THE ALTERNATION PROBLEM

A Preliminary Study

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INTRODUCTION

In the discrimination experiment animals are required to choose between several paths according to some given temporal scheme. It is recognized that the animals may ignore the stimuli to be discriminated and solve the problem by reacting to this temporal order of presentation. This possibility is usually eliminated by several means:—1. By instituting a sequence of such complexity that the animals are unable to master it. 2. By varying the given temporal order after the problem is mastered; and 3, by removing the stimuli and requiring the animals to rely upon sequence alone. The control tests have almost invariably shown that the sequence factor is relatively insignificant in the solution of these problems.

The ability of animals to master given sequences of position habits has not been adequately investigated. Such a problem presents several aspects of interest:—1. The determination of the limits of complexity which a given animal can master. 2. The relative difficulty of sequences differing in kind and degree of complexity. 3. The possibility of discovering new aspects of the learning process. 4. The determination of the various conditions conducive to the development of such habits; and 5, the character of the sensori-motor mechanisms involved in such series of alternating habits.

This paper reports the results of an experiment which was designed as a preliminary attack upon the above program. Before designing and constructing an apparatus especially adapted for this purpose, it was deemed advisable to test a group of animals upon a simple sequence. For this purpose we utilized a piece of apparatus which had been employed in the study of a particular phase of the discrimination problem. The essential features of this discrimination box are represented in fig. 1. The center consists of a 2′ x 3′ rectangular area. Opening from this enclosure are two exits, R and L, each 4″ x 4″ in dimensions. These exits are separated from each other by a distance of 6″, and they open into two runways, A and B, both of which lead to the food box F. These paths to the food box can be closed by means of two sliding doors situated at C and D.

A group of eight white rats was tested upon a simple alternation between two positions habits. On each trial the animal was taken from the food box and placed by hand at the position marked by an arrow in the figure. Both position and

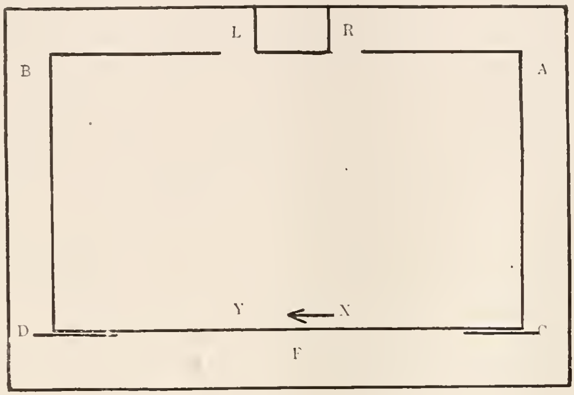

FIGURE 1.—Plan of apparatus. R and L, two exits; A and B, two pathways; C and D, sliding doors; F, food; Arrow, position in which rats are placed in apparatus; X and Y, two positions at which rats were placed in control tests.

body orientation were kept constant from trial to trial, the head of the animal being placed at the position of the arrow head equidistant from the two exits. On the first trial of each day the path leading from the exit R was left open, while the path from L was blocked. On the next trial L was opened and R blocked, and this procedure was repeated for each day so that the order of presentation may be represented by the schema of R-L-R-L-R-L, etc. The number of trials per day was varied from two to eighteen according to the condition of the animal and the stage of learning. Progress in mastery was measured in terms of the percentage of correct choices, and a choice was termed correct whenever the proper door was entered sufficiently to secure a body orientation along the length of the passage way. The time devoted to a single run varied somewhat with the animal and the stage of mastery, but it became practically a constant after the first fifty trials. This time was determined for each animal for different stages of mastery. The average time per rat ranged from 21.5 to 25.5 seconds with a group average of 23. Of this time, 6.5 seconds were devoted to the run and 16.5 seconds to feeding and handling between runs.

