WYLAND

Memorial Factors in Learning among Ants

Psychology

A. B.

1915

MEMORIAL FACTORS IN LEARNING AMONG ANTS

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF ARTS

COLLEGE OF LIBERAL ARTS AND SCIENCES

UNIVERSITY OF ILLINOIS

1915

MEMORIAL FACTORS IN LANGUAGE
AMONG APES

UNIVERSITY OF ILLINOIS

May 21st, 1915

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

RAY ORION WYLAND

ENTITLED MEMORIAL FACTORS IN LEARNING AMONG ANTS

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Instructor in Charge

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HEAD OF DEPARTMENT OF Psychology

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MEMORIAL FACTORS IN LEARNING AMONG ANTS

I. THE HISTORY

Experimental studies in the learning of ants have been carried on in almost unbroken succession since the work of Lubbock. Lubbock discovered that, among the species which he studied, smell and vision are the senses principally used by the ant in 'homing' and in general orientation. Bethe , who entered the same field of investigation, decided, upon the basis of experimental evidence, that light is not a guide to ants in finding the way, but that the following of a chemical trace is the only means of orientation. Bethe proposed the theory that the ant in returning to the nest follows a 'polarized chemical trace' in her own foot-prints. Bethe used smoked paper laid before the nest to record the movements of the insects. Fielde described the effects of white and colored light upon the movements of the ant. She concluded that "the eyes of the ant may perceive there [in the spectrum] only two fundamental colors; one made up of red and green rays, the other of violet and ultra-violet rays". She also devised a series of experiments which seem to disprove the theory of Bethe pertaining to the 'polarized chemical trace' of the ants' foot-prints. Turner records the learning-times for paths with variable intervals between the trials. He used incandescent lights in his experiments and he learned that the sensitivity of response to light as well as to sound is more decisive and invariable within the nest than elsewhere. He placed scented

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1. Lubbock, J. Ants, Bees and Wasps. N.Y. ~~1834~~ 1883.
2. Bethe, A. 1898. { Dürfen wir den Ameisen u. Bienen psychische Qualitäten zuschreiben? Pflügers Arch., 70, p. 15.
3. Fielde, A.M. A study of an ant. Proc. Phila. Nat Acad. Sci., Vol 53, p. 425. 1901.

trails beside new unscented trails; then, when the ants were going down the scented trail, he replaced it with the unscented. The ants continued to go down the old way over the new (unscented) trail, which is further disproof of Bethe's theory of a 'polarized trace'. Ernst tried again the use of the smoked paper of Bethe, but gave it up as impracticable.

Extensive studies of the natural environment, habits, and distribution of ants have been published by Wasmann, Turner, Washburn, and Wheeler.

The work of the authors above mentioned has shown conclusively that ants profit by individual experience. It has recorded many instances of more or less rapid modification of performance. In the establishment of a course or path, for example, subsequent journeys are taken with reduction of time and elimination of unnecessary movements. Now while it is of interest to know that the immediate memory of ants,-so far as memory is involved in the learning of a course,-has been established, it remains to be seen whether the modifications in behavior due to previous experience of the ant are retained, and if they are retained, what the term of the modification is. These are questions pertaining to the permanence and the stability of learning. It is to this problem that the present paper is devoted.

4.
Ernst,
6.
Wasmann, E., 1891. Die zusammengesetzten Nester and gemischten Kolonien der Ameisen. Münster.
Turner, C.H. The Homing of Ants. Chicago. 1907.
Washburn, M.F. 1908. The animal mind. N.Y.
Wheeler, W.M. Ants: their structure, development and behavior. 1910.

II. THE METHOD EMPLOYED.

The method of enquiry into this problem is quite simple. The ant is given a task to perform. The task is repeated a number of times and a record of each period is preserved until a series of fifteen or twenty trials is completed. These successive periods are plotted into a "learning-curve" for the first series. When the first series is completed the subject is given an interval of rest. Various intervals are used, ranging from fifteen minutes to three days. After each interval, the subject is put through another like series and records are preserved of the periods of each trial at the task. The records of the trials and of the time consumed in each form the basis of comparison of initial series with subsequent series, and this comparison gives us information concerning the effects of the first performance upon the subsequent experiences of the ant. The faithfulness with which the reduced time of the later trials of the previous experience persists in the subsequent series indicates more or less exactly the degree of retention the ant possesses and the period through which it persists.

