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THE ACQUISITION OF SKILL IN ARCHERY

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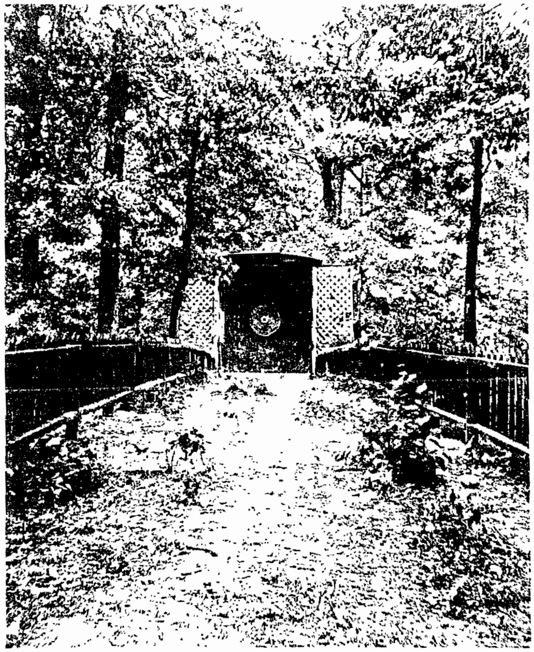

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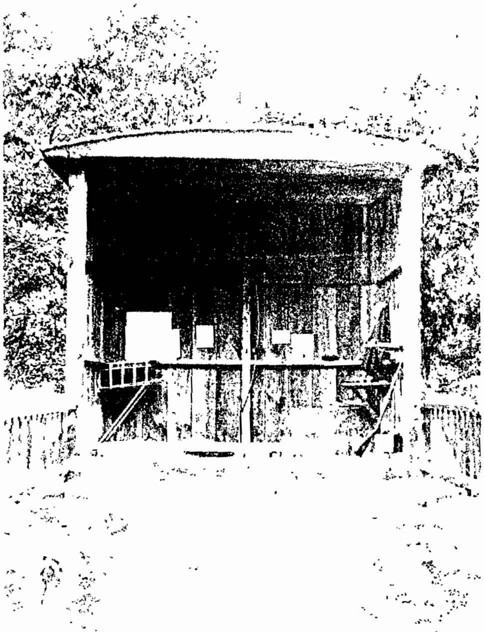

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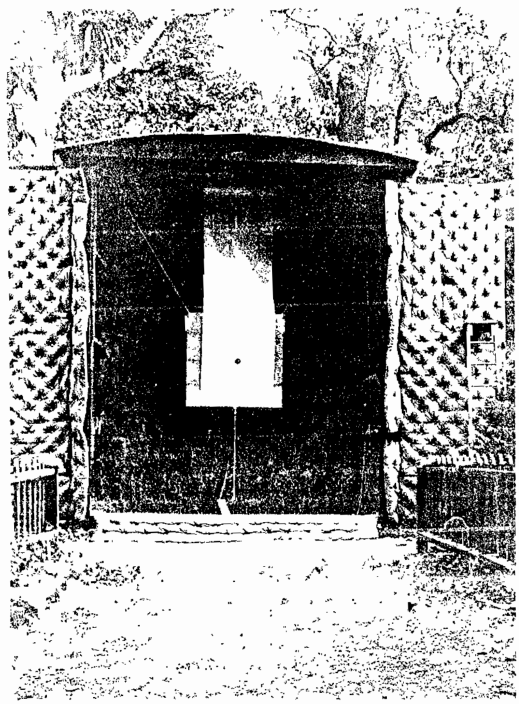

EQUIPMENT FOR ARCHERY.

Fig. 1. Homewood target as it appeared to the archers. Fig 2. Practice shed with equipment.
Fig 3. Target arranged for rifle practice.

THE ACQUISITION OF SKILL IN ARCHERY.

The great majority of experiments upon habit formation in man have dealt with functions involved in implicit behavior; functions connected chiefly with the speech mechanisms have received most attention. Improvement in such activities as addition, translation into code or from code, solving mechanical puzzles, checking letters on a printed page, or memorizing word material is due almost wholly to increase in complexity of language habits. Practice in typewriting and musical technique is, in the beginning, followed by the formation of implicit* habits which later are dropped out to leave only the direct sensory-motor reactions from eye to fingers. Improvement in writing and in telegraphy probably involve similar changes. In the study of all such functions in human adults the subjects have already, at the beginning of the experiments, a vast number of constellations of habits in the implicit systems which have more or less in common with the problem offered by the experimental situation and may influence the course of learning in unknown ways. This is illustrated by the relation between the fullness of "meaning" of word material (*i. e.*, the number of habits in which the material is already involved) and the ease with which it is learned.

The existence of such complex systems of implicit behavior with their equally complex relations to overt activity makes it difficult to distinguish the different functions improved in learning, or to say whether a given amount of improvement is the result of a gradual coordination of many unrelated habits or of the simpler union of a few constellations of habits; whether the practice is distributed over a large number of nervous changes or is concentrated upon the fixation of a very few new neural pathways. For an insight into the mechanism of habit formation some simple, more direct sensory-motor associations must be studied, particularly such as permit of the control of related functions, metabolism, etc. This is best accomplished with animals, as they may be subjected to more vigorous training methods than is possible with man, but some types of learning in man, free from the complications of language habits, must be studied before the extension of the results obtained with animals to man will be completely justified. The activities studied by Bair (tossing shot), Whitley (tracing the smooth maze), Swift (tossing balls), Wells (tapping), and Partridge (inhibition of the winking reflex) call for the formation of relatively simple motor habits, but have the disadvantage of giving little to interest the subjects and probably offer a weaker stimulus to learning than is provided by more complex activities.

In the spring of 1913 Dr. J. B. Watson suggested archery as a means of studying habit formation in man which would in part avoid the complexity of language habits. Material for practice in archery was obtained and a preliminary experiment was begun by him at the Marine Biological Laboratory of the Carnegie Institution of Washington on Loggerhead Key, Tortugas. The

*The term "implicit" is used in the sense defined by Watson (1914) as a common name for the movements, too slight for detection, which seem to bridge the gap between external stimulus and overt reactions when more than a single reflex is involved.

chief object of this experiment was to test the value of the method and to work out the technique of experimentation, but the range of the experiment was extended to include a comparison of the rate of improvement in two groups of men differing in certain respects, to be considered later. The writer acted as subject and assisted in conducting this experiment. During the spring of 1914 the range described below was constructed on the grounds of The Johns Hopkins University and the experiments were continued in a study of the relation of the rate of improvement to the distribution of practice.

I wish to express my very great indebtedness to Professor Watson for the unrestricted use of the data obtained at the Tortugas, for the main features in the design of the apparatus employed in the later work, and particularly for his generous advice and assistance throughout the experiments.

My thanks are due also to Dr. Alfred G. Mayer for his interest in the work and for permitting his laboratory staff to devote their time to it.

Finally, I owe a great deal to the people who have taken part in the experiments, particularly to those in the "5-shot group," whose regular practice for many weeks was carried out at no small inconvenience to themselves.

EQUIPMENT.