ANALYSIS OF THE LEARNING PROCESS

All members of the group were able to master this simple alternation with a high degree of accuracy. A consistent record of 85% of correct choices for the group was obtained at the end of 600 trials. The number of trials per rat necessary to secure such a degree of proficiency ranged from 168 to 588, with a group average of 412. The number of trials for five of the eight animals closely approximated 450.

Three graphs representing progress in mastery are given in fig 2. The group curve is represented by the solid line. In its general features it is similar to the usual learning curve. The distribution of choices between the two exits is at first a matter of chance as the initial record is 50% of correct choices. The initial trials are more effective than the later ones though the curve approximates a straight line more closely than does the typical learning curve. There is some indication of the existence of a plateau beginning at the 340th trial. This phenomenon is to some extent a group artefact, though four of the eight individual curves give some indication of a plateau in this region. The individual curves exhibit some pronounced differences. Four graphs exhibit a relatively rapid initial ascent followed by a period of slower progress. Only one of these, however, approximates the typical learning curve. The curves for three animals exhibit an approximately straight line ascent; progress is uniform for all stages of mastery. One curve is quite unusual in this respect as it descends rather rapidly for 200 trials, then rises abruptly, and this period of ascent is followed by the usual slow progress. This curve is represented by the broken line graph of fig. 2. The dotted line curve represents the case in which the initial trials are relatively the most effective. These two individual curves represent the two extremes between which are to be found all degrees of gradation.

The animals were required in the initial trial of each day to choose the right exit in order to secure food. Alternation was the rule for the remaining trials of that day's test. Mastery of these initial trials thus represents a different type of problem from that involved in the subsequent alternation. For this reason separate records were kept of these initial trials and the results were plotted and the curve compared with that representing the mastery of the problem as a whole. 1. Mastery of this initial choice proved to be extremely difficult for the majority of the animals. Five rats consistently made poorer records for the first trial than for the whole day for all stages

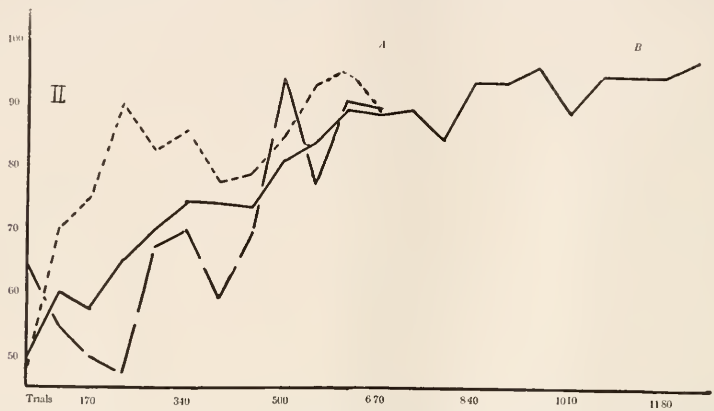

FIGURE 2.—Curves of learning. Solid line, group curve; broken lines, typical individual curves; curve from A to B, progress of group during period when control tests were given.

of learning. Only one rat found the initial choice to be easy and reversed the above relation. 2. Seven of the eight animals made poorer records for the initial choice at the middle of the learning period than at the beginning. With one exception the curves for the initial choice exhibit a pronounced descent for the first stages of mastery. 3. With four animals progress in the mastery of the initial choice was correlated with the degree of success for the day, although these choices were the more difficult. In these cases the mastery of the problem as a whole was apparently dependent upon the ability of the animal to get the day's sequence started properly. With the remaining four animals, these two aspects of the problem were apparently not related. 4. All animals finally succeeded in mastering this initial choice with a high degree of perfection. Some typical examples of these curves are given in figures 3 and 4. The solid line 1 represents the curve of learning for the problem as a whole, while the dotted curve 2 represents the course of mastery of the initial choice. Fig. 4 represents the exceptional case in which the solution of the two aspects of the problem were related and equally difficult. In fig. 3 the initial choice exhibited the greater difficulty; for some periods the two aspects were mastered together, at other times progress was antagonistic, while for most periods one problem was mastered independently of the other.

