The Effect of Various Temporal Arrangements of Practice on the Mastery of an Animal Maze of Moderate Complexity

Cook

THE EFFECT OF VARIOUS TEMPORAL ARRANGEMENTS OF PRACTICE ON THE MASTERY OF AN ANIMAL MAZE OF MODERATE COMPLEXITY

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CONTENTS

The Effect of Various Temporal Arrangements of Practice on the Mastery of an Animal Maze of Moderate Complexity

I. Introduction

The problem of the relative efficiency of massed versus distributed effort in animal learning has been the subject of much controversy, although the majority of evidence would seem to favor some degree of distribution. On examining the problem one finds several complicating factors that make it impossible to say with anything like positive assurance what particular temporal array of practice is preferable even in a given type of problem. Such factors as age, the type of subjects used, difficulty of the problem, primary or terminal massing, length of interval between successive periods of the training series, the number of records on which one may fairly base general conclusions, and the criteria of learning employed have an important bearing on the main problem.

As early as 1907 Yerkes (12) compared the relative effect of two, ten, twenty and a hundred trials per day (with a lapse of twenty-four hours between successive learning periods), in building up a black-white discrimination habit in the dancing mouse. There was a marked advantage in favor of the shorter practice period. Below is shown a table setting forth his results. The index of modifiability means "that number of tests after which no errors occur for at least thirty tests."

Group		*No. of Cases*	*Index of Modifiability*
A	2 and 5 trials per day	6	81.7 ± 2.7
B	10 trials per day	10	88.0 ± 4.1
C	20 trials per day	10	91.0 ± 5.3
D	100 trials per day	3	170.0 ± 4.8

The differences between the groups are small, with the exception of Group D, and are obscured by the probable error. The general results are rendered still more doubtful by reason of (a) the smallness of the groups, (b) the influence of an epidemic which caused a change in the technique of Group A from 2 trials to 5 trials per day, and the inclusion of the records of only six of the original 10 animals, and (c) the wide variations in age of the members of Group D (8, 17 and 22 weeks).

Hunter (4) in 1913 used different forms of distribution in the training involved in the delayed-reaction experiment. Some of his work was done by means of a multiple-choice box offering three possible alternatives, using reward and punishment as part of his technique, and white rats as subjects. The animals learned to choose the lighted box in preference to either of the two unlighted ones as training preliminary to the main study of the delayed reaction. When five trials a day were given, the animals learned to respond correctly after an average of 175 trials, whereas when ten trials per day were given the average was 347.5 trials, and Hunter concluded, "The use of five trials favors rapid learning more than does the use of ten trials." His results can hardly be considered very significant since only four animals were used in each group, and no definite norm of learning was indicated.

Ulrich (8) was the first (1915) to make a systematic study of the relative effect of various degrees of distribution of effort on animals. He used white rats as subjects, and both a simple latch box and a Watson circular maze as problems. The various distributions were one, three and five trials per day. His results are shown in the table below.

		Latch Box		*Maze*	
Group	*Distribution*	*No. of Cases*	*No. of Trials*	*No. of Cases*	*No. of Trials*
A	1 trial per day	17	17.0	8	23.62
B	3 trials per day	12	25.0	8	66.37
C	5 trials per day	11	32.7	8	90.00

He found that both for the latch-box and the maze the frequency of one trial per day was more economical than either three per day or five per day. His work is open to serious criticism in view of the fact that the animals used were not all of the same strain, and several animals of Groups B and C were not perfectly normal. Also his norm for learning the latch-box was one second per trial for two successive *days,* which meant two successive errorless trials for Group A, six for Group B, and ten for Group C. Furthermore, his time criterion was not strictly adhered to, as in some cases he allowed two seconds per trial for rats that ran slowly. With different norms of mastery for the three groups, reliable comparisons of the relative efficiency of the three methods of distribution cannot well be made. The norm for maze learning was an average of six seconds on two successive days, and "in addition to this criterion the runs in the maze had to be relatively free from error,"—which introduced still another variable, with its consequent effect on the reliability of the final scores.

In comparing variations in interval between successive periods of practice Ulrich used intervals of one, two and three days with the latch-box in this same study. The groups contained seventeen, twelve, and nine cases respectively with averages of 17.0, 14.8 and 8.66 trials required for learning the problem. For this type of problem the longest interval used was thus the more beneficial although the effect of interval was less pronounced than length of practice period.

Reeves (7) in 1917 found that ten trials per day were distinctly preferable to twenty per day for the white rat in learning to discriminate between a moving and a still light. Her results may be criticised in that (a) only four animals were used, (b) one animal was emotionally disturbed after eight days of training, and (c) the subjects were given ten trials a day until the 160th choice—when the number of trials per day was raised to twenty—thus varying the method during the course of the experiment, and (d) results were calculated in terms of every 100 choices, in spite of the fact that the technique was varied after the 160th choice.

A year later Lashley (5) found that two trials a day were more advantageous than ten trials a day in learning a maze having a single cul-de-sac (T-pattern). The group given ten trials per day, under normal motivation, learned the maze in an average of 51.7 ± 4.3 trials, while those allowed only two per day mastered it in 21.1 ± 0.8 trials—thus affecting a saving of 59% in the number of trials. The norm of mastery employed was ten consecutive errorless trials, which is open to the criticism that the final test period of the first group was completed in two days, whereas that of the latter group extended over five days.

Brockbank (1) experimented with rats in 1919, using the Watson circular maze as Ulrich had done. His study was primarily an investigation of retention, but as he used two distributions of effort in the initial learning his results may be cited. In the case of nine subjects given one trial a day the average number of trials for learning the maze was 61.45, with an average of 143.4 errors; whereas seventeen subjects given three trials per day required 138.3 trials, with an average of 431.5 errors, for mastery. The norm of learning "covered a period of the last fifteen trials, the first six of which were required to show perfect integration of all movements, and at the same time such speed as would indicate the establishment of the integrations." Here again, as in the case of Lashley's work, the test series for one group was spread over a larger number of days than the test series for the other group,—the first group requiring fifteen days, and the second group only five.