The equipment used in the Tortugas experiments consisted of bows, arrows, target, screen to mark the results of wild shots, and a shield for the experimenter near the target. The arrows were of good quality, 28 inches in length. The bows were of lemon wood, 6 feet in length, and requiring a pull of 44 pounds to draw the arrows to the head. An arrow properly discharged from such a bow will pierce a half-inch pine board at a distance of 40 yards and has an almost flat trajectory for that distance. The target was the official 48-inch target of rye straw faced with white canvas, on which was painted a 10-inch black bulls-eye. It was mounted on a metal tripod so that the center of the bulls-eye was 4 feet from the ground.

The length of the range used in all the experiments was 40 yards, at which distance the bulls-eye subtends a visual angle of 33′. The target was set up at the foot of a sand-bank, which served to stop the arrows passing the target. As beginners rarely hit the target at this distance, some method of recording the distance of wild shots from the bulls-eye was necessary. For this purpose a muslin screen, 14 feet square, was erected around the target. The arrows made holes in the cloth and the distance from these to the center of the bulls-eye was taken as the record of the shots. This made it necessary to measure each shot as soon as it was fired, a method which proved neither convenient nor safe.

The method employed in the first experiment was the following: The subject was given instruction by word and example of the method of nocking, drawing, and loosing the arrow, but was told nothing of the method of aiming, the choice of a point of aim, or the general bodily position in aiming and loosing. He had to find out for himself how to aim, to prevent the bowstring from catching on his clothing or arm, to allow for the curve of the arrow's trajectory, to counteract the kick of the bow by increased tonus of the flexors of the left arm, together with the large number of finer details which make for accuracy. After the first instruction he was given a bow and 12 arrows and sent to a point 40 yards in front of the target, where he stood alone and loosed the arrows

at intervals of 2 minutes, or in each case as soon as the preceding shot had been measured and recorded. Twelve shots were fired thus each day for 30 days. The subjects had no opportunity to observe each others' methods of shooting from a distance of less than 40 yards. Discussion of methods of shooting was prohibited, but not with perfect success. The result of each man's practice was posted daily and for group B (page 111) a prize of $5 was offered to the subject making the best score on the greatest number of days.

For the continuation of the work in Baltimore a safer and more convenient range was necessary. A plot of open ground, 40 yards in length by 8 in width, was laid out and the buildings shown in plate 8, figures 1, 2, and 3, were put up at opposite ends of this. The small shed (figure 2), which serves to protect and isolate the subject, is 12 feet high and 12 feet wide by 8 feet deep. It is equipped with racks for arrows, bows, etc., and a small telescope for use in rifle practice. The target shed is somewhat larger, 14 feet high by 12 by 12 feet (plate 8, figures 1 and 3). Three feet back from the open front of this shed is a pile of baled straw, packed tightly from the floor to the roof. The space behind this straw partition is used for the storage of extra equipment. The front of the shed is provided with large swinging doors, padded on the inside with heavy quilted canvas mats. When these are opened, as in the photographs, a surface 14 by 24 feet is exposed, which will catch and hold the arrows wherever they strike. The 4-foot straw target is mounted in the center of the baled straw and a 10-inch paper bulls-eye marks the center of this. Plate 8, figure 1, shows the appearance of the target-shed from the opposite end of the range.

In the main experiment rifle practice was used as an index of the relative ability of the subjects under the same conditions of practice. An efficient single-shot air-rifle was used at a range of 40 yards. The 4-foot steel-faced target used with this is shown in plate 8, figure 3. A constant supply of paper targets was provided, a separate one being used for each subject's daily practice. The entire equipment could be swung out of the way readily in preparation for arrow practice. As the bullet holes in the paper are not clearly visible at 40 yards it was necessary for the experimenter to watch the target through a telescope and report the position of each shot to the subjects.

COMPUTATION OF AVERAGES AND COMPARISON OF INDIVIDUAL AND GROUP RECORDS.

A series of records of shots with the bow or rifle invariably shows a great range in the accuracy of the shots, even in the case of subjects who have acquired a considerable degree of skill. With increasing skill the range of variation decreases, but the relative amount of variation as measured by the coefficient of variation remains practically constant. This is illustrated by the record of one subject given in table 33.

Some of this variation may be the result of the learning process itself (the successive trial of different methods), but the greater part of it is certainly due to chance external agents, such as variations in the strength of the wind, weight of the arrows, tightness of the nock on the string, tension of the bow, temperature, and extent of fatigue. As a result the average of any small number of shots does not give a fair measure of the skill of the individual, and the use of such averages as a measure of the initial and final accuracy and amount of improvement does not lead to trustworthy results.

All group records, each based upon 20 successive shots, are included in table 39, but for the computation of the amount of improvement it has seemed best to use averages based upon as large a number of shots as possible. The simplest method, and the one which probably gives the most dependable results where comparisons are made of the total amount of improvement in a given amount of practice, is that of using the average of all shots during the first half of practice as an index of the initial accuracy, and the average of all during the second half as an index of final accuracy.

TABLE 33.—*Relative amount of variation in records of shots during successive practice periods for one subject of the 12-shot group.*

Av. distance from bulls-eye.	Av. variation.	Av. coefficient of variation.	Av. distance from bulls-eye.	Av. variation.	Av. coefficient of variation.	Av. distance from bulls-eye.	Av. variation.	Av. coefficient of variation.
inches.	*inches.*	*per cent.*	*inches.*	*inches.*	*per cent.*	*inches.*	*inches.*	*per cent.*
109.0	31.8	0.28	43.8	24.2	0.55	38.5	8.0	0.21
79.9	15.4	.19	43.9	13.1	.30	40.1	10.7	27
48.3	22.4	.42	49.6	16.6	.33	39.9	9.4	.24
46.6	20.8	.45	47.3	29.9	.63	29.5	7.3	.25
49.7	19.3	.39	40.2	15.4	.38	28.1	9.0	.32
72.3	35.6	.49	41.8	15.3	.37	39.0	13.2	.34
53.5	24.2	.45	38.4	10.8	.28	39.3	14.8	.38
52.0	19.3	.37	29.5	10.0	.34	29.6	15.2	.51
46.6	21.0	.45	39.2	11.3	.29	41.0	11.4	.28
54.2	25.5	.47	31.5	10.8	.31	33.7	15.5	.46

The chief objection to this method is that it assumes a like form for the learning curves of the groups compared and does not give sufficient weight to rapid initial improvement, final spurts, or similar variations in the rate of learning. To meet this objection the improvement from the first to the last 5 and from the first to the last 40 shots has also been computed and compared with that obtained by the first method.

In comparative studies of learning, the further question of the relative value of the absolute amount of improvement and the percentage improvement, in terms of initial skill, arises. It seems to the writer that the use of percentages is justified only when it is clear that each step in learning presents the same difficulty to all individuals compared. If the first stages of learning present, for the individual with a low initial skill, the same difficulty as do the second stages for the individual with greater initial skill, then the absolute improvement would seem a more accurate measure for the effects of such factors as distribution of practice. Figure 11 shows the relations of initial and final skill in archery for the individuals studied. On the average, the absolute improvement of those of low initial accuracy was little greater than that of the others, which indicates that the problem really presented greater difficulties for them throughout.