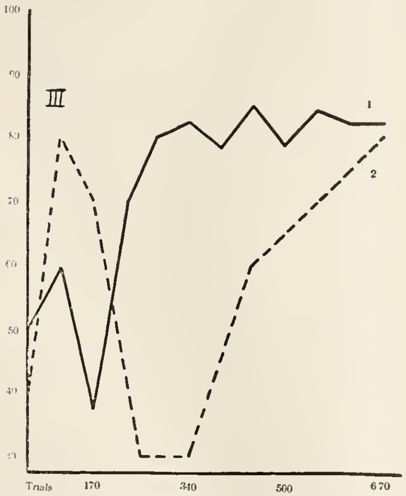

FIGURE 3.—Graph 1, individual learning curve; graph 2, curve of learning for mastery of initial choice.

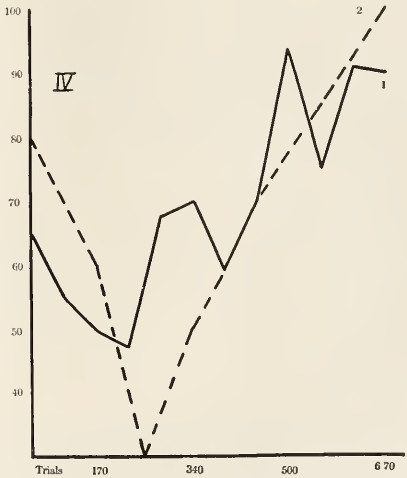

FIGURE 4.—Graph 1, individual learning curve; graph 2, curve of learning for mastery of initial choice.

Separate records were kept for the mastery of the two position habits. A comparison of the individual graphs reveals two general results. 1. Five animals found the mastery of the left position to be the easier. More correct choices of the left exit were consistently made for all stages of learning. The two positions were practically equally difficult for the other three animals. Mastery of the two habits was synchronous. 2. With four animals, the two habits antagonized each other's progress for the first half or two-thirds of the learning period. A rise in one curve was generally correlated with a fall in the other, and vice versa. The mastery of one path was made at the expense of an increased number of wrong choices of the opposite path. In the final periods of learning, however, the two habits were brought up to the same degree of perfection and progressed together. In all four of these cases the left path proved to be the easier and was mastered first. The reverse situation obtained for the other four animals. Progress in one habit was almost invariably associated with progress in the other. The two curves were thus similar in form. Typical examples of these relations are represented in figures 5 and 6.

FIGURE 5.—Graphs R and L, curves of mastery of the right and left exits respectively.

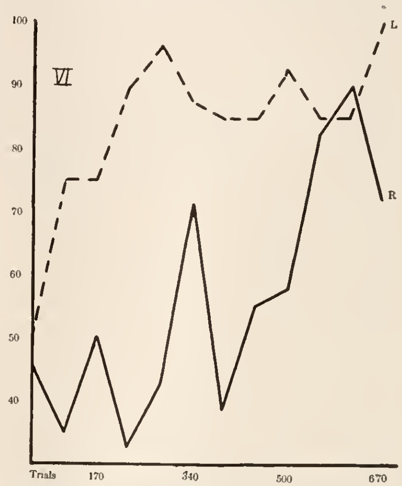

FIGURE 6.—Graphs R and L curves, of mastery of the right and left exits re spectively.

The graphs L and R represent the progressive mastery of the left and right paths respectively. In fig. 6 the two habits antagonize each other's progress in the main, and the left position is the first to be mastered with any degree of perfection. In fig. 5 the two positions are mastered simultaneously, although the right habit maintained somewhat the higher degree of perfection for most stages of development.