In his study of whole vs. part learning in the white rat in 1921 Pechstein (6) brings forward data bearing upon distribution of effort, as indicated in the accompanying table. Nine animals mastered each of the four sections, and finally combined them, at the rate of two trials per day; while a like number learned each section of the maze in one daily practice period and connected the sections on the fifth day. The norm of mastery was four perfect runs out of five.

Section	*Method*	*Trials*	*Time*	*Errors*
I	Distributed	34	470	52
	Massed	11	256	27
II	Distributed	2	33	3
	Massed	5	51	6
III	Distributed	14	127	14
	Massed	7	72	12
IV	Distributed	9	111	11
	Massed	1	11	2
I–IV	Distributed	15	1166	119
	Massed	4	439	88
TOTAL	Distributed	30	1907	199
	Massed	10	829	135

Sections I, II, III and IV of the table represent the four parts of the large maze, each section being a simple maze in itself. I-IV indicates that in this part of the learning the animals were given an opportunity to put together as a whole the four parts of the maze that they had learned as separate units. "Total" indicates the average (trials, time and errors) of I, II, III and IV plus the average of I-IV which completed the learning of the maze as a whole.

The "massed" learning of the four-part maze, as indicated by the total score was not done under strictly massed conditions since as above noted only one section was learned in a single practice period, with a daily interval between the mastery of each section and also between the fourth part of the maze and the task of connecting the sections. The "total" scores for this group represent two factors: a relative massing of effort, and the "part" method of attack. However, it is possible to think of each of the parts as a simple maze, which rules out the latter factor from the scores of the separate parts. It will be seen that in general the parts (or simple mazes) were learned much more readily under massed than under the two-trial-per-day arrangement. These results very clearly support Pechstein in his conclusion that "provided the problem is short it is more economical to mass learning effort than to distribute it, irrespective of whether economy is estimated in terms of trials, time or errors." Incidentally he found the same rule to apply to human stylus maze learning. The norm requirement, four perfect trials out of five, extended over two or more days in the "distributed" group but was met by the "massed" group in one day.

In 1923 Warden (9) called attention to the fact that any given distribution involves two major factors—length of practice period (or Frequency of Interpolated Interval), and length of interval between practice periods. Accordingly he ran a series of practice periods through a series of intervals, using a Carr maze with white rats as subjects. His results in terms of trials required to learn were as follows:

Length of Interval	*Frequency of Interpolated Interval*					
	After 1 Trial		*After 3 Trials*		*After 5 Trials*	
	No. of Trials	*M.D.*	*No. of Trials*	*M.D.*	*No. of Trials*	*M.D.*
Six hours	45.0	12.0	62.4	11.1	74.1	17.5
Twelve hours	36.8	9.7	54.8	12.1	63.6	11.4
One day	46.4	13.1	65.4	18.4	86.1	15.2
Three days	71.9	13.5	91.1	24.2	86.1	18.4
Five days			129.7	26.0	107.1	20.7

The maze was considered learned when nine out of ten trials were made without error. Here again the distributions employed necessitated a varying number of days in which to attain the norm of learning set for the experiment.

Warden criticised the usual type of statement that the greater the distribution of effort the more efficient the learning, and introduced the notion of an optimum distribution of practice for problems of a given type and difficulty. In his own work it appeared that one trial every twelve hours was the optimum interval between periods of practice. When 1-trial, 3-trial and 5-trial practice periods were employed the twelve hour interval proved the best of those studied. The loss in efficiency when intervals longer than one day were used was very marked. However, his results show that with the longer intervals there was a tendency for the longer practice periods to be superior to the shorter ones. This suggests that length of practice period and length of interval are functions of each other, and is in agreement with the work of Perkins on this point. Using pairs of nonsense syllables as learning material, and four students as subjects, she found one repetition per sitting better than two, four, or eight, in the order named. She also found that a comparatively short interval (two to three days) was preferable when one or two repetitions were used, whereas a longer interval (four to eight days) was better if four or eight repetitions were given at a sitting.

None of the above workers have investigated the problem concerning the relation of distribution to the stage of mastery (primary and terminal massing). For example, nothing has been attempted comparable to the work of Carr on the stylus maze or of Steffens on memory material, both of whom found that distribution was more advantageous when introduced in the early part of the training series. Nor has a varying arrangement of the type employed by Cummins (3)—an increasing-decreasing schedule and vice versa—been tried with animal subjects.

Our study takes its departure in the main from the work of Pechstein in which he found, as above stated, that massed was decidedly superior to distributed effort in learning very simple mazes (sections of his four-part pattern); whereas in general, other investigators have found that massed practice is less efficient than some arrangement of temporal distribution for various complex maze patterns.

This finding of Pechstein's suggested that the efficiency value of temporal arrangement of practice may be so largely a function of the complexity, or difficulty of the pattern that massed effort would prove to be in general superior for easy, and distributed effort for more difficult habit formation of the maze type. An interpretation of results to date, in so far as this point is concerned, could hardly be made until actual data on a maze of moderate difficulty were at hand. The present experiment constitutes a most thorough testing of this factor, inasmuch as such temporal arrangements as have most commonly been investigated on simple and complex mazes were now used on a maze of moderate difficulty. In addition to the massed, one trial per day, and two trials per day arrangements, an attempt was made to determine the influence, if any, of certain temporal arrangements that have not been investigated to date on either simple or complex animal mazes, and which have a bearing on the point as to the relative effect of the temporal factor on the stage of mastery at which it is introduced.

TABLE I

Showing Various Temporal Distributions of Practice Investigated

Group	*Number of Animals*	*Temporal Distribution*
A	49	20 trials in one day (successive)
B	38	2 trials per day (for ten days)
C	8	1 trial per day (for twenty days)
D	37	2-4-6-8 series (increasing no. of trials)
E	35	8-6-4-2 series (decreasing no. of trials)
F	29	*12-108 series (interval increased by 12 hour increments)
G	28	*108-12 series (interval decreased by 12 hour decrements)

*These groups were given two trials in each practice period.