In the case of rifle practice this does not seem to be true. Figure 12 shows that individuals of low initial accuracy made by far the greater absolute improvement, and in this case it seems that the percentage rather than the absolute improvement should be used in comparison of the groups.

FIG. 11.—Initial and final accuracy with the bow in 19 subjects computed from first and last 40 shots. The ordinates are *inches from the bulls-eye;* the abscissæ, the different subjects arranged in the order of their initial skill. The groups of which they are members are given below. The straight lines show the average amount of improvement for any given initial accuracy.

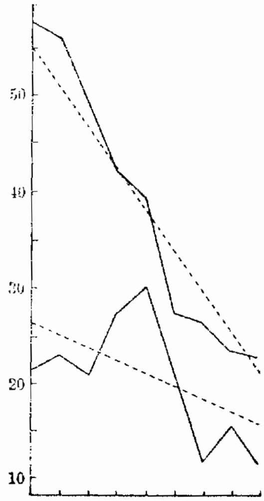

FIG. 12.—Initial and final accuracy of 9 subjects with the rifle, arranged as figure 11, except that the ordinates represent centimeters.

A COMPARISON OF UNLIKE GROUPS OF INDIVIDUALS UNDER THE SAME CONDITIONS OF PRACTICE.

The first experiment was conducted with 8 subjects, each shooting 12 arrows daily under the same conditions. Four of the subjects (Group A) were investigators working in the laboratory, 4 (Group B) were skilled laborers. The men of the first group were all trained in habits of delicate manipulation, such as those required by microscopic technique, and to a much less extent in acts of skill demanding coördination of widely dispersed groups of large muscles. The second group included a good marine engineer, another of less thorough training, a carpenter (acting as cook), and a first-class pilot who had served apprenticeship as a common sailor.

TABLE 34.

	Group A.	Group B.
	inches.	*inches.*
1 to 40 shots..	60.1	78.0
341 360 shots..	38.6	46.8
Absolute improvement.	21.5	31.2

The distinction between the groups was made primarily upon professional status, and it is not certain that they differed materially in the number and variety of habits of manipulation at their command. Certainly Group A possessed a much greater range and complexity of implicit habits than Group B, while the reverse was probably true of habits of the type involved in archery.

In computing the relative progress of the groups it has been found necessary to omit the record of the writer as involving a different type of learning, and hence not fairly comparable with other records. Acting both as subject and as experimenter, the writer was forced to read such instructions on the use of the bow as were available, and to question the other subjects as to their methods of aiming and loosing. From this it followed that many of the adjustments which the others must make by the method of trial and error were reached by him directly through the mediation of preëxisting language habits. The advantage of this learning with instruction is shown in figure 13,

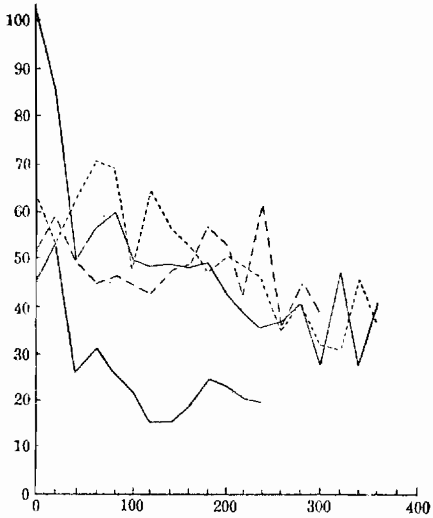

FIG. 13.—Rate of improvement with and without instruction. The heavy line is the learning curve of a subject who received detailed instructions. The lighter lines are typical curves of learning without instruction. Ordinates, distance from the bulls-eye in inches; abscissæ, successive shots arranged by twenties.

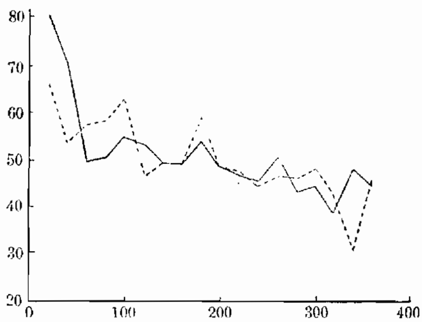

FIG. 14.—Learning curves of group A (........) and B (——) under light conditions of practice.

where the experimenter's record is compared with 3 other typical curves of learning without instruction. (In this figure, as in all the following learning curves, the ordinates represent the average distance from the bulls-eye of successive groups of 20 shots plotted on the abscissæ.)

TABLE 35.

	Group A.	Group B.
	inches.	*inches.*
1 to 180 shots.	55.78	56.91
181 360 shots.	44.80	45.77
Absolute improvement.	10.98	11.14

The scores of the two groups, this one record being omitted, are given in table 36 and graphically in figure 14. If the averages of the first and last few shots are taken as indices of the total improvement, there is a fairly large difference in the amount of improvement shown by the two groups. The average, in inches from the bulls-eye, of the first and last 40 shots are given in table 34.

These averages make it appear that the laborers made the greatest absolute improvement, while the investigators showed the greater initial and final skill. From the appearance of the learning curves, it seems probable that the averages of the first and second halves of practice give the truer view of the skill and improvement of the two groups. These averages are given in table 35.

TABLE 36.—*Average distance from bulls-eye of successive groups of 20 shots, for two unlike groups of men under like conditions of practice with archery.*

Shots.	4 laborers.	3 investigators.	Shots.	4 laborers.	3 investigators.	Shots.	4 laborers.	3 investigators.
1 to 20	80.2	66.1	121 to 140	49.3	50.0	241 to 160	50.9	46.8
21 40	70.4	54.2	141 160	49.2	47.5	261 280	43.4	46.5
41 60	49.4	57.7	161 180	54.3	50.1	281 300	44.7	48.7
61 80	50.6	58.2	181 200	48.9	48.8	301 320	38.7	43.2
81 100	54.9	62.8	201 220	46.9	46.9	321 340	48.8	31.1
101 120	53.9	46.3	221 240	45.8	44.9	341 360	44.8	46.2

From this it appears that there is no significant difference, either in the absolute accuracy or amount of improvement shown by the two groups of men shooting under the same conditions.

DISTRIBUTION OF PRACTICE AND RATE OF LEARNING.

PURPOSE AND METHOD OF THE EXPERIMENT.

A year after the end of the experiment just described, with the completion of the Baltimore range, the work was taken up again in a test of the effect of the distribution of practice upon the rate of improvement. 26 subjects were distributed in 4 groups, shooting daily 5, 20, 40, and 60 arrows respectively. Owing to irregularity in attendance of some of the subjects, only 19 records complete to more than 300 shots were obtained, and this fact accounts largely for the differences in the number of subjects and composition of the different groups.

The method employed in the experiments carried out in Baltimore was not greatly different from that used in the Tortugas experiment. The subjects were given only as much instruction as seemed necessary to prevent accident. They were forbidden to discuss their methods of shooting or to seek outside instructions, and in his attempts to follow the various steps in the learning process the experimenter avoided, as much as possible, asking questions which might give the subjects a clue to better methods of shooting. In one respect the technique of the later experiment differed from that of the earlier. The subjects were practically all volunteers and so interested in each other's shooting that it was found impossible to prevent them from watching each other practice. This gave a considerable opportunity for imitation, which was not

offered in the first experiment. The problem of imitation is considered on page 118. Rivalry between the various members of the groups was encouraged and the daily averages were posted on a bulletin board in the shooting-shed.