During the solution of the problem, the animal may develop several modes of attack. 1. The rats may acquire a position preference, or they may distribute their choices equally between the two exits. A fixed preference for either of the two exits will give a percentage of 50 of correct choices and no improvement will be possible until the habit is broken. An equal distribution of choices will give a score of 50% with no improvement so long as the choices are a matter of chance. When the alternation system is mastered, the choices will still be equally distributed and a score of 100% will be attained. 2. The rats may develop the tendency either to repeat or alternate from the previous choice. An invariable repetition of the previous choice irrespective of whether it was correct or incorrect is equivalent to a position habit and it will give a score of 50% with no improvement. Alternation from the previous choice will give a score of zero if each day's initial choice was incorrect, while a perfect score of 100% will be attained if each day's sequence gets started properly. 3. The rats may also develop the tendency either to repeat or to alternate from the previous exit that gave food. The repeating tendency will necessitate a wrong alternation with a score of zero. The alternating tendency will solve the problem and give a score of 100%.

All possibilities thus reduce to two, the development of a position preference, or the acquisition of a habit of alternation and this alternating sequence of choices may or may not conform to the objective sequence. Our results were now analyzed and tabulated with the purpose of studying the development of these two tendencies.

The relative number of R and L choices, irrespective of their correctness, was determined for the successive stages of learning. The group exhibited a slight preference for the R exit for the first 100 trials. A pronounced L preference was now developed and this persisted with some degree of strength until the 500th trial, after which point the choices were equally distributed between the two exits. The L exit was consistently chosen in two-thirds of the trials for a period of 200 trials. The development of the L preference was confined to five of the eight animals, while the other three rats maintained a practically neutral attitude towards the two exits throughout the entire period of learning. The L preference began to develop somewhere in the period from the 50th to the 170th trial and it persisted for a period of 300 to 600 trials. Four of the five animals at times chose the L exit in 80% of the trials. The development of this preference may be both advantageous and detrimental to the mastery of the problem. It must certainly be detrimental in part because this habit must be broken before the problem can be mastered. The detrimental character of the habit is evident from the following facts. Each animal was ranked as to speed of learning. The three rats that developed no preference stood 1st, 2nd, and 6th in quickness of mastery. Among the five rats with a position preference those two which first eliminated this tendency were also the first to master the problem, while that animal which was the last to eliminate the tendency was also the last to complete the mastery of the problem.

The existence of these position preferences explains the relative speed of development of the two habits as previously described and illustrated in figures 5 and 6. The group of five animals that developed a preference for the left position contained the same individuals as the group that exhibited the greater progress in the mastery of the left path. The three animals that developed no position preference were the ones which mastered the two habits simultaneously. The distribution of the total choices between the two exits was practically identical with the distribution of the correct choices alone; this relation holds for the records of the group and each of the individuals. No matter how the total number of entrances are distributed between the R and L exits, the percentages of correctness for each are practically the same. In case a rat chooses the left exit 80 times in a series of 100 trials when it has developed an accuracy of 75%, the numbers of correct choices for the left and the right exits will be 60 and 15 respectively. The absence of a position preference will give 50 entrances for each of the exits in a series of 100 trials, and in this case the number of correct and successful responses will be equally distributed between the two paths. Since the percentage of successful responses is independent of the distribution of the choices, the number of correct choices of either exit must be a function of the frequency with which it is entered. In other words, the relative progression in the mastery of the two habits as illustrated in figures 5 and 6 is almost wholly a function of the position preferences which have been developed.