A more detailed account of our method and our materials follows. A large colony of ants with a goodly supply of eggs was secured from a decaying log in an adjacent forest. These were transported to the laboratory and comfortably housed in a modified Fielde-Janet nest. This nest consists of three compartments, 3x5 inches in dimensions, and one-half inch deep, hollowed out of a solid plaster-of-paris block 3 inches deep, seven inches wide, and 20 inches long. Narrow partitions are left between the rooms which are connected by small openings at one end of the partition. One room is

used as a manger and is kept open to the light. The whole nest is covered with plate-glass with a packing of turkish towel under the edge to admit air. This confines the ants to the nest. Two rooms of the nest are darkened by placing card-board over the glass. At one end of the plaster-of-paris block a space is left in which a deep well is hollowed out, 2x5 inches and 2 inches deep. In this well water is kept to moisten the nest.

A normal, healthy worker is captured and confined in a small "experimental nest" with twenty or thirty eggs. The experimental nest is a one-inch hollow cube of plaster-of-paris, with one side removable and with a small door on the side just large enough to admit the ant. Stages of heavy white card-board, 4x4 inches square, are fastened by pins driven through the center into the corks of two low, heavy bottles in such a way that the two stages lie in the same horizontal plane. The bottles are set in a large basin filled with water up to the card-board stages. The adjacent edges of the stages are separated by the space of three inches and the gap is spanned by a bridge of card-board 1 cm. wide and 10cm. long.

The ant is taken from the nest where she has been confined with eggs long enough to leave her "nest-smell" with the nest, and she is deposited with the eggs upon one of the stages at its center. The experimental nest is placed on the other stage with its door toward the bridge . The stage containing the eggs is between the stage containing the nest and the window. A card-board bridge connects the stages. This relation is preserved throughout the experiment. The eggs and the ant having been placed on the stage near the end of the bridge, it is now her task to find her way across

the bridge and into the nest. To enter the nest, she must climb up one side to reach the door.

In the first trial, the ant consumes several minutes. The next trial usually marks a shorter time, and there is a gradual decrease in the time of each successive trip until a minimum is reached. Fifteen or twenty trips establish a fairly constant time-period for the task. When the first series is completed the subject is removed to a Petri dish where she is kept for the desired interval of time; and, meanwhile, the stages and bridges are replaced so as to remove all traces of the former path. Then the subject is again placed on one stage with the eggs, and the nest is placed on the other in the same position as before: the position of the stages relative to each other and to the window is also the same as before. So far as possible, the ant now has all conditions the same as when she began the first series of trials, excepting the modification of her own psychophysical organism by reason of the first experience in finding the nest. A record of the time consumed in each successive trip is taken until a second series is completed. The operation is repeated with various intervals and with numerous subjects.

