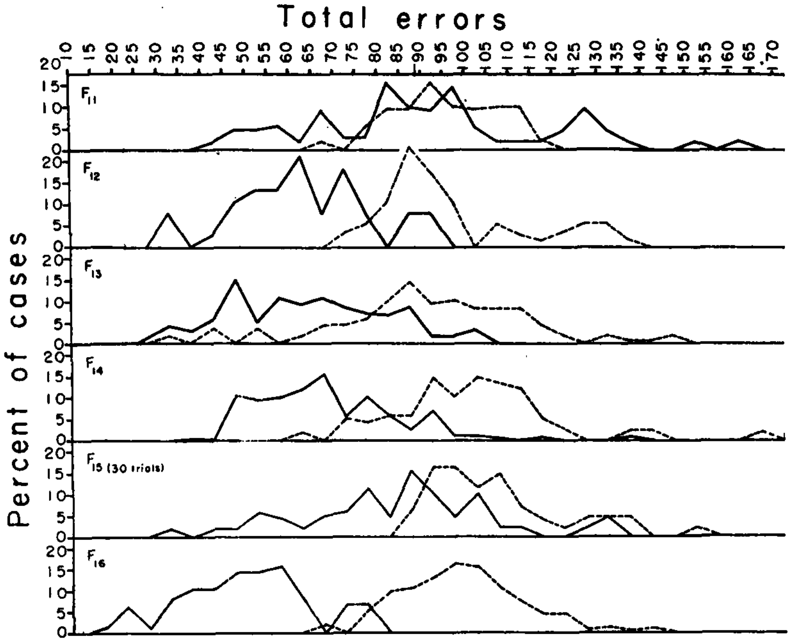

FIGURE 2

DISTRIBUTION FOR THE 11TH, 12TH, 13TH, 14TH, 15TH AND 16TH GENERATIONS
F_{15} were run for 30 trials, but the distribution is based upon 15 trials only in order to make it comparable with the others.

There are several points to be noted in this table. First, there is a good deal of fluctuation in the mean score from one generation to another. The causes of these fluctuations are not apparent to me except as noted in the table. As I have indicated above, we try to handle and run the animals in the same way from generation to generation. Apparently, however, there are some factors which are not being controlled. It will be noted also that the two strains tend to vary together, which indicates that these factors are of an experimental variety. If the fluctuations were caused by poor selection of the parents it is improbable that there would be concommitant variation in the strains. This concommitance is measured roughly by a correlation of +.58 between the means not including the 15th and 16th generations. Although this failure to control factors is

TABLE 1
DATA OF 5TH TO 16TH GENERATIONS, INCLUSIVE

Generation		No. cases	Mean error per rat	σm	D	σd
F_5	D	55	103.59	2.04	26.84	2.76
	B	34	76.75	1.84		
F_6	D	53	111.65	2.52	50.55	3.52
	B	50	61.1	2.46		
F_7	D	73	74.05	2.45	15.40	3.07
	B	53	58.65	1.85		
F_8	D	63	102.1	2.56	45.85	3.54
	B	44	56.25	2.45		
F_9	D	32	108.75	2.71	36.60	3.55
	B	43	72.15	2.30		
F_{10}	D***	41	109.55	1.62	36.10	6.34
	B	37	73.45	6.13		
F_{11}	D	51	120.9	2.83	37.40	3.74
	B	49	83.5	2.45		
F_{12}	D	55	117.75	2.28	52.55	3.19
	B	37	65.2	2.33		
F_{13}	D**	130	103.85	1.93	30.20	2.76
	B	75	73.65	1.97		
F_{14}	D	78	113.15	2.24	27.55	2.93
	B	89	85.60	1.89		
F_{15}	D*	48	195.0	7.01	46.00	9.18
	B	50	149.0	5.92		
F_{16}	D	130	116.05	1.35	69.15	2.08
	B	75	46.9	1.58		

***F_{10} rats run 16 trials only.
**In the F_{13} generation the error recorder for unit 6 was inadvertently disconnected. This affects the mean error.
*The data for this generation are based upon 30 trials.

disappointing, the fluctuation in results nevertheless has an interesting implication. It indicates that there are environmental conditions which will increase the efficiency of the dull rats. For example, there is a difference of approximately 37 errors in the means of the F_6D and the F_7D. This difference is statistically significant. There are, of course, differences between the various generations of brights also but it is well known that there are many environmental factors which will lower the efficiency of the organism. The more interesting and important problem is to find an environment which will cause the organism to respond more efficiently than would be predicted on the basis of its ancestral history. Or perhaps a better statement of the problem is: what is the environment which will enable the organism to realize to the highest possible degree the potentialities of his heredity? The immediate and specific problem in the present case is to discover the environmental chances which have been inadvertently introduced in the experiment.