COMPARABILITY OF THE GROUPS STUDIED.

The subjects for the 5-, 20-, and 40-shot groups were boys and men ranging in age from 14 to 36 years. Those of about the same age were assigned to different groups, with the result that the average age of all the groups is approximately the same. Furthermore, from the data presented in figure 15, it seems clear that there is no correlation between the age of the individual and the rate of improvement of the function, and hence the slight difference in the average ages of the groups (a maximum of 3 years) may be safely disregarded.

The records of a woman are included in the averages of the 5-shot group. Analysis of the individual records shows that the averages of the group were not seriously influenced by the inclusion of this series of records.

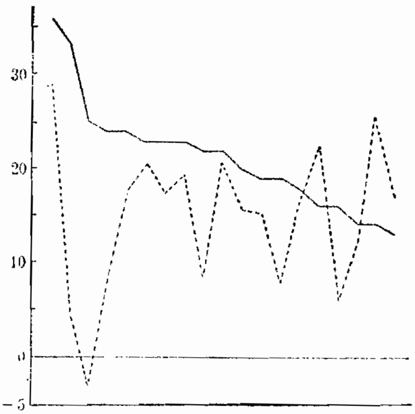

Fig. 15.—Relation of age to rate of improvement. Solid line represents ages of subjects in years arranged in order from left to right. Dotted line gives in inches the absolute amount of improvement for the subject in the corresponding position on the solid line. Averages are computed from first and last 40 shots.

With respect to previous training, none of the subjects had ever shot with the bow, beyond the sporadic practice with umbrella ribs and unfeathered arrows which comes within every boy's experience. In training in other functions there was a good bit of variation, but none of the subjects was particularly well trained in athletic sports or in difficult habits of manipulation, and, in general, the groups average out fairly well, with the exception of that whose members loosed 60 shots per day.

The study of the 60-shot group was undertaken after the others had finished shooting and after their average improvement had been computed. As it seemed that there was some advantage in favor of the 5-shot group, the attempt was made to test the effect of a still greater concentration of practice, continued until quite appreciable fatigue was produced. For this purpose the 60-shot group was organized, but since in the early part of practice this number is excessive, it was necessary to pick subjects who were physically able to meet the exactions of the experiment. As a result, the group was made up of young men ranging in age from 19 to 23 years, in better physical condition than the members of the other groups. The range of variation in age is less in this group than in the others, which fact probably gives an advantage to the group at the start. Furthermore, the superiority in physical strength of the members of this group gives an advantage quite aside from the question of fatigue, in that the bow may be drawn with greater ease and steadiness by an individual whose strength is not greatly taxed by its weight. Sixty shots rep-

resent about the limit that a beginner can shoot without rest during the first few days of practice, and it seemed that if fatigue had played an important part in determining the different rates of learning of the other groups, its effects should be much more marked in the records of the 60-shot group.

The averages of the Tortugas group, shooting 12 shots per day, have been included in the tables for comparison with the later groups, although these averages, like those of the 60-shot group, are not strictly comparable with the others. The average age of the group is considerably higher than that of the remainder, and the range, from 22 to 46, is likewise greater. The practice of the group was carried out under what seemed to be much more unfavorable conditions (at a temperature ranging as high as 110° F. and at times in a blinding glare of light, at others in a very strong wind which carried the arrows several feet from their direct course).

In all of the experiments enough arrows were provided to allow each subject to shoot his full daily number without pause. The arrows were marked individually and arranged in groups of 5, and the results of the shots were

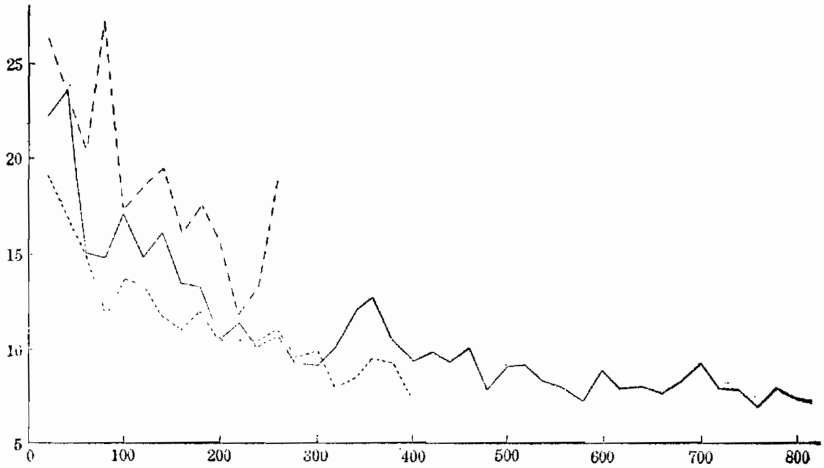

FIG. 16.—Learning with the rifle; all subjects shooting 20 shots daily. ——— 5 shot group; .... 20 shot group; – – – – – – 40 shot group. Ordinates are distance from the bulls-eye in centimeters; abscissæ, successive shots averaged by twenties.

recorded by successive fives, as it was found to require too much time to keep all of the records in regular order. In the case of the 5-shot group the arrows were recorded in the order in which they were loosed.

Finally, as a control upon the respective abilities of the groups to form habits of manipulation under like conditions of practice, each subject was required to shoot 20 shots daily with the rifle. The daily averages were computed and from these the average improvement of each group was obtained. Owing to the difficulty in securing subjects for the experiment, three individuals who had had some rifle practice were included. One of these was assigned to each group. Their records for rifle practice were not included in the group averages.

The daily rifle scores of the three groups are shown in figure 16. As in the case of practice in archery, it has seemed best to use the averages of the first

and second halves of practice in judging the improvement rather than the records of the first and last few shots (see p. 110). The amount of improvement measured in this way is shown in table 37.

In so far as the improvement in rifle shooting may be considered an index of the relative ability of the groups, the 5- and 40-shot groups seem to be almost equal, the 20-shot group somewhat inferior in rate of improvement. When the percentage of improvement over initial accuracy is considered, as seems justifiable by the data given on page 111, the inferiority of the 20-shot group is less marked.

TABLE 37.—*Relative improvement of subjects shooting 20 shots daily with the rifle.*

[The figures represent centimeters from the bulls-eye.]

Average of all shots.	Group shooting with the bow. (Shots daily.)		
	5	20	40
From 1 to 140	17.5	14.4	21.9
141 180	11.3	10.8	15.1
Absolute improvement	6.2	3.6	6.8
Percentage	35	28	31

CONDITIONS AFFECTING IMPROVEMENT.