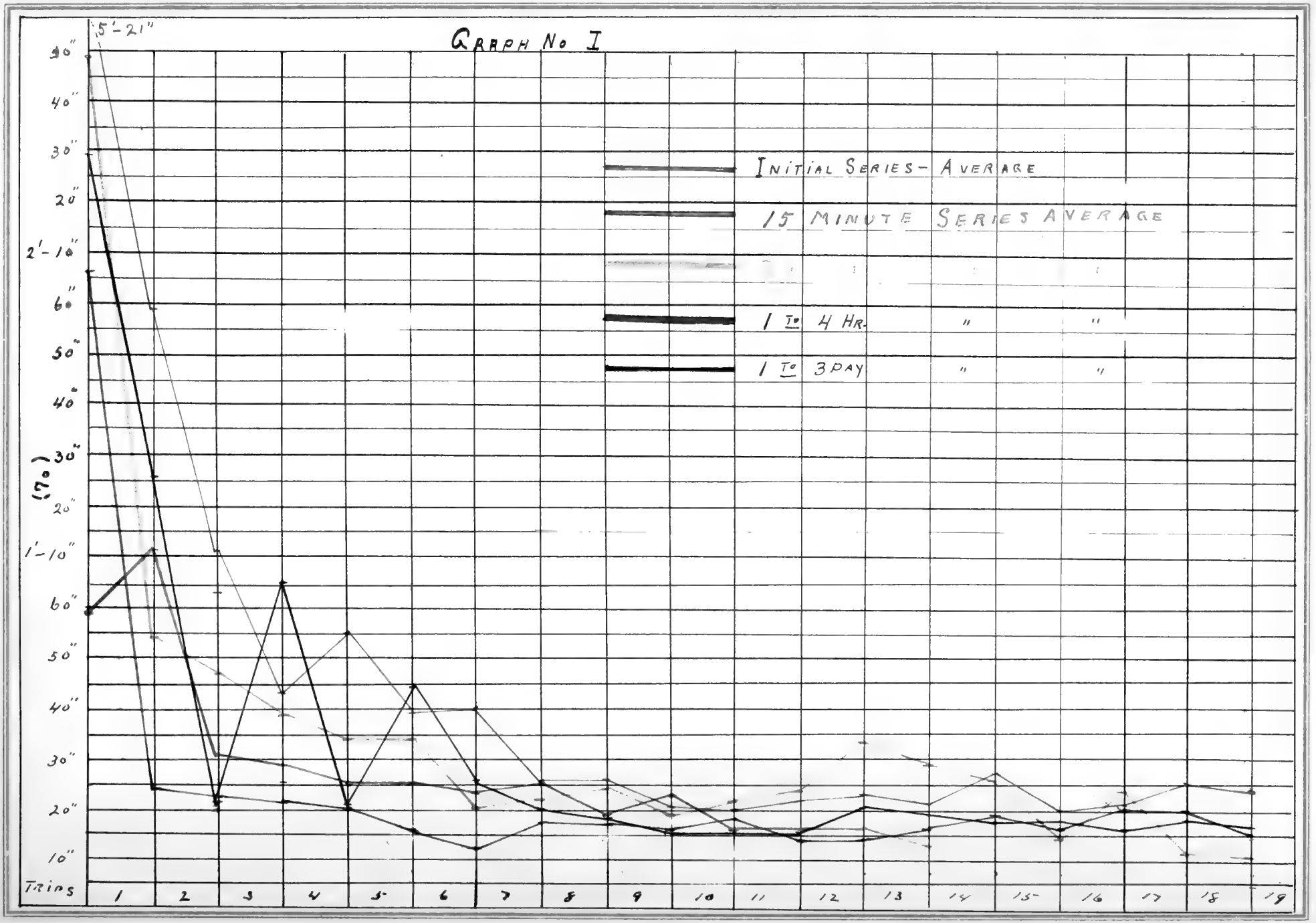
III. RESULTS.

For the initial series, twenty-two subjects were used and from 9 to 25 trips (average 16) were made by each subject. Only one subject made less than twelve. With each subject the first trip of the initial series marks a rather long time-interval. The range is from 95 sec. to 840 sec., with an average of 321 sec. plus or minus 202 sec. (m.v.). The second trip of the initial series shows a

marked decrease in the time interval. The range is from 15 sec. to 270 sec. and the average is 119 sec. ,plus or minus 78 sec. For the third trial the time is still less and the range is from 12 sec. to 242 sec. with an average of 71 sec., plus or minus 40 sec. In the fourth trip, there is a still more marked decrease in the time consumed. The range is from 15 sec. to 120 sec., average is 43 sec., plus or minus 19 sec. The time interval of the fifth trip is increased by the exceptionally long periods of subjects B. and Z., which consumed 345 sec and 270 sec. respectively. By reason of these, the average is raised to 55 sec., plus or minus 38 sec. From this point forward there is a fairly constant and gradual decrease in the times until the twelfth trip, which shows an average of 20 sec., plus or minus 7 sec.. After the twelfth trip there is a gradual rise in the average time and mean variation until the nineteenth trip (average time 25 sec.,plus or minus 10 sec.).

A summary of the initial trips was made and the average time and mean variations are given in Table I, below. A graph of the average of the initial series was also plotted. (Graphs I,II, red ink). The rapid falling away from 321 sec. in the first trip to 119 sec. in the second and 105 sec. in the third and on down to 22 sec. in the tenth trip, indicates the rate of the modification of behavior in the learning of ants of this species and under our conditions. The succeeding trips show a marked degree of constancy in time, indicating that the task has become well automatised.

The first rest- or memory-interval observed was that of fifteen minutes. Nine subjects were used. Great care was taken to avoid rough treatment that would excite the subjects and possibly destroy the normal effects of their previous training. The record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INITIAL SERIES - AVERAGE
15 MINUTE SERIES AVERAGE
1 TO 4 HR. " "
1 TO 3 DAY " "

for the series after the fifteen-minute interval shows a notable reduction in the time-rate over that of the initial series. Without exception, there is a decided decrease in the time of the first trip as compared with the first trip of the initial series. The average time for all nine subjects is shown in blue on Graph I. It begins at 60 sec. and rises to 70 sec. in the second trip. But this rise is due, for the most part, to the long period (330 sec.) of subject A. Apart from this exception, the average drops to 34 sec. In the third trip the average is 32 sec. and then it steadily declines to 13 sec. in the thirteenth trip.