Secondly, the greatest deviation from this trend is found in the 16th generation where the mean for the brights falls to its lowest level while that for the dulls is consistent with previous generations. The probable explanation is that this maze situation has reached the limit of its discriminative power so far as the dull rats are concerned and also for the bright rats if they are given only 17 trials. However, additional trials in the maze tend to increase the discrim-

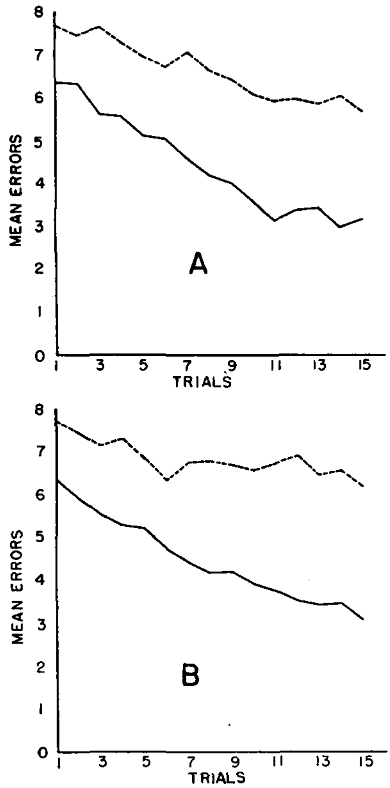

FIGURE 3

LEARNING CURVE

A is for the 5th, 6th and 7th generations combined. *B* is for the combined 14th, 15th and 16th generations. Dotted lines represent the dull animals.

inative power for the bright rats. Thus in the 15th generation with a 32-trial run we made a better selection among the bright animals with the result that their offspring markedly reduced their mean error score. A glance at the learning curve (Figure 3) for the dull rats for the last four generations will indicate to the reader that these animals never reduce their errors below the chance level. Chance in the present maze should give a mean of six errors per trial as there are 12 alternatives.

The problem which faces us is one which is familiar to those who work with tests for human subjects. The differences in the scores for the dull rats do not reflect differences in ability to any appreciable extent because the problem is too difficult for all of them. It is hardly likely that the group is in reality homogeneous in ability. Real differences in ability must still exist. The problem is to make them apparent. The obvious answer is to make the problem easier, but if this is done it is likely to cause a loss of discriminative power for the bright animals. Another answer is to run the dull rats on one problem—perhaps on six units of the maze instead of 12—and the bright animals on the whole maze as before or perhaps even extend the problem to 15 or more units for them. Only experimentation can indicate whether this will be the solution, as it is impossible in the a priori reasoning to take into account all of the intricate relationships which may be involved in the learning of the maze pattern. Still another possible solution is to run the animals in a number of different mazes and to select on the basis of a combined score. The time required to do this should be prohibitive. Another suggestion by Dr. H. P. Longstaff is of interest. It is to run all rats in two units of mazes to a criterion of learning. As each rat reaches the criterion add a unit for it and when it reaches the criterion in the three units repeat the procedure. We would thereby measure what we might call the "maze mental age" of each animal. Selection for breeding would be on the basis of this "mental age."

This is an ingenious suggestion and holds important possibilities. There are, however, some technical difficulties. It is possible in the maze which is used to allow the animals to run through any number of the 12 units and to finish the distance to the food by going through the tunnel which runs underneath all of the units. However, unless the readjustment of the maze for each rat can be solved by an automatic arrangement, the plan would be very time consuming. Also, there would arise the question of how many trials to allow the animal on a given number of units before deciding it to be beyond his capacity. This limit would have to be set arbitrarily. Other problems would no doubt arise but possibly all can be solved.