Before comparing the relative abilities of the groups a few words are necessary concerning the complexity of the habits formed and the general character of the learning curve. Very delicate adjustments, both of the eye-hand coördinations at the moment of aiming and particularly in the quick changes in muscular tension at the moment of loosing, are necessary. The movements involved in loosing the arrow are the most difficult to control exactly. At the moment of aim the extensor muscles of the bow arm are resisting a pull of about 40 pounds; the flexors are under no strain. When the bowstring is released the extensors are suddenly freed from strain and tend to throw the arm outward. The tonus of the flexors must be increased immediately to counteract this tendency. The bow-arm of a beginner frequently swings 4 inches out of position before the arrow leaves the string and the delayed tensing of the flexors then draws it a still greater distance in the opposite direction. This movement must be almost wholly overcome before accurate shooting is possible. Equally accurate and difficult movements of the loosing hand must be acquired. An average variation of 2° of arc in the relative position of the hands results in an average of 25 inches from the center of the bulls-eye. Some of the championship records given below require an average variation of less than 30′ of arc in the alignment of the arrows.

The record of a subject whose practice extended to more than 1,300 shots is given in figure 17. This is the subject mentioned on page 122 as having had opportunity for practice of implicit habits before the beginning of the experiment. This accounts for the high initial skill and for the resulting flatness of the first half of the learning curve. With the exception of the high initial accuracy the curve seems to be typical for this amount of practice.

1

2

3

DIFFERENT METHODS OF AIMING.

Fig 1 Sighting and kinæsthesia combined in aiming. Fig 2 Aiming without sighting along the arrow.
Fig 3 Position of the right hand determined by contact with the face.

Improvement after the average of 25 inches is very slow, with the suggestion of a plateau just before the quick improvement after 900 shots. Such periods of no improvement occur frequently in the practice curves. In some cases it has been possible to determine the cause of these with certainty. Thus one subject, after witnessing a slight accident occurring to another in loosing the bow, assumed, to avoid a repetition of the accident, an awkward aiming position and a slow release which interfered seriously with accurate shooting. The aiming position was quickly corrected, but the slow release persisted for many days and kept progress almost at a standstill. In general it seems that the plateaus are the result either of the accidental formation of conflicting habits, or that they represent points where no improvement can be made until a new method of shooting is hit upon by the method of trial and error.

The amount of practice recorded in the experiments was not sufficient to bring the skill of the subjects near the limit of improvement. The final accuracy of about 15 inches indicated in figure 17 is greater than that obtained by any of the other subjects. In comparison with championship records this average is still very high. The championship scores at the distance of 40 yards made in the double American round from 1880 to 1908 vary from 312

FIG. 17.—Improvement in long practice.

to 412. Reduced to inches from the center of the bulls-eye, they are about 11 and 7.8 respectively. The most consistently good record available is a practice score averaging about 5 inches for 90 shots. Studies of the rate of improvement from 15 to 10 inches are not available, but progress is certainly extremely slow. The writer, after reaching the average of 15 inches, has made scarcely any progress in 1,000 shots. The records used for comparison extend over only the first 360 shots, and deal therefore only with the preliminary stages of learning. During the first 100 shots, particularly, progress is made by leaps. The relation of the bow, hands, and arrow call out suddenly group habits of reaction to geometrical relations; the subject, for example, begins to nock the arrow at a constant place on the string and shows at once a marked improvement in accuracy. Most of the coördinations of larger groups of habits are formed very early in practice and probably account for the negative acceleration in the learning curves.

An attempt has been made to test the effect of fatigue upon the daily improvement. All first shots for daily practice were averaged for the 5-shot

group. The second, third, etc., shots were averaged in the same way. The differences between the average of the first and fifth shots gives a rough measure of the improvement during practice. In the same way averages were obtained for the 20- and 40-shot groups, but the averages of successive 5 shots instead of single shots were taken, making the average improvement shown a little too small in comparison with that of the 5-shot group. These were then reduced to terms of average improvement during 5 shots loosed in rapid succession. The averages are 1.5 inches for the 5-shot group; 1.5 inches for the 20-shot group; and a negative improvement of 0.2 inch for the 40-shot group. The full data are given in table 38. Little more can be deduced from the results than that fatigue is much more severe after 40 shots than after 20, in the former case obscuring any progress made or perhaps preventing progress (see p. 126).

The question of improvement during periods of no practice is closely related to that of the effect of fatigue in obscuring the improvement during practice. The data have not been analyzed carefully for the improvement during the 24-hour periods of rest, but the effects of some 48-hour periods of rest have been examined. In the 5-shot group there was a decided loss during these periods in the case of 3 of the 4 subjects. The fourth showed a slight gain. The absolute amount of gain was

+1.5 −5.0 −3.5 −3.2

With the results not obscured by fatigue there is a decided loss after practice is stopped.

For the 40-shot group the average gains during 48-hour periods without practice were

−0.5 −0.7 +2.5 +5.5

The record of the individual making the greatest progress during this period is given in figure 18. The solid lines of the figure connect the averages of the first and second 20 shots loosed daily. The dotted lines represent the intervals of no practice. The effects of fatigue are very pronounced in this case. Other individuals of this group show such effects to a less marked degree.

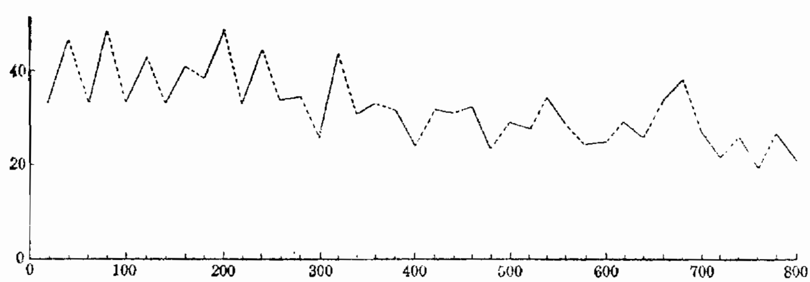

Fig. 18.—Effects of fatigue. Learning curve of one individual in 40-shot group is shown, plotted for successive groups of 20 shots. Solid lines show improvement during practice; dotted lines, improvement from one day to next.

The question of the part played by imitation in the improvement of the subjects is an interesting one. They watched each other's practice and the practice of the experimenter during the greater part of the experiment. From the different methods of aiming employed by different subjects it seems that

imitation played no large part in the learning. Plate 9 shows the different methods of aiming which gave equally good results within the limit of practice. In the one case (figure 1) the alignment was obtained by sighting along the arrow, while the elevation was determined from the position of the right hand in terms of kinæsthesia; in other cases the subjects looked only at the bulls-eye and determined the relative positions of the hands almost wholly by kinæsthetic stimuli (figure 2). In the method of aiming shown in figure 3 the position of the right hand was determined by contact with the face, almost the whole adjustment being made in terms of visual and tactual stimuli. In the

TABLE 38.—*Effect of fatigue.*

		Average of successive shots in daily practice.					Average.
							inches.
5-shot group	1	32.7	38.7	24.2	26.4	.	30.5
	2	20.2	37.5	26.9	27.4	....	28.0
	3	28.9	35.4	28.8	25.3	. .	29.6
	4	25.1	36.8	22.4	28.2	...	28.1
	5	22.7	43.2	24.9	25.1	....	29.0
Average improvement in 5 shots							1.5