The second rest-interval observed was thirty minutes. Eleven subjects were used for this series. The record shows still a decided reduction in the time over that of the initial series. Both the average and the mean variation are much reduced, as compared with the initial series. Both are greater, however, than in corresponding series taken after the fifteen-minute interval. The weighted average represented in Graph I, (green ink) begins with 168 sec., and drops to 58 sec. in the second trip, and then it gradually declines to 21 sec. in the seventh trip.

The third rest-interval observed was ~~inconstant~~ variable and ranged from one to four hours. Eight subjects were employed. The results of this series show an apparent improvement over the thirty-minute series. The average begins at 126 sec. (Graph I., violet ink) and then falls to 24 sec. in the second trip and to 12 sec. in the seventh. Nowhere does the violet line of this series touch the green line of the thirty-minute series. This fact is occasioned in part ~~partially~~ by the exceptionally long and irregular periods of subjects A. and

B, which occur in the thirty-minute series, but neither of which appears in this series. The time-rates of A and B are very long in each series in which they appear.

The next interval was extended to cover from one to three days. Only five subjects were used. This series is marked with greater irregularities than appear in any other ~~series~~, including the initial series. The mean variation is greater. The average of the first trip as plotted on Graph I (black ink) is 148 sec. It then drops to 86 sec. in the second trip, and to 22 sec. in the third. From this point it rises and falls from 60 sec. to 21 sec., with much irregularity until the eight trip, from which point it remains fairly constant until the end.

IV. CONCLUSIONS.

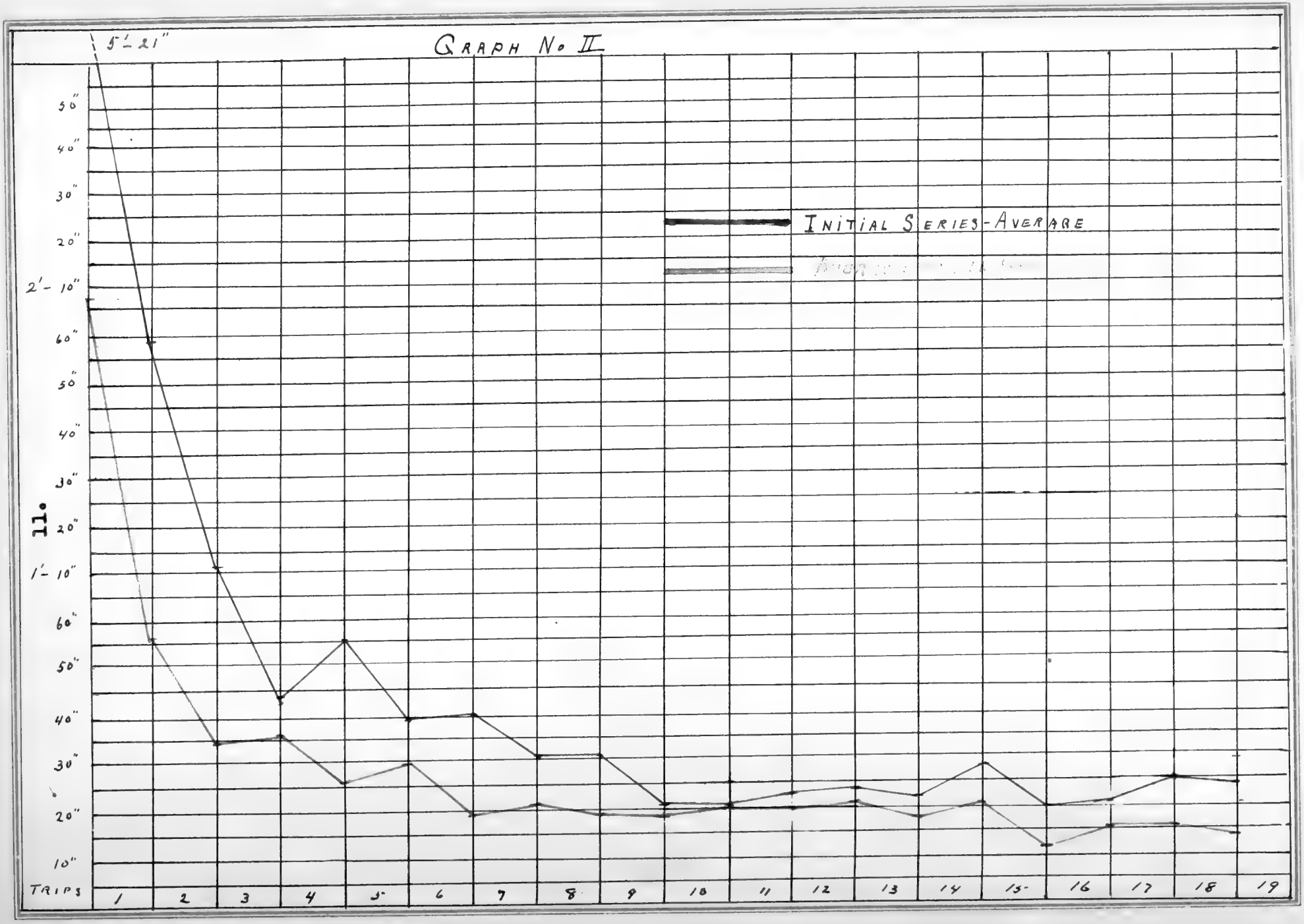
No very definite conclusions can be drawn from the results of the last series on account of the small number of subjects used. The work of the remaining series, including in each case no less than 160 trips (where 11 subjects were used, 240 trips), can be taken as the basis for the following conclusions.