The rats may repeat or alternate from the previous choice and this alternation may or may not conform to the objective sequence. An analysis of the results reveals the following facts:—1. The repetitions and the alternations are practically equal in number for the first 50 trials. Evidently no animal came to the problem with a preference for either mode of choice. 2. Three rats maintained this neutral attitude for 150 trials, and then rapidly developed a pronounced preference for the alternating mode of attack. One animal immediately developed a slight preference for alternation and maintained this attitude for 400 trials, relapsed into a neutral attitude, and then rapidly developed the habit of alternation. Three animals rapidly developed a repeating preference for 300 to 400 trials, and then shifted quite rapidly to the opposite mode of attack. The remaining animal first developed a slight preference for alternation, shifted to the repeating tendency for 100 trials, and then perfected the habit of alternation in 300 trials. 3. The correctness of the choices due to repetition is a matter of chance. Each rat closely approximated a score of 50% of correct choices for every stage of learning. 4. The correctness of the choices due to alternation is at first a matter of chance. All rats approximated a score of 50% for the first 50 trials. Finally the rats learn to adapt their alternate choices to the objective series and approximate a score of 100% for this mode of attack. 5. Four rats rapidly learned the trick of adapting their alternate choices to the objective sequence. A score of 90% or better was attained in 150 to 250 trials. One of these individuals lost the trick for quite a long period and then remastered it. The other four animals at first increased their percentage of wrong alternations for 160 to 280 trials, and then quickly learned to adapt their choices to the objective series. 6. There is no correlation between initial ability to alternate and success in adapting this to the objective sequence. Of the four rats that immediately developed a preference for alternate choices, two succeeded in adapting these to the objective sequence and two did not. Of the four animals that decreased the initial number of alternate choices, two succeeded in adapting them to the given order of presentation and two did not.

Our problem thus presents four distinct difficulties which must be mastered:—1. The rat must learn to choose correctly the initial entrance for each day's trials. 2. The animal must learn to keep its choices equally distributed between the two exits, or, in other words, it must inhibit all tendency toward the development of a position preference. 3. The animal must learn to alternate its choices, and 4, it must further master the trick of adapting these to the temporal order of presentation.

The progressive mastery of the above aspects of the problem accounts for the peculiarities of the various curves of learning. An analysis of three typical learning curves into their four components will be given as illustrations.

The dotted line curve of fig. 2 exhibits the most pronounced initial rise and this rat was the first to master the problem with any degree of perfection. This animal also made the most rapid progress in mastering the initial choice, developed no serious position preference, belonged to the group which made the greatest progress in learning the habit of alternation, and was the first to learn the trick of adapting its alternate choices to the objective sequence.

Curve 1 of fig. 4 exhibits a rapid descent for 220 trials and this is followed by a normal rate of ascent until the problem was mastered. Likewise we find that the percentage of correct initial choices rapidly decreases for 250 trials and then increases at a normal rate. The animal also developed a position preference which reached its maximum strength at the 330th trial, and which was then quickly eliminated. The rat also developed a repeating preference up to the 390th trial, and then shifted very quickly over to the system of alternate choices. The percentage of correctness of the alternate choices decreased for 220 trials, and the animal then began to learn to adapt these to the objective sequence.

Curve 1 of fig 3 exhibits four aspects, an initial rise at the 100th trial, a pronounced fall at the 150th trial, a rapid rise to the 330th trial, and a subsequent plateau period. The corresponding percentage record of the initial choices is represented by curve 2 of the same figure. The animal first succeeded in choosing correctly, then failed dismally, and again succeeded. This rat also exhibited for 150 trials a position preference which was then quickly eliminated. The rat made no progress in increasing the number of alternations for 150 trials, and then practically perfected the habit in 150 trials. The curve representing the percentage of successful alternations is practically a replica of the learning curve of fig. 3.

The most important aspect of the problem is the ability to adapt the alternation to the objective sequence. The curves representing the percentages of successful alternations approximate most closely to the learning curves. Next in order of importance is the ability to alternate. The success of the initial choice is the least important factor; this fact is readily comprehensible from two considerations. The number of initial choices constitutes a very small proportion of the total, and the ability to alternate successfully depends but little upon the success of the initial choice except after the problem is practically mastered.

NATURE OF THE CO-ORDINATION

Each of the two alternating habits consists of an association between a movement and a certain stimulus. The two stimuli must fulfill at least one requirement; they must be presented in a given temporal order. Four possibilities exist:—1. The animals may be reacting in a differential manner to the two acts of adjusting the sliding doors, or to two different sensory conditions resulting from the adjustment. 2. They may be reacting to two different ways in which they are handled and placed in the starting position. 3. Each movement may be aroused by the cutaneous and kinaesthetic stimuli resulting from the previous act. This hypothesis assumes that the two acts are functionally related to each other in much the same way as are the two leg movements in locomotion. 4. The rats may be reacting to two different motor attitudes maintained during the act of feeding. The arrangement of the apparatus was such that the animals were forced to alternate between two opposite directions of approach to the food. It is possible that the body orientation involved in approach may be continued during the act of feeding, and hence that each run is preceded by a distinctive motor attitude toward the food.