		Average of successive groups of 5 shots in daily practice.					Average.
							inches.
20-shot group	5	26.9	44.4	50.2	50.2	48.5	55.5
	10	25.5	43.1	46.6	44.3	43.5	50.7
	15	23.3	41.4	46.3	47.5	45.1	50.9
	20	25.2	45.3	46.1	41.2	39.7	49.4
Average improvement in 5 shots							1.5+

		Average of successive groups of 5 shots in daily practice					Average.
							inches.
40-shot group	5	36.4	37.1	53.1	42.1	....	42.8
	10	30.8	31.0	54.1	50.2	....	41.5
	15	35.4	31.2	53.2	42.7	....	40.6
	20	29.0	31.1	48.5	46.4	....	38.7
	25	32.1	45.7	41.1	40.2	....	39.8
	30	31.3	41.6	54.6	45.1	....	43.2
	35	27.2	38.0	45.0	43.0	....	38.2
	40	31.4	46.1	50.8	49.5	...	44.4
Average improvement in 5 shots							—.2

case of every subject some such peculiarities of aiming and loosing could be distinguished, and in most cases the aiming position could be traced out as the result of adjustment by trial and error to difficulties occurring in the early part of practice. Thus the position in figure 1 was assumed originally to prevent the arrow from falling off of the left hand when the bow was drawn.

The great opportunity offered in the experiment for imitation and the small extent to which it seems to have been used raises the question of the real value of imitation in human learning. It is hoped that the further use of archery will furnish more adequate evidence upon this point.

EFFECT OF THE DISTRIBUTION OF PRACTICE.

The group shooting 5 shots daily was organized first and their practice continued for about 2 weeks before the 20- and 40-shot groups started. Their practice extended, altogether, from June 22 until September 20. Practice could not be carried out on Sunday and comparable records of 360 shots were obtained from the 12 weeks' practice.

The 20- and 40-shot groups were organized at the same time and their practice was continued for 4 weeks, giving records of approximately 400 shots for each subject in the 20-shot group and 800 for each in the other group. Comparisons have been made only of the rate of improvement, measured in various ways, in the amount of practice represented by 360 shots. A more certain method of comparing the groups would have been perhaps to continue the practice of each group until a given degree of accuracy was attained and then comparing the amount of practice necessary to reach this stage, as was done by Ulrich in his study of the rat, but this method is practicable only when the final accuracy selected is near the limit of improvement, and the time requirements for such an experiment could not be met.

For purposes of comparison the records of the groups have been averaged in series of successive 20 shots and the curves in figure 19 have been plotted upon the basis of these averages, which are given in table 39. The daily averages are disregarded in this treatment of the data, which consist of averages for like amounts of practice. The records of the 12- and 60-shot groups are included for comparison with these others, although, as has been shown, these groups are not strictly comparable with the remainder.

TABLE 39.—*Averages of successive groups of 20 shots for the groups of subjects compared.*
[Figures are in inches from the center of the bulls-eye.]

Arrows loosed per day.					Arrows loosed per day.				
5	20	40	60	12	5	20	40	60	12
56.9	58.4	55.8	48.9	75.4	35.6	40.9	40.3	33.1	48.9
40.1	49.2	47.8	44.4	66.1	30.9	45.4	33.5	29.6	46.9
39.2	45.3	44.7	39.7	51.5	27.1	32.9	42.6	32.2	45.5
35.2	43.6	46.6	36.2	54.0	30.7	36.1	40.0	30.6	49.6
43.1	40.9	41.8	35.7	60.1	25.6	36.7	38.3	29.1	44.5
39.6	38.8	42.4	36.6	50.7	28.9	38.3	38.9	31.3	46.0
40.7	43.6	36.9	33.9	50.7	35.7	35.3	40.6	32.6	40.2
40.8	40.8	39.1	32.8	48.7	31.4	38.6	37.8	29.1	44.3
35.4	36.2	38.4	32.1	55.9	27.1	44.5	34.9	32.7	45.1

From inspection of the curves in figure 19 it appears that the 5-shot group is considerably superior to the others in final accuracy and in the amount of improvement, possibly excepting the 12-shot group. The superiority of this group is really somewhat greater than is apparent from the curve, for the sudden loss in accuracy coming at the 320th shot is the result of a few days of extremely cold weather, which stiffened the fingers of the subjects and made accurate shooting impossible.

The 60-shot group shows a greater average accuracy but less improvement than the 5-shot group. The 12-shot group shows a much lower accuracy than

any of the other groups, with a somewhat greater amount of improvement. The improvement shown by the 12-shot group is in part spurious, owing to the method of recording the shots in this group. At the beginning of practice many arrows fell short. These were recorded as *failures*. In computing the averages these failures are counted all as 84 inches from the bulls-eye, which was, probably, an overestimate, and added something near 6 or 8 inches to the average records of the first 60 shots.

The amount of improvement in the 5 groups has been expressed in three ways: by the difference in average between the first and last 5 shots fired; between the first and last 40 shots; and by the differences in the averages of the first and last half of practice. These results are given in table 40.

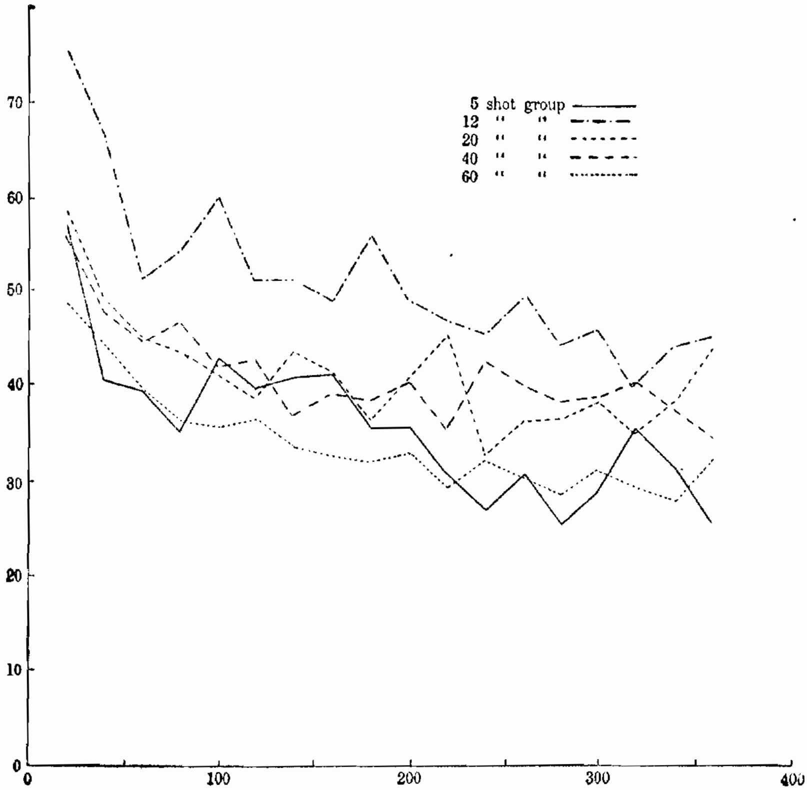

FIG. 19.—Learning curves for improvement in archery for 5 groups shooting 5, 12, 20, 40, and 60 shots daily. Arranged as in figure 13.