The various temporal arrangements investigated are indicated in Table I. Attention is called to the unusually large size of the groups in every case except Group C, which though small compared with the others is still about the size usually employed in studies of this sort. All the groups (except C) are from two to five times as large as those used in previous studies of distribution of effort. Furthermore, in each case, they are made up of several smaller groups (of eight or ten each) run at different times and taken from various shipments of animals, which insured a better sampling of the subjects than is usually obtained. We had hoped to use such large groups throughout the study as to insure the validity of the data, feeling that much of the "unreliability" of the maze is due to the use of small groups. It had been planned to increase the numbers of Group C, but before this could be done the animal laboratory was removed to another building, and the maze was destroyed in moving. In building a new maze for the laboratory the old maze was not duplicated. Instead a new maze (the Warner-Warden) was devised, and although it was developed along similar lines, a pattern exactly duplicating the writer's could not be arranged with it.

II. Apparatus and Procedure

The maze employed was the pattern designed by Warden for the Columbia Laboratory in 1922, and similar to the Warden stylus maze. A diagram of the Warden rat maze is given on Plate XIII in *The Development of a Standardized Animal Maze* (11).

This maze was specially devised for the study of serial animal learning, the pattern presenting a succession of similar pattern elements so constructed that the animal cannot distinguish a cul-de-sac until it has actually approached the end by rounding the turn. As will be seen it consisted of eight culs-de-sac with ninety degree angles of juncture with the pathways, uniform distance between junctions, and with the order of correct turns l, r, r, l, l, r, l, r. The maze was built of wood painted a dull black to minimize the effect of shadows and reflected light. The total length of the true pathway was thirteen feet, four inches. Each cul-de-sac was five inches in depth. The complete maze was covered with window glass set in six narrow wooden frames, so that each section lay flat on the wooden partitions, preventing the animal from climbing or looking into the adjoining compartments. The top sections could be removed individually for cleaning the maze. The entrance box was provided with a metal door hung from a wooden rod, sliding in grooves, and operating almost noiselessly.

At the opposite end of the maze was the food box, provided with a sliding door to be closed behind the animal after he had entered.

The whole maze was mounted on a large wooden base twenty-four inches high, solidly built, and provided with casters to permit of its being moved about. It was placed in a position in the center of the room directly beneath a single indirect 110-watt light, and the shades drawn so as to control the illumination factor. During the entire course of the experiment the maze was never moved from its initial position, nor was the position of the animal cages or feeding cage changed. The time of day varied, naturally, but in each part of the experiment an equal number of morning and evening runs were made. Seasonal variations also were encountered, but a comparison of groups run in March and June showed no measurable advantage to either group, so this factor may be ignored. For example:

Group	Division	No. of Animals	Date	Av. No. of Errors
20 trials in 1 day	I	24	March, 1925	30.9
	II	25	June, 1925	28.16

A total of 224 male albino rats were used in this investigation. They were all obtained from a carefully selected strain of the Douredoure Colony, Philadelphia, Pa. All were approximately eight weeks old, and weighed between eighty and a hundred grams when received. Preliminary work in which animals of varying age and of different strains were used—the results of which were discarded—demonstrated to us the importance of the most extreme care in selection of strain, on account of temperamental and other differences, and the inadvisability of mixing strains in a given experiment. Furthermore, the recent work done on drives in this and other laboratories has demonstrated the desirability of taking account of the variations due to the oestrous cycle in the female. Such variations were avoided in this experiment by using male rats only.

Two days after arrival the animals were marked by ear clips. The rats were kept in the laboratory for a week before being given the preliminary training. They were housed in cages thirty by fifteen by fifteen inches, of galvanized iron wire provided with sliding doors and removable galvanized iron floors covered with a layer of sawdust. About twelve animals were kept in a cage, and were fed during this period at twelve hour intervals by removing them one at a time to a feeding cage where whole wheat bread soaked in condensed milk was provided. They were allowed six minutes for feeding, during which time their original cages were washed, new bedding of sawdust provided, and fresh drinking water supplied. The cages were scrubbed and disinfected once a week with a carbolic acid solution.

Two days before the beginning of the experiment proper each animal was fed separately for three minutes in the entrance box of the maze, and then transferred to the food box for the remaining three minutes of the meal. This method of giving each single animal its preliminary contact with entrance box and food box is, we believe, a forward step in the development of a more scientific maze technique. The older method of giving preliminary feeding to an entire group at a time is of course much more convenient, but does not duplicate the actual experimental situation so well.

In the first run a nibble of food (ground fine in a food chopper so that the animal could seize only a small portion at a time) was allowed in the food box of the maze. The animal was then removed to the starting box, entered gently through the doorway, and the sliding door closed behind it. The experimenter stepped quietly around to the food box so as to remove the animal, recording in the meantime the errors made by the animal in each cul-de-sac. Time was taken in the usual manner, with a stop watch. The animal was then placed in the feeding cage where he remained until the group had completed its preliminary run when all were given their customary six minute feeding and then returned to their own cage. Precisely the same procedure was followed in the main experiment.

The order of running each group, and each animal in a given group, was preserved throughout. The experimenter was careful to move always in the same direction around the maze in transferring the animal from the food box to the starting compartment, and in taking his place at the food box.

The first run in the maze was included in the preliminary training. It has been conclusively demonstrated many times that the record of the first run does not correlate with the final learning scores. Naturally this discrepancy is exceedingly large as no connection between the pathway and the food has yet been made. A special reason for ruling out all possible chance factors of this sort in our own study was that the total practice was to be limited to twenty runs, in which case the proportional effect of the first run would be greater than in the usual complex maze.

On the day following the preliminary trial each group of rats was given the number of trials in the maze required by that part of the experiment, and this was continued on subsequent days in such a manner that twelve hours had always elapsed between the last feeding period and the next running of the maze. Where several trials were given in a single practice period care was taken to see that the animal was rewarded with only the merest morsel of food after each trial so that the incentive would not lose its effectiveness.

In computing records the total time per run was calculated in seconds. Errors were recorded whenever the nose of the animal was seen to project a discernible distance into any pathway leading to a cul-de-sac. This criterion of an error was the most accurate and practical that we could devise. Both forward and backward cul-de-sac errors were counted, but retracings in the true pathway were not taken. It has been shown by several investigators (cf. Warden, p. 58) that returns along the true pathway are of little or no value in computing a final learning score. Furthermore it seems to the present writer that such returns are usually attempts to pick up the trail after making a cul-de-sac error. Often an animal on coming out from an alley would retrace the pathway for several sections, suddenly whirl about, and go directly to the food box without making an error.