The first possibility was eliminated by instituting tests in which both sliding doors were left open; in other words the rats were forced to react when the usual acts of adjustment were omitted. Again the doors were adjusted only after the choice of exits was made. Such control conditions did not decrease the percentage of correct responses.

The second possibility was tested in several ways. 1. The rats were placed in the box as usual with the exception that the head was placed at X when a choice of the left exit was demanded and at Y when the right exit constituted the correct response. The animals were thus compelled to start from two distinctive positions of such a character that a correct response necessitated a diagonal course from each position to the appropriate exit. The percentage of correct choices for the group under these conditions is represented at A in the graph of fig. 7. 2. The rats were now placed at the two positions, X and Y, in such a manner that a correct choice necessitated a direct course to the proper exit. The percentage result for the group is represented by B in the curve. 3. The animals were handled and placed in the usual position by Dr. Vincent. These results are represented in the curve at the points C. 4. The animals were subjected to normal conditions when the left opening

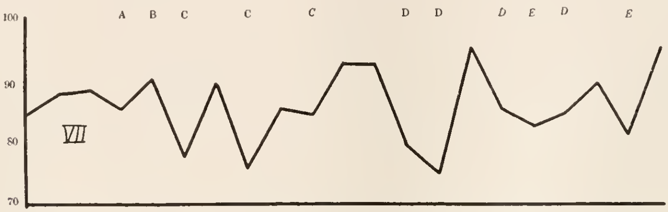

FIGURE 7.—Group curve representing the effect of the introduction of control tests.

constituted the correct choice, but whenever the right exit was to be chosen the animals were given a body orientation with the head pointing toward the right instead of to the left as under normal conditions. This orientation of the animal compelled the experimenter to place the rats in position with the left hand. The two choices are thus preceded by two distinctive methods of handling and two different orientations of the body. The results from this test are represented at the points D. 5. The rats were invariably given a head orientation toward the right instead of to the left as with normal conditions. This procedure involved a new method of handling and a new method of turning in starting for the exits. The results of the test are represented at the points E.

Tests for normal conditions were interpolated among these control experiments. The records secured for these normal conditions are represented in the graph at those points not marked by letters. The value for each point of the curve represents the percentage of correct choices for the group out of 224 trials.

The following conclusions may be derived from the results of these control tests. 1. The introduction of the novel conditions decreased the number of correct choices for the group by 10%. 2. The alterations did not disturb two of the eight animals. The percentage of correct choices of the rat manifesting the greatest disturbance was lowered from 91 to 75%. No animal fell below a record of 75%. 3. The most disturbing conditions were those in which the animals were handled by strange hands and in which they were subjected to a new body orientation in starting. 4. The rats quickly adapt to these novel conditions. This fact is evident from an inspection of the graph. 5. The interpolation of these novel conditions interfered little, if any, with the progressive perfection of the two habits. At the beginning of the tests the animals had just attained a consistent group average of 85% of correct choices. At the end of the tests a record of 95% was secured. An improvement of 10% was thus attained during the period in which the tests were given. The perfection of the two habits during this period relative to the progress attained during the previous learning period is represented by the solid line graph of fig. 2. The curve up to the point A represents the progress attained during the learning period. The part of the curve between A and B represents the records secured from the tests for normal conditions which were interpolated among the various control experiments. The rate of progress during the control period is somewhat less than that obtaining for the period of learning. It is impossible to assert, however, that this decreased rate of learning is due to the introduction of the controls. 6. As previously noted the animals experienced difficulty in mastering the initial choice for each day's trials. This fact indicates that the animals were not relying exclusively upon sensory data derived from the mode of handling or the position in which they were placed in the apparatus. If such stimuli were efficacious, the first choice should have been no more difficult than the subsequent ones.