The absolute improvement, measured by any of these methods, is greatest in the 12- and 5-shot groups. The 60-shot group comes next with considerably less improvement, and the 20- and 40-shot groups are about equal. It appears from this that the rate of improvement per unit of practice is somewhat greater when the practice is distributed over many days than when it is concentrated into a few days. Whether there is a closer correspondence between the distribution of practice and the amount of improvement is not brought out by this method of treating the results, but an analysis of the data in a some-

what different way indicates that there is probably a fairly close correlation between distribution of practice and rate of improvement when chance causes of variation in the records can be eliminated.

During the first part of practice improvement is made largely by a series of what Thorndike has called "insights," such as those found so constantly by Ruger in the solution of mechanical puzzles. The sight and feel of the bow, arrow, and target present certain elements in common with the stimuli which call out many habits of manipulation and habits dealing with space relations and so tend to call out the same movements. Thus habits of aiming with the rifle are transferred to sighting along the arrow and need little modification to become efficient in producing accurate shooting with the bow. Such coördinations of complex preëxisting habits occur early in the practice of every subject, but whether they come before a single shot is fired, at the fifth shot, or at the sixtieth shot is largely a matter of chance. The subject whose record is shown in figure 17 had opportunity to see the practice of the 5-shot group for two weeks before his own practice was begun, with the result that many of the simpler problems of aiming were worked out in terms of the speech mechanism before hé loosed a single shot. The result was somewhat the same as learning with instruction, as shown in figure 13.

TABLE 40.—*Improvement in accuracy after 360 shots with the bow.*
[Averages are in inches from the center of the bulls-eye.]

	Average of shots.				
	Group 5.	Group 12.	Group 20.	Group 40.	Group 60.
From 1 to 5.....	69.2	94.2	69.8	66.0	61.4
356 360.....	34.0	46.6	49.2	39.2	32.3
Improvement.	34.2	47.6	19.6	26.8	29.1
From 1 to 40.....	48.5	70.7	53.8	51.8	46.6
321 360.....	29.2	44.7	41.5	36.3	30.9
Improvement.	19.3	26.0	12.3	15.5	15.7
From 1 to 180.....	41.2	57.1	44.1	43.7	37.8
181 360.....	30.3	45.7	38.7	38.5	31.2
Improvement.	10.9	11.4	5.4	5.2	6.6

These factors result in a greater variability in the earlier part of practice than in later practice, which is independent of the distribution of practice, for few large groups of habits are added after the first 100 shots, as is evidenced by the fact that in later practice the subjects can rarely tell to what changes in their method of shooting their improvement is due, while in the early stages of practice such exclamations as "Oh, I've caught on to something," are frequently followed by sudden large increases in accuracy.

The elimination of the first trials, then, probably gives a truer picture of the effect of the distribution of practice than the inclusion of the earlier practice period. The averages of the first, second, and last third of practice have been computed for each group and are given in table 41.

As in all other methods of treating the data, practice with few shots per day seems to be more economical than that with many. In the first half of practice there is no close correspondence between the amount of improvement and the distribution of practice, but in the second half, where the effects of variations in the initial stage of learning are omitted, the correspondence is quite striking, the 60-shot group alone being out of order. The position of the 12-shot group, as inferior to the 5-shot group, is very probably correct, since in this case the error due to the overestimate of *failures* (p. 121) is no longer significant. The order of improvement per unit of practice is, then, 5, 12, 20, 60, and 40, with unrelated evidence to show that the 60-shot group was somewhat superior to the others.

To what extent do these results express the effect of the distribution of practice, and to what extent may they be due to chance? As has been stated, the 5-, 20-, and 40-shot groups seem very closely comparable in their make-up. The rifle practice, though not very dependable as an index to the abilities of the individuals, does give some indication that the relative rate of learning of the groups practicing under similar conditions is not the same as that

TABLE 41.—*Improvement during the first and second halves of practice.*

Average of shots.	Shots per day.				
	Group 5.	Group 12.	Group 20.	Group 40.	Group 60.
	inches.	*inches.*	*inches.*	*inches.*	*inches.*
From 1 to 120.....	42.35	59.60	46.03	46.53	40.25
121 240.....	35.08	49.40	39.96	38.47	32.29
241 360.....	29.90	44.95	38.25	38.42	30.90
Improvement:					
First half.....	7.27	10.20	6.07	8.06	7.96
Second half..	5.18	4.45	1.71	.05	1.39

obtained in the archery practice, which differed from the practice with the rifle only in its distribution, and thus that the differences in the rate of learning to shoot the bow are due primarily to differences in the distribution of practice. If the rifle records are to be trusted as an index to ability, it appears that the improvement of the 20-shot group should be counted as relatively somewhat greater than that of the 40-shot group, since the latter seems to show superiority in rate of learning under like conditions of practice.

From the results of this experiment it is certain that practice distributed over many days is more economical than when concentrated to a few days. From the improvement shown in the later part of practice and general considerations of the relative abilities of the groups, it seems probable that there is a very close relation between the distribution of practice and the amount of improvement.

THE PROBLEM OF "DISTRIBUTION-RATE" RELATION.

These results agree very well with the general findings for the effect of the distribution of practice in the formation of other types of habits. Thorndike has summarized the more important work done before 1910, and it is unnecessary to review this work here in detail. In general, studies upon human learning indicate that the amount of improvement for a given amount of practice is directly proportional to the time interval between the practice periods and inversely proportional to the length of the practice periods, but there is some conflict in the results of experiments upon different types of habits. The results of a few experiments fail to show these relations, but do not seem to be conclusive.

For students learning to write English words in German script Leuba and Hyde give the results shown in table 42 for four groups practicing for periods of equal length but at different intervals. The group practicing every third day alone fails to show the advantage of distributed practice, and not enough subjects were used to eliminate the possibility that this is only a chance variation.

TABLE 42.

Group practicing.	Gained from fifth to tenth practice period.
	letters.
Twice a day......	240
Once a day.......	290
Once in 2 days....	395
Once in 3 days....	235

Lyon finds that short practice periods give better results in the formation of language habits, except in the case of short verse and prose selections whose meaning can be grasped as a unit; these are learned most readily by concentrated practice. In the case of such material, involving preëxisting language habits of almost inconceivable complexity, it seems very questionable whether the learning process is comparable to the formation of simpler habits.

Hahn and Thorndike found no advantage in favor of either of two distributions of practice, but their groups of subjects are not strictly comparable. The habits studied were those involved in computation and in every case the group with concentrated practice had the greater number of preëxisting habits, which may have obscured any disadvantages due to the concentration of practice.

With the exception of these cases the evidence favors the belief that the rate of learning varies inversely as the concentration of practice. The majority of investigators seem to believe that this holds true only within certain time limits, but with the possible exception of the results of Leuba and Hyde, no such limits have been established experimentally. The types of habits subject to the "distribution-rate" relation and the time-limits of the relation are not yet settled and the solution of the problem will demand a closer inquiry into the physiological causes of the relation than has yet been made.