Throughout its course, the curve for the initial series (Graphs I, II, red ink) stands higher than the curve which represents all of the subsequent series (Graph II, green ink); that is, series with memory-intervals. Moreover, it appears that the fifteen-minute series shows, from the first trip onward, a decided improvement over the initial series. The modification of behavior is marked. (Graph I, red and blue curves). ~~Whether the progressive obliteration rests upon a true memorial obliviscence or upon~~

~~organic changes without conscious accompaniments, our method does not inform us.~~

As regards the results with the longer interval-times, (one-to-four hrs., and one-to-three days), no differential effect of intervals can be certainly traced in the results. The differences in the time of the first trips (168 sec. ± 122 , 126 sec. ± 90, and 148 sec. ± 133) are considerably less than the corresponding mean variations. They cannot, then, be held to be of significance; and a similar conclusion is to be drawn from their further course.

In general, we may say that a memory-interval of fifteen minutes effects a decided saving in the subsequent relearning. And our results offer some support to the belief that longer intervals are also economical, although this effect seems to be somewhat weaker than the effect of the shortest memorial time of which we made use. Our experiments have made it evident that the psychophysical residues of learning a course do,— under the conditions named,— persist with modification through memorial intervals of considerable extent. The qualitative analysis of these residues into conscious and organic factors must be left to subsequent research.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TRIPS
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INITIAL SERIES-AVERAGE

TABLE I.

AVERAGE TIME AND MEAN VARIATION IN SECONDS OF INITIAL AND SUBSEQUENT SERIES.

TRIPS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
I	A	321	119	71	43	55	38	40	26	26	21	21	20	22	23	21	27	20	21	25
	M	302	78	40	19	38	19	29	11	12	7	6	7	10	8	9	11	9	7	10
II	A	59	71	31	28	25	23	25	19	22	16	16	16	13						
	M	30	84	12	11	8	9	8	7	4	5	3	0	2						
III	A	168	54	44	39	34	34	20	22	24	19	22	24	33	28	26	14	24	12	11
	M	122	41	44	28	22	25	7	9	12	11	10	15	17	8	9	0	0	0	0
IV	A	126	24	23	22	20	16	12	17	17	16	18	14	14	16	19	16	20	20	15
	M	90	8	8	6	4	3	2	3	4	2	4	4	2	2	5	5	9	4	4
V	A	148	85	23	65	21	44	26	20	18	16	16	16	21	18	17	17	16	17	16
	M	133	92	11	65	7	39	10	4	3	3	4	5	5	3	3	5	3	3	0
VI	A	127	56	34	36	26	29	19	21	19	18	20	20	21	18	21	13	15	15	14
	M	94	56	18	27	10	19	7	6	6	6	5	6	6	6	4	5	0	0	0

I = INITIAL SERIES

II 15-MINUTE-INTERVAL SERIES

III 30 " " "

IV 1 TO 4-HR.-INTERVAL SERIES

V 1 TO 3-DAY " "

VI AVERAGE OF II, III, IV, V.

A = AVERAGE.

M = ±MEAN VARIATION.