The above results prove rather conclusively that the animals did not rely exclusively upon the second class of stimuli. Neither does the slight decrease in efficiency resulting from the altered conditions prove that the rats are relying upon these stimuli in part, for any alteration of the subordinate and supplementary sensory environment may produce disturbances as readily as those aspects which are utilized as guides and controls. In other words, these altered conditions may have operated merely as sensory distractions. There are several considerations which indicate the truth of this hypothesis. The rapid adjustment to these changes is readily interpreted on this basis. The relatively poor records secured by the second experimenter were evidently due to fear. This emotional reaction was quite evident in the animal's behavior. The hypothesis is further supported by the fact that these changes did not materially effect the rate of progress in the final perfection of the habits.

The animals usually did assume and maintain a bodily orientation during feeding resulting from and characteristic of their direction of approach to the food box. However constancy of motor attitude was not the invariable rule. No attempt was made to control this factor nor were systematic records of bodily orientation taken. We are thus forced to the conclusion that the controlling and guiding stimulus to each choice consists either of the sensory aspects of the alternate act or of a motor attitude resulting from that act.

EFFECT OF INCREASING THE TIME INTERVAL

During the mastery of the problem, a period of 16.5 seconds was devoted to feeding and handling between runs. After the perfection of the association, this time interval between the two acts was gradually increased in order to determine whether the ability of the animals to make correct choices was dependent upon the length of this interval.

The results of this experiment are graphically represented by curve 1 of fig. 8. The percentages of correct choices are represented by the ordinate values while the various time intervals in seconds are distributed along the abscissa. The first four percentage values were secured for the normal time interval of 16.5 sec. All percentage values for the periods of 16.5 and 44 seconds inclusive are based upon a total of 224 trials. As the time interval is increased, the animals are given a greater opportunity for feeding, and necessarily fewer trials per day can be given. As a consequence the percentage values for the intervals of 50 to 95 seconds are based upon a total of 48 trials each. The following results are apparent from an inspection of the graph. 1. A gradual increase of the interval from 16.5 to 50 sec. exerts but little effect upon the accuracy of the act. The lowest record of correct choices for any animal for two successive days' trials was 82%. Six of the animals were able to make a record of 100% for a similar number of trials. 2. An increase of the interval up to 44 sec. did not disturb the accuracy of the act for normal conditions. A test for the normal time interval was interpolated after the group was given the 44 sec. interval. A group record of 96.5% was secured for a total of 288 trials.

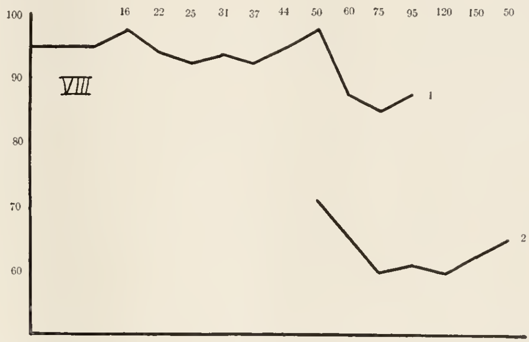

FIGURE 8.—Graph 1, percentage of correct choices for group with increasing time intervals. Graph 2, percentage of correct choices for group for large time intervals and the introduction of new conditions during the delay.

This value is not represented in the curve. 3. The number of correct choices suffers after a period of one minute is reached. This drop in the percentage values for the longer time intervals is not due to a diminished hunger motive as the number of trials per day was decreased from fourteen to six. The introduction of the longer intervals decreased the percentage values for the group about 10%. The lowest individual percentage record for the eighteen trials devoted to the three large intervals was 80, while the highest was 100. The decrease in the values was limited to five of the eight rats.