The following quotation from Starch summarizes practically all the explanations which have been advanced to account for the effect of the distribution of practice upon the rate of learning:

Why are shorter and more numerous periods economical? The main reason, no doubt, is the well-known fact that a period of rest after newly formed associations gives them a chance to become settled and fixed. The slower rate of improvement of the third and fourth groups is due in part to fatigue. The forty-minute group shows no gain in the last

period, and the two-hour group shows no improvement after the first hour. A third minor factor was that those working for a short period at a time were more apt to work with maximum concentration than those working for longer periods.

The majority of investigators have been content to ascribe the results obtained to "fatigue" or "interest," without attempting further analysis. In planning further experimental work the writer has found the following classified list of possible explanations helpful. It probably is not exhaustive, but may help to define the problem more accurately.

TRIAL AND ERROR.

A. Variety of Proprioceptive Stimuli.

When an organism is confronted with a new set of conditions its reaction is the summation effect of the elements of the external stimuli and the momentary proprioceptive stimuli. The latter may remain fairly constant during a single practice period, resulting in a rather stereotyped reaction. During the relatively long interval between practice periods the proprioceptive "set" may change and thus practice distributed over several days may offer the possibility of a greater variety of activities (some of which may lead to improvement) than the same practice confined to a period during which the same "set" persists.

B. Loss of Conflicting Habits.

W. F. Book has suggested that improvement during intervals without practice is due to the dropping out of habits which make for low efficiency and which have not had time to become well established, while the principal successful actions, more firmly established by longer practice, persist. Such evanescent habits, by restricting the variety of activities, may delay progress considerably and give a decided advantage to the interrupted practice.*

C. Change in the Primary Stimulus.

For successful learning by trial and error it is necessary that the organism perform diverse activities in response to a given set of stimuli. In experiments with animals such as those of Ulrich, the primary stimulus to this activity is furnished by hunger, pain stimuli, unfamiliar surroundings, etc.; in man by the many sublimations of instinctive reactions which constitute "interest," "fear of ridicule," "rivalry," etc. The number and variety of trial movements may depend upon the force of the primary stimulus, either as a result of the amount of diverse activity produced or of the concentration of the activity in responses to a limited number of stimuli, as when the hungry rat spends its time before the door of the problem box and is not distracted by the movements of other rats; or when the human subject keeps his attention strictly on the problem in hand. "Loss of interest through fatigue" probably represents a change in the intensity of the primary stimulus to activity.

*The appearance and disappearance of habits of this type have been noted frequently during the experiment. For example, a subject assumes an incorrect aiming position in order to avoid catching the bowstring on his sleeve. This position persists for some time after the sleeve is rolled back out of the way, and may even become firmly fixed.

DIRECT EFFECTS OF FATIGUE.

Fatigue may have an effect upon the rate of learning in other ways than by changing the intensity of the primary stimulus.

A. Neurone Patterns.

It is probable that in order to obtain a given result different groups of neurones must be employed when the organism is fresh from those employed when it is fatigued. Thus, subjects in the 40- and 60-shot groups were seen to adopt different attitudes in aiming as they grew tired. The result of this is that a greater number of coördinations must be made to produce the same degree of skill whenever practice involves much fatigue.

B. Muscle Changes.

In archery there is a possibility that the effect of the distribution of practice is a function of muscle growth under different conditions of exercise. There seem to be no adequate studies on this subject.

PRACTICE BETWEEN PRACTICE PERIODS.

Where the subjects are interested in the experiment it is impossible to prevent their thinking and talking about it during the intervals between practice periods. This is the suggestion made by Thorndike in respect to Munn's results for language habits in substitution tests. It seems to apply equally well for the early stages of habits of manipulation in man (see p. 122), but its application to the rat in the maze test is questionable.

FIXATION OF THE NEURAL ARC.

Starch's first suggestion quoted above implies that a single activation of a neural arc starts up a process of fixation which continues for some time and that the further functioning of this arc during the process of fixation does not accelerate the process of fixation proportionately. By way of illustration, the following analogy may serve: Each time that a door with rusty spring hinges is opened it swings more easily. But when one man has opened the door others may follow him before it swings shut without wearing the hinges smooth. It is only when some time intervenes between the passage of the men that each reduces the friction in the hinge equally.

THE TIME RELATION OF PRACTICE TO THE CHANGES IN THE PRIMARY STIMULUS RESULTING FROM SUCCESSFUL ACTIVITIES.

The conception that the fixation of a habit is the consequence of its pleasurable result has been stated in a somewhat objective form by Ladd and Woodworth in a discussion of the escape of the animal from the problem box, as follows:

> We must assume in the animal an *adjustment* or determination of the psycho-physical mechanism toward a certain end. The animal desires, as we like to say, to get out and to reach the food. Whatever be his consciousness, his behavior shows that he is, as an organism, set in that direction. The adjustment persists till the motor reaction is consummated; it is the driving force in the unremitting efforts of the animal to attain the desired end. His reactions are, therefore, the joint result of the adjustment and of stimuli from various features of the cage. Each single reaction tends to become *associated* with the adjustment. But the unsuccessful reactions are less strongly associated than the successful, because each one of the former is at some moment given up or inhibited; and this inhibition, too, being

made under the influence of the adjustment, tends to become associated with it, and so to interfere with the association between the adjustment and the performance of this particular reaction. In the case of the successful reaction, however, the phase of inhibition does not occur and the only association with the adjustment is of the positive sort.

If habit fixation takes place in this way, progress perceptible to the subject should cause a quicker fixation of the habit. It is generally stated that long-practice groups can make an appreciable improvement in one practice period; that on this account their practice is more satisfying; and that this should result, therefore, in quicker learning. This would tend to produce a "distribution-rate" relation the reverse of that found.

In the present experiment the evidence makes it seem highly improbable that the "distribution-rate" relation was the result of differences in the primary stimulus. Members of the 5-shot group showed no greater interest in the problem than did the others; indeed, toward the end of practice, it seemed to the experimenter that the members of this group, after two months of faithful practice, were beginning to find the work something of a bore. The members of the 12-shot group were very busy with other work and seemed less interested in practice than any of the remaining groups. Yet these two groups made the greatest progress.

So far as the other possibilities are concerned, the present experiment offers little that is helpful in eliminating any of them. The effects of fatigue probably should not be emphasized too much. The 40- and 60-shot groups suffered far more from fatigue than did any of the others and their slower rate of progress does not seem proportionate to the amount of fatigue resulting from such long-continued practice. Changes in the muscles themselves, while possible in archery, are almost certainly precluded from language habits.

Which, if any single one, of the possibilities suggested is the real cause of the relation between the rate of learning and the distribution of practice, the evidence at hand is not sufficient to decide. Certainly some seem more, others less probable, but it is not certain that any of the four chief classes mentioned has been absolutely eliminated from any of the experiments thus far completed.

RÉSUMÉ OF RESULTS.

(1) The rate of learning to shoot with the bow was studied in two groups of men, one of the artisan, the other of the professional class. No significant difference in the rate of learning in the two groups was found.

(2) The rate of improvement of five fairly comparable groups during practice of the same function was tested under different conditions of practice. A close correspondence between the distribution of practice and the amount of improvement appeared, a given amount of practice being more efficient when distributed through many short periods than when concentrated in a few long ones.

(3) An attempt has been made to define the physiological problems involved in this "distribution-rate" relation.

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