III. Results and Conclusions

The central problem of this study is concerned with the effect of various temporal arrangements of practice on learning efficiency in connection with a maze of moderate difficulty. Groups A, B, and C were run primarily to test this factor, since they correspond in temporal arrangement to similar studies on both more simple and more complex types of maze. Groups D and E cover the factor of primary and terminal massing in so far as such occurs in a decreasing-increasing series in length of practice period (with a constant interval of one day); Groups F and G cover the same point in so far as an increasing-decreasing series in length of interval (with a constant practice period of two trials) introduces such a factor. However, since the four latter groups, as we shall see, show little or no influence of the temporal factor, the results of the entire seven groups may be taken to support the general conclusions reached concerning the main factor of complexity of the task. All the group scores, then, bear directly upon the problem of the effect of temporal arrangement on a maze of moderate difficulty.

It will be convenient in presenting the data of this investigation to discuss it from the standpoint of the following methods used in treating them: (A) Total score values covering a constant period of practice (20 trials). (B) Rate of error elimination and time reduction in successive groupings of two trials each. (C) Percentage of animals that mastered the maze, within the total practice period, under three different norms. (D) Percentage of animals making errorless runs on successive trials.

The error scores will be used in the main in discussing the results, for the reason that they constitute a more valid index of learning in maze work, in spite of the fact that on the whole the relative variability of the data for time and error indices in this study is about the same. Time scores in maze studies involve marked individual differences in (1) speed of running, (2) so-called "latent time" (stopping to scratch, etc.), and (3) loss due to such influences as extraneous noises and other chance factors, as discussed at length by Warden (10, p. 21 ff.). More weight will therefore be given to the error scores than to the time records, especially in dealing with progress in learning. The error records are on the whole much more consistent in the present study, although the time scores agree more often than not with the error scores.

A. Total Score Values

The data covering total score values are presented in the following tables:

TABLE II

Distribution Table for Errors and Time

Errors	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Seconds*	*A*	*B*	*C*	*D*	*E*	*F*	*G*
10								100							
11								120							
12								140		1		1	1		
13								160	3			1	6		1
14	1							180	1	2	1	4	6	4	1
15	1				1			200	4	1		6	7	2	3
16	1		1		1		1	220	4	5	1	6	5	9	1
17	3			1	1		1	240	2	10	1	2	2	4	2
18	1			1	2			260	1	4		6	5	3	3
19	1	3		1		1		280	2	2		3		2	
20	3	1		2	3	1	1	300	7	2	1	4		1	6
21	2	2	2	1	1	1		320	2			2			2
22	2	1		3	1	1	1	340	2	2		2	1		3
23	2	2		1	1	2	1	360	4	3				1	3
24		3			2	3		380	1	2			1	1	1
25	1	2		2	2	1		400	1	1	1		1		
26	3		1	3	4		4	420	2	1					
27	3	1	1		1	2	1	440	2						
28	4	3		3	1	4	2	460		2					1
29	1	2		3	3		1	480	1					1	
30	2				1	2	1	500	1					1	1
31				2		1		520	1						
32		3		1		1		540							
33	1	3				1		560	2						
34	2	3		2	2			580			1				
35	3			2		2		600							
36				3		1		620							
37	4	1	1	1	1		2	640							
38	1			1	1		3	660							
39	1	1		1	2			680							
40	2		1					700	2						
41					1		1	720	1						
42	2	1				1	1	740	2						
43	1				1			760							
44		1				1	1	780	1		1				
45		2				1	2	800							
46					2		1	820							
47								840							
48				2			1	860							
49				1			1	880							
50	1					1	1	900							
51		1						920							
52		1						940							
53		1						960							
54								980							
55								1000							
56								1020							
57								1040							
58								1060							
59								1080							
60			1					1100							
61								1120			1				

Table II shows the actual distribution of scores for all groups both for errors and time.

Table III presents the standard measures of central tendency for the various groups in terms of errors and time.

Table IV shows the reliability of the differences between the various groups whose error and time averages are to be compared.

TABLE III

Showing Results of Different Groups, in Terms of Errors and Time, for the 20-Trial Learning Series

Group	*Errors*							
	Number of Animals	Median	Mean	P.E. (Av.)	S.D.	σ_σ	Coefficient of Variability	Range
Group A (20 in 1 day)	49	28.0	28.3	1.11	8.15	.78	28.68	14-50
Group B (2 per day)	38	30.5	31.1	1.03	9.43	.72	30.29	19-53
Group C (1 per day)	8	26.5	31.0	2.57	10.87	2.71	34.77	16-60
Group D (2-4-6-8 series)	37	29.0	29.7	1.34	8.16	.64	27.44	17-49
Group E (8-6-4-2 series)	35	26.0	28.0	.97	8.54	.68	30.49	15-46
Group F (12-108 series)	29	27.0	30.8	1.18	9.42	.83	30.58	19-50
Group G (108-12 series)	28	33.5	33.6	1.28	10.04	.90	29.87	16-50

*The high value for average time for Group C is probably due to the small number of animals in this group,—running time being an individual factor of considerable variation,—the use of a large number of animals tended to average down the time score.

Group	*Time*						
	Median	Mean	P.E. (Av.)	S.D.	σ_σ	Coefficient of Variability	Range
Group A (20 in 1 day)	320	363.0	20.4	127.2	12.2	35.0	160- 780
Group B (2 per day)	240	279.2	11.9	73.7	5.7	26.3	140- 460
Group C (1 per day)	350	477.6	74.6	313.0	44.9	65.5	180-1120
Group D (2-4-6-8 series)	240	241.0	5.7	51.8	4.0	21.5	140- 340
Group E (8-6-4-2 series	200	215.6	6.8	59.9	4.8	27.8	140- 400
Group F (12-108 series)	220	250.6	8.5	68.2	6.0	27.1	180- 500
Group G (108-12 series)	300	295.2	9.8	77.0	6.9	26.1	160- 500

TABLE IV

Showing Reliability of the Difference Between Total Score Averages

Groups	*Errors*			
	Difference	*Sigma (Diff.)*	*D / P.E. Diff.*	*Chances in 100 of a Real Difference*
A and B	2.80	1.51	1.85	89
A and C	2.67	2.79	.95	74
B and C	.13	7.66	.13	54
D and E	1.76	1.65	1.06	76
F and G	2.82	1.73	1.63	87