Figure 4 illustrates another relationship which has been found

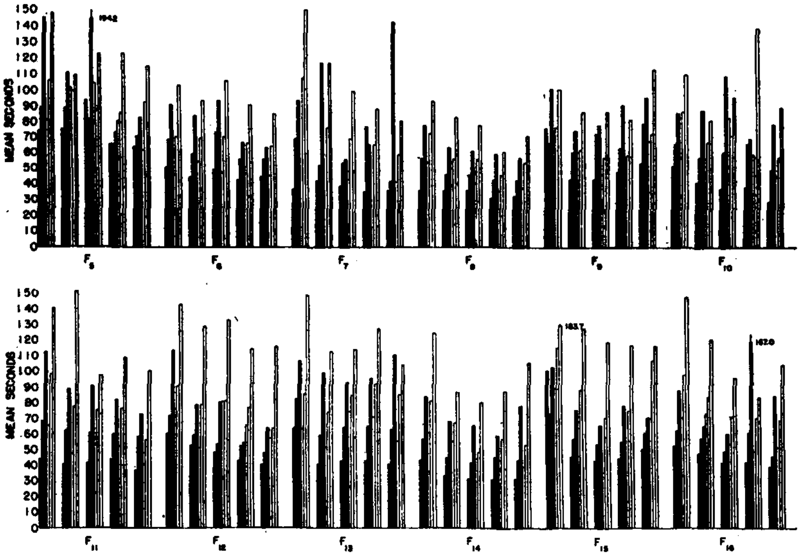

FIGURE 4

HISTOGRAM SHOWING THE DIFFERENCE IN TIME BETWEEN THE DULL AND BRIGHT ANIMALS FOR TRIALS WITH SAME NUMBER OF ERRORS AND AT DIFFERENT STAGES OF LEARNING

The brights are represented by the solid black. The figure reads as follows: starting in upper left-hand corner, the first step in the solid black indicates the mean time for bright rats in Trials 1 to 3, inclusive, in which 1 to 3, inclusive, errors were made. The next step is for Trials 1-3 in which 4-6 errors were made, and the next Trials 1-3 in which 7-9 errors were made. The three open bars repeats this for the dull rats. The next group of 6 bars are for Trials 4-6, the next for Trials 7-9, and so on to Trials 13-15. The whole procedure is repeated for the F_6 generation and for each succeeding generation.

to exist. The dull rats progress through the maze at a lower rate of speed than the brights. This fact was first noticed by Harris and his interpretations based upon it will be found in his articles (1, 2). It is to be expected that an animal which makes more errors than another will take longer to go from the beginning to the end of the maze. In order to eliminate this factor as much as possible the mean time for runs involving the same number of errors has been calculated for both the brights and the dulls. As indicated on the figure this has been done for various portions of the learning curve. With very few exceptions the brights show a faster time than the dulls. The exceptions which do occur can be accounted for in terms of the abnormal behavior of one or two rats.

Figure 4 does not show times for correct runs or for runs in which more than nine errors were made. A calculation shows, however, that in all 12 generations under consideration in this paper the dull rats have made a total of only 28 errorless runs with a mean time of 113.2 seconds per run. The bright rats have made a total of 334 such runs with a mean time of 32.2 seconds. On the other hand, the dull rats have made 289 runs in which there were 12 errors or more with a mean time per run of 610.4 seconds, while the bright rats have made 42 of these runs with a mean time of 939.8 seconds. Apparently when the bright rats become confused they are very hesitant in their running.

It might reasonably be assumed that the fact that a larger time is required by the dull rats indicates a difference in motivation, and that this difference in turn would account for the difference in learning. This possibility was examined by Harris (1, 2), and he concluded that while the two strains differed in motivation under the maze running conditions, this difference was not sufficient to account for all the difference in learning.

C. Conclusions

1. There can be no question that maze learning is largely determined by hereditary characteristics. Strictly speaking, this statement should be qualified by designating the maze learning as the learning of the particular maze employed. However, unpublished evidence shows that these rats will differ in their learning of the Stone Multiple-T maze also. To what extent there is a generalized maze learning ability can only be determined by further experimentation.

2. The evidence indicates that the maze problem as used at present in this experimentation has no further discriminative power for the dull rats, and that the validity of selection of bright rats would be increased by increasing the number of trials or possibly by increasing the number of units in the maze.

3. It is felt that some evidence has been presented which bears on the question of the influence of heredity, and suggests the problem of specifying the optimal environment for the realization of hereditary potentialities.

4. As a general rule, the dull animals take longer in running the maze than the brights when errors are held constant.

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