Groups	*Time*			
	Difference	*Sigma (Diff.)*	*D / P.E. Diff.*	*Chances in 100 of a Real Difference*
A and B	83.76	22.00	3.80	99
A and C	134.60	77.41	1.73	88
B and C	98.36	75.09	1.30	81
D and E	25.35	8.93	2.83	97
F and G	44.53	13.61	3.27	99

It will be seen by reference to Tables III and IV that there is little or no difference between the various groups in so far as total error scores are concerned. The scores from Groups D-E, and for Groups F-G, are extremely similar. Even the differences between Groups A, B, and C, which repeat the usual temporal arrangements in studies of distribution of effort, are obscured by the probable error. In the case of Groups A and B the coefficient of variability and range are very similar. The standard deviation and its probable error, the coefficient of variability, and the range for Group C are appreciably greater, indicating a less homogeneous group and consequently less reliable figures. We also find considerable range in variability in the time data, which makes any generalizations based on the time factor quite unreliable.

B. Rate of Error Elimination

The problem of relative efficiency of the various temporal arrangements can be approached from another angle, i.e., speed of learning in terms of error elimination. It is doubtful whether total time and errors give a true representation of

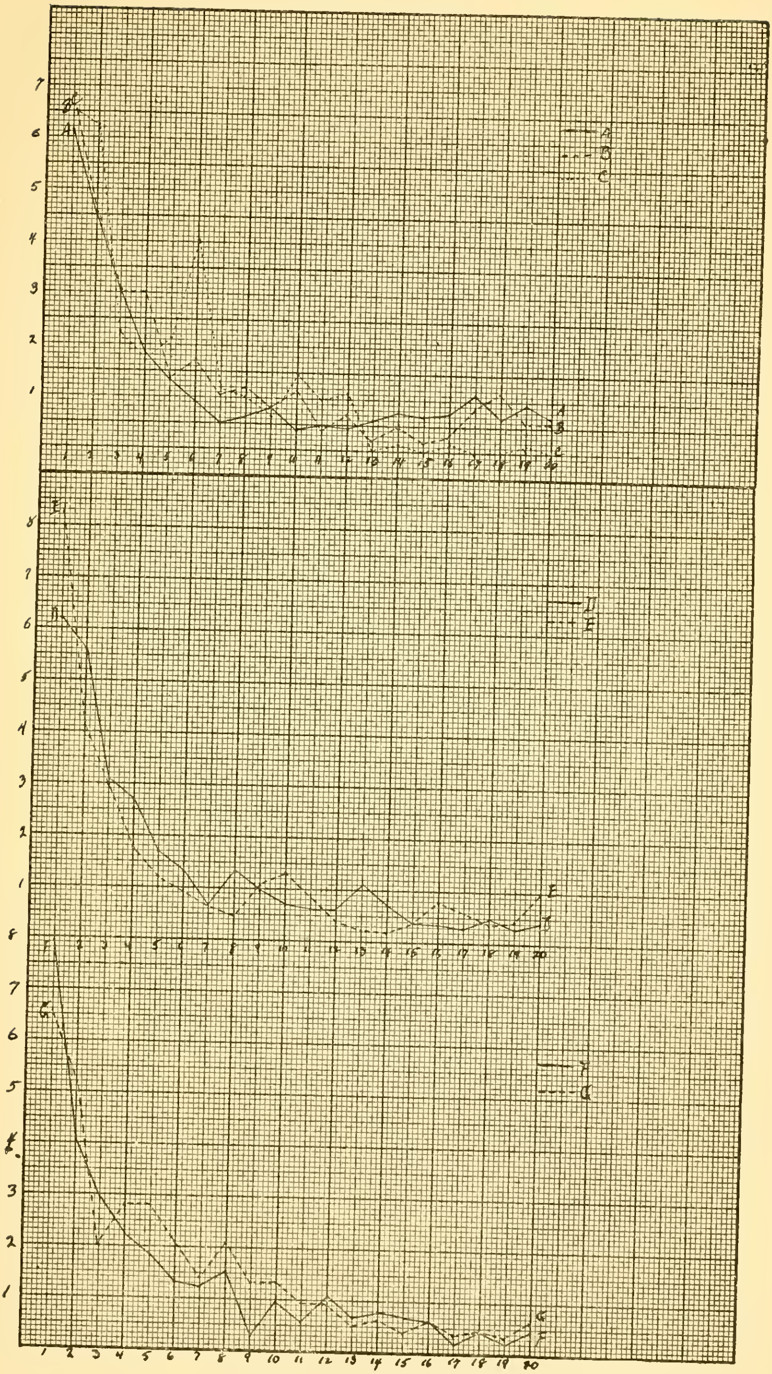

Figure I

actual learning progress under our conditions. As has been noted, the task in terms of the total number of trials was kept constant in the case of each of the seven groups. It is possible for an animal, or even a group, to complete the learning of the maze before the end of the twenty-trial practice period, without the fact being adequately reflected in the total error and time scores. Rate of error elimination may be used to bring out the factor of speed of learning, which is likely to be obscured by the total scores.

The data showing the relative rates of error elimination are set forth in the following tables and graphs:

Table V shows the average number of errors for each group on each of the twenty trials of practice.

Figure I presents the data of Table V in graphic form.

Table VI shows the percentage of total errors made by the different groups in each successive pair of runs during the twenty-trial training series, based on the mean total scores shown in column 1 of the table.

Table VII indicates the percentages of Table VI computed as cumulative scores.

TABLE V

Showing the Average Number of Errors for Each Group on Each Trial of the Learning Series

Group	*No. of Cases*	*Trials* 1	2	3	4	5	6	7	8	9	10
A	49	6.14	4.43	2.98	1.84	1.37	.97	.55	.67	.80	.43
B	38	6.50	4.51	3.00	3.08	1.34	1.71	1.03	1.21	.88	1.24
C	8	6.50	6.25	2.37	1.75	2.25	4.10	1.25	1.12	.75	1.50
D	37	6.21	5.56	3.10	2.72	1.72	1.32	.73	1.30	.97	.73
E	35	8.31	4.20	2.91	1.71	1.22	.97	.60	.48	1.09	1.37
F	29	7.96	4.20	2.93	2.75	1.82	1.34	1.27	1.55	.24	.93
G	28	6.55	5.18	2.00	2.82	2.86	2.10	1.43	2.10	1.32	1.39

Group	*No. of Cases*	*Trials* 11	12	13	14	15	16	17	18	19	20
A	49	.59	.55	.65	.85	.75	.88	1.21	.77	1.00	.78
B	38	.47	.76	.23	.50	.21	.37	.92	1.26	.66	.68
C	8	1.00	1.25	.12	.25	.12	.25	.00	.00	.12	.00
D	37	.65	.62	1.11	.70	.40	.37	.32	.46	.27	.40
E	35	.83	.40	.23	.17	.37	.80	.60	.37	.37	1.00
F	29	.58	1.06	.68	.79	.68	.62	.17	.48	.24	.44
G	28	.96	.92	.53	.68	.46	.64	.32	.43	.25	.64

TABLE VI

Showing the Percentage of Total Errors Made by the Different Groups in Each Successive Pair of Runs

Group	*Av.*	*1-2*	*3-4*	*5-6*	*7-8*	*9-10*
A	28.3	37.34	17.03	8.26	4.31	4.34
B	31.1	37.04	19.54	9.80	7.20	6.81
C	31.0	41.12	13.29	20.48	7.64	7.25
D	29.7	39.62	19.59	10.23	6.83	5.72
E	28.0	44.67	16.50	7.82	3.85	8.78
F	30.8	39.25	18.32	10.87	9.09	3.77
G	33.6	34.91	14.34	14.76	10.50	8.06

Group	*Av.*	*11-12*	*13-14*	*15-16*	*17-18*	*19-20*
A	28.3	4.02	5.30	5.75	6.99	6.28
B	31.1	3.95	2.34	1.86	7.00	4.30
C	31.0	7.25	1.19	1.19	.00	.38
D	29.7	4.27	6.09	2.59	2.62	2.25
E	28.0	4.39	1.42	4.17	3.46	4.89
F	30.8	5.32	4.77	4.22	2.09	2.19
G	33.6	5.59	3.60	3.27	2.23	2.64

TABLE VII

Showing Cumulative Scores Arranged from Table VI

	Pairs of Trials				
Group	*1-2*	*3-4*	*5-6*	*7-8*	*9-10*
A	37.34	54.37	62.63	66.94	71.28
B	37.04	54.94	64.74	71.94	78.75
C	41.12	54.41	74.89	82.53	89.78
D	39.62	59.21	69.44	76.27	81.99
E	44.67	61.17	68.99	72.84	81.62
F	39.51	57.95	68.89	78.04	81.83
G	34.91	49.25	64.01	74.51	82.57

	Pairs of Trials				
Group	*11-12*	*13-14*	*15-16*	*17-18*	*19-20*
A	75.30	80.60	86.35	93.34	100%
B	82.70	85.04	86.90	93.90	100%
C	97.03	98.22	99.41	99.41	100%
D	86.26	92.35	94.94	97.56	100%
E	86.01	87.43	91.60	95.06	100%
F	87.18	91.98	96.23	98.34	100%
G	88.16	91.76	95.03	97.26	100%

It will be seen by reference to Table V and the graphs of Figure I that the rate of error elimination based on the absolute scores for each trial are very similar for the various groups. This is especially true of the pairs D-E and F-G. If the curves (Fig. I) of these pairs were smoothed they would very nearly coincide. This means, obviously, that increasing-decreasing arrangements of interval and of practice period, as here employed, have no appreciable effect on speed of learning, as measured by error elimination.

The values for Groups A-B-C show only slight differences. For example, Group C shows the most consistent and rapid elimination of errors, particularly for the last third of the training series, attaining also a more perfect elimination of errors finally. However, this difference in favor of one trial a day, as opposed to either two trials per day, or massed learning, while reasonably marked, should not be taken too seriously in view of the small number of animals in this group. The same general agreement is shown by the percentage scores, as will be seen by reference to Tables VI and VII. The percentage scores can be directly compared throughout, since the mean absolute values of the total scores for errors are practically the same for all seven groups, as indicated in the first column of Table VI. We have already shown that these total scores differ no more from one another than two sub-groups run under the same temporal distribution. (See Section I.)

The percentage scores agree with the absolute scores of Table VI (and Fig. I) in showing no measurable difference between D-E and F-G. Group C again stands out from A and B in the matter of early and consistent error elimination. For example, Group C on trials 5-6 shows about the same percentage of total errors made up to that point, as Group A on trials 11-12; while the values for Group B fall about midway between. The position of advantage of Group C was maintained throughout the rest of the series, and on trials 11-12 this group showed a greater degree of error elimination than was attained by either A or B on the 17-18th trials. This tendency corresponds to that noted in treating the absolute scores.

It would seem from the above analysis that speed of mastery, as measured by error elimination, was not greatly affected by any of the various temporal arrangements used in this study. The evidence for the superiority of the one trial per day group over the others is questionable in view of the small size of this particular group. If one were inclined to consider the superiority of Group C as valid, a possible explanation would be found in the fact that a practice period of more than one trial has generally been found to be disadvantageous, and a practice period of two trials or more was included in all other cases. This fact was noticeable to some extent in our own work, as can be shown by comparing the odd and even trials of the various groups on the graphs in Fig. I.

Two possible explanations for this phenomenon suggest themselves. First, the nibble of food after the first trial might have the effect of cutting down the incentive value of the situation for the second trial, and thus account for this result. Nothing in the behavior of the rats observed at the time would indicate this, and it will be noted that even when a larger number of trials was given at one time (as in Groups D and E) the scores were about as high as in the case where only two trials were given. It may be that Lashley's interpretation (5) most adequately explains this result. He suggests that the errors made on any first trial of a multiple-trial practice period tend to be repeated on a succeeding trial—the "set" established in the initial trial carries over to later trials—reducing the random activity. This amounts to a stereotyping of errors growing out of massing effort.

That neither of these factors were of much consequence in the early part of the learning process is evident from the fact that massed effort proved to be somewhat better than any form of distribution investigated for the first eight trials of the series. To show this we may combine the scores (Table V) for the first eight trials of Groups A and E (massed), and compare these with the corresponding scores of the other five groups. If the combined scores of the latter group be taken as 100% trial by trial, the combined values for A and E for the first eight trials run as follows:

107, 83, 110, 68, 65, 46, 50, 39 per cent.

There is thus a fairly consistent tendency to eliminate errors at a faster rate during what amounts to practically the first half of the training series—the average for the eight trials amounting to over 28%. Evidently the nibble of food after each trial, as is necessary in massed effort, does not seriously affect the rate of learning since error elimination actually proceeds at a higher rate under massed conditions; the same argument would carry against Lashley's principle. Of course our findings apply only to a maze of moderate difficulty—although Pechstein found the same rule to hold, as previously noted, on various simple mazes. Carr (2) interprets Ulrich's results on the Watson circular maze as showing that massed effort was more disadvantageous in the early trials, and this he himself found to be true of a fairly difficult stylus maze. So far as our own maze is concerned it is clear that massed effort was a positive advantage during the early trials, based upon an extremely large number of cases (84 massed, 140 distributed). The variability of temporal arrangements for the remainder of the practice series is so great that no general conclusions regarding the differences in score between the massed and distributed methods can be drawn.

C. Percentage of Animals Reaching Various Norms of Mastery

Rate of error elimination as treated in the above section probably gives the most important index of speed or efficiency of learning from trial to trial. Another method of attacking the problem of relative rate of mastery is that of considering the number of animals that completely learned the maze during the 20-trial practice series, according to certain selected norms of mastery. As will be seen, three norms representing increasingly higher standards, in terms of number of perfect runs required, were employed. The highest norm used was four correct runs out of five, which meant that an animal meeting this requirement had mastered the maze by the fifteenth or sixteenth trial; a higher norm such as nine perfect runs out of ten did not seem feasible in view of the fact that the total training period consisted of only twenty trials.

The results of an analysis of the data by this method appear in Table VIII. It is clear from an inspection of the table that the matter of relative efficiency of the groups is complicated by the factor of the particular norm used as a criterion of complete mastery. Under Norm I there is practically no difference in efficiency between any of the seven groups, since 96% or more of each group attained this degree of mastery within the 20 trials of practice. Under Norm II there is considerable divergence in percentage of animals that learned, while this divergence becomes very marked when the data are computed according to Norm III.

TABLE VIII

Showing Percentage of Animals in Each Group that Mastered the Maze in the 20-Trial Training Period Under Three Different Norms

Group	*Norm I* %	*Norm* II %	*Norm III* %
Group A (20 in 1 day)	100	96	62
Group B (2 per day)	97	92	55
Group C (1 per day)	100	100	100
Group D (2-4-6-8 series)	97	83	78
Group E (8-6-4-2 series)	97	91	71
Group F (12-108 series)	96	86	65
Group G (108-12 series)	96	76	55

Legend: Norm I—2 correct out of 3 trials; Norm II—3 correct out of 4 trials; Norm III—4 correct out of 5 trials.

If Norm I be taken as a fair index of complete mastery, then we have here further evidence that the factor of temporal distribution of practice had little or no effect under our conditions. Even under Norm II the group comparisons agree fairly closely with those noted above when the data are analyzed from the standpoint of rate of error elimination. Thus Groups A, B, and C differ only slightly, D and E show a somewhat greater difference, while the greatest difference (10%) is to be found between F and G. Under Norm III Group C stands out as distinctly superior to all other groups.

The inconsistency here found when the data are computed by different norms of mastery raises the question of the relative fairness of the three norms as indices of mastery under our conditions. The validity of the lower over the higher norms, in the present case, would seem to be indicated by the fact that the total training period was limited to twenty trials. A high norm would, in such a case, naturally take less account of partial learning and, therefore, would tend to lower the scores unevenly to the disadvantage of the groups that had made the least progress in learning—that is they would tend to be placed lower than they should be, because partially learned elements would not show in their score. This theoretical consideration would seem to be actually borne out by the values of Table VIII, and therefore the lower norm should be used in interpreting our results. We have already pointed out that under Norm I no differences of consequence appear between the various groups.

Warden (10) has called attention to the importance of norms of mastery in connection with studies of animal learning. He computed his results on distribution of effort in the original report (9) on the basis of nine perfect trials out of ten, and later found that more than 50% of the group averages shifted their rank position when the data were computed according to five less rigid norms. These shifts did not affect his main conclusions, for the reason that they had been based upon a pooling of group averages. Our results above support his contention that the norm factor in any set of learning data may be of major importance, especially when the differences found are small, as measured by a single norm.

D. Number of Animals Making Errorless Runs on Successive Trials

Another method of dealing with relative speed of mastery among the various groups is by computing the percentage of animals making errorless runs from trial to trial throughout the learning series. This method of analysis was carried out for all seven groups and arranged in graphic form. However, the curves for Groups A, B, and C only have been included (Fig. II) inasmuch as the curves for Groups D-E and F-G were found to practically coincide with the curve for Group B. We should expect this, of course, in view of the fact that the other measures of rats of mastery (sections B and C above) have shown all of the groups except C to be highly similar.

It should be noted that making a single errorless run may indicate very little in so far as complete mastery of the maze is concerned, and hence the percentage of animals making errorless runs on a given trial can hardly be considered a very significant group index of rate of learning. The very fact that the curves of Fig. II are so irregular suggest the influence of chance factors in a score of this sort. If these curves were smoothed, they would be highly comparable except for the last half-dozen trials. From this point onward the curve for Group C diverges rather markedly from the other two by showing a steady rise. Inasmuch as the curves for the other four groups (D, E, F, and G) are similar to that of B, as noted above, the rise in the curve for Group C would seem to indicate the superiority of this latter group, except for the fact that it is comparatively small in size.

We have now analyzed the results from various angles, and compared the several groups, representing seven temporal arrangements of practice according to four indices of efficiency, i.e., total error and time scores, rate of error elimination during the learning process, percentage of animals mastering the maze according to different norms, and percentage of animals making errorless runs from trial to trial. As has been brought out, certain of these indices are more adequate and valid than others, although obviously all are more or less closely interrelated. All methods of treating the results tend to confirm our main conclusion that temporal distribution of practice, within the limits investigated, has no measurable influence on efficiency of learning a maze of this degree of difficulty. It is true that

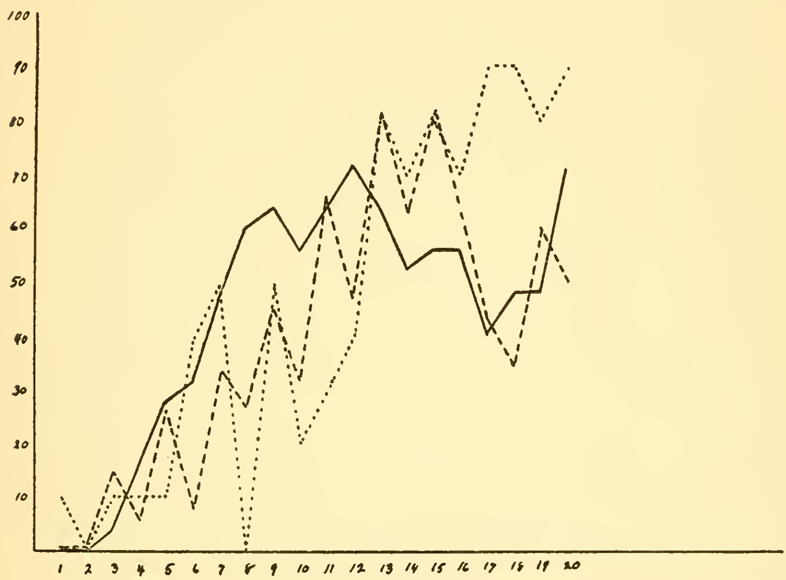

Figure II
Based on Percentage of Each Group Running Maze without Error on Each Trial of the Series
· · · · · · Group C (1 per day).
———— Group A (20 in one day).
– – – – – – Group B (2 per day).

the one trial per day group (C) seems to be somewhat superior to all the other groups in speed and consistency of progress by the various criteria used but, as we have seen, this advantage is not large enough to show up in the total error and time scores. Furthermore, the small size of this group taken in conjunction with the greater variability of the measures, renders this apparent advantage highly questionable.

The explanation of these results would seem clearly to lie in the fact that a maze of moderate difficulty was used in our work. Ulrich and Warden both found distributed effort, within reasonable limits, highly advantageous on more complex mazes, while Pechstein found massed effort to be decidedly superior to two trials per day on a very simple maze (single sections of his four-part maze). In point of simplicity and ease of mastery the maze used in the present study lies somewhere between that employed by Ulrich and Warden on the one hand, and that used by Pechstein on the other. The logical conclusion is that our maze is of about that degree of difficulty in which the factors favoring massed, and those favoring distributed, arrangements neutralize one another. This would mean that the influence of temporal arrangement in animal maze learning, if not in animal motor learning generally, is to a very large extent a function of the complexity and difficulty of the problem.

In comparing our results wih those of previous investigators several points of difference should be kept in mind. The most important of these, perhaps, is the fact that we kept the total amount of practice constant at twenty trials for all groups, and made our primary scoring in terms of how well the maze had been learned within the total period of practice, or at some intermediary point during the practice. The more usual method is to require the various groups, representing as many temporal arrangements, to meet a certain norm and to score in terms of the number of trials required to attain complete mastery. As a matter of fact, we were able under our conditions to make a secondary scoring of this sort (Method C of preceding section), since the twenty-trial practice series proved long enough to permit a considerable number of the animals of each group to meet a reasonable norm of mastery (2 perfect trials out of 3). As matters stand, then, the present results have been analyzed by both general types of scoring method, i.e., the one in which amount of practice is kept constant and individual and group differences taken in terms of degree of mastery; the other in which the degree of mastery is kept constant by a norm requirement, and individual and group differences taken in terms of number of trials required to learn. From the standpoint of methodological treatment, therefore, our results stand upon a more solid footing than previous experimental findings on this problem in which a single method of scoring only has been used.

Another point arguing for the validity of conclusions based upon the present results is the large size of the groups in comparison with those employed by previous workers on this and similar aspects of learning in the animal field.

Ulrich's groups ranged in size from 8 to 17; Warden's groups from 6 to 15; and Pechstein's groups contained 9 animals. Yet our present knowledge of temporal distribution of practice in the relation of the building up of motor habits in animals rests primarily upon these three studies. We have consistently avoided drawing any conclusions concerning the validity of the apparent superiority of Group C in the present work because of the unavoidably small size of the group (8 animals). Our main conclusion—that temporal distribution had no measurable effect on efficiency under our conditions—is based upon groups ranging in size from 28 to 49. We do not wish to call in question the general conclusions of these previous workers, since in most cases the differences they obtained were so large that repetition with larger groups would be unlikely to change the major trend of their findings. It may very well be, however, that their quantitative indices of the temporal factor would be changed considerably, and probably reduced, should their work be repeated with groups as large as we have used and under more standardized conditions; and especially if the factor of different methods of scoring, norms of mastery, etc. were taken into account as they should be.

IV. Summary

1. A maze of moderate difficulty was learned under seven different temporal arrangements of practice, including in one case a complete massing of effort. Efficiency was measured by (a) total error and time scores, (b) rate of error elimination, (c) percentage of animals effecting complete mastery within the twenty trials allowed, and (d) percentage of animals making errorless runs from trial to trial.

2. The factor of temporal arrangement of practice had no measurable influence on efficiency of learning, except in the doubtful case of a small group of eight animals run at the rate of one trial per day. When taken in conjunction with previous results on mazes of less and of greater complexity these findings seem to indicate clearly that the influence of temporal distribution is to a great extent a function of the complexity and difficulty of the maze, i.e., massed effort is apparently more efficient if the maze is simple and easy; distributed effort within reasonable limits is advantageous if the maze is decidedly difficult; and the factor of distribution is unimportant if the maze is of a moderate degree of difficulty.

3. Improvement in maze technique is suggested for general use along the following lines (1) the use of much larger groups than are ordinarily employed in analytical learning studies of this sort, (2) individual treatment of animals in preliminary conditioning, (3) inclusion of the initial trial as a part of the preliminary conditioning, instead of as a quanttative factor in the score, (4) the necessity of analyzing data on learning functions by more criteria than are usually employed.

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