The experiment was continued with somewhat different conditions. After each trial the rats were allowed a few bites of food and then were placed upon an adjacent table. At the expiration of the given time interval, they were again placed in the apparatus for the succeeding trial. These conditions are radically different from those under which the problem was mastered. With the previous conditions the animals devoted themselves during the period of delay to the act of eating and they usually maintained a relatively constant position. On the table the rats were free to run around and react to whatever stimuli that may attract their attention. The purpose of the experiment was twofold. 1. We wished to determine the dependence of the choices upon the activities obtaining during the period of delay. To this end, we repeated the tests for the intervals of 50, 75 and 95 seconds. 2. We wished to continue the experiment with larger time intervals than the previous conditions permitted. With the new conditions the usual number of trials per day can be given even though very large time intervals are employed.

The results secured for these conditions are represented by curve 2 of fig. 8. The percentage value for the interval of 50 sec. is based upon a total of 1070 trials. The remaining values are each based upon a total of 100 trials. The following conclusions have been derived from these data. 1. The introduction of the novel conditions during the delay has decreased the percentage of correct choices by about 27%. The validity of this conclusion is readily apparent from a comparison of the two curves of fig. 8. 2. All of the animals were able to approximate a record of 70% of correct choices for the interval of 50 sec. 3. No improvement was manifested for the 50 sec. interval although the rats were tested daily for a period of 15 days. 4. The co-ordination was again disrupted for intervals greater than 50 seconds. The similarity of the two curves for the intervals of 50 to 95 seconds is striking. This fact indicates that the 60 sec. interval is a critical point. 5. Further increases beyond 75 sec. seem to be without effect. 6. The larger time intervals did not wholly destroy the functional efficiency of the co-ordinations for six of the eight animals. The group averages for these larger intervals are all at least 60%. Two rats made records of but 51 and 52% for the four large intervals. The percentage records of the remaining animals are at least 60%. The highest record was 70% and this score was made by two rats. Since these values are based upon a total of 52 trials for each rat, it is probable that some of these scores are significant. 7. The introduction of the long delays has tended to disrupt the act for the shorter intervals. The rats were finally tested again for the 50 sec. interval. Much poorer records were obtained than for the initial tests. The group record was decreased by 10%. Only four of the animals were now able to choose correctly for a score of 67% or better.

The experiment permits of the following general conclusions. 1. The guiding and controlling stimulus to each choice is constituted in part by the sensory aspects of the preceding act. A certain percentage of correct responses was obtained when all possibility of distinctive motor attitudes during the delay was wholly eliminated. Furthermore, any increase of the time interval beyond 60 sec. decreased the percentage of correct responses. 2. The rat may thus establish an associative nexus between a sensory stimulus and an act which are separated by a time interval of 16.5 sec., provided that relatively constant conditions exist during this period. 3. When an association has been established for a period of 16.5 sec., approximately one minute is the maximum time of separation of the stimulus and the response that may be obtained without disturbing their functional relation. 4. The functional efficiency of the coordination depends in large part upon the stability of the conditions that obtained for the period of delay. This fact supports the hypothesis that the guiding stimulus to each choice is constituted to a large extent by a distinctive motor attitude resulting from the previous act. The proof is not at all conclusive, however, for it is entirely possible to assume that the disruption of the act was due to the distractive influences of the novel sensori-motor conditions. 5. The efficacy of motor attitudes in the solution of the problem is indicated by the following facts. The relative disturbing effects of an increase of the time interval and the introduction of new conditions during the delay differ with animals. One may infer that some animals rely mainly upon the sensory aspects of the previous act as guides to conduct while other animals rely mainly upon motor attitudes. It is logical to suppose that those animals that place their chief reliance upon motor attitudes will learn the problem with the least effort because of the closer temporal contiguity of the stimulus and the response. As a matter of fact a positive correlation of .60 obtains between the ability to master the problem and the degree of disturbance due to the introduction of novel conditions during the interval of delay. In other words, those rats that rely mainly upon motor attitudes learn quickly and display the most disturbance when these motor attitudes are altered. On the other hand a negative correlation of .48 obtains between speed of learning and the degree of disturbance due to an increase of the time interval. Those rats that rely mainly upon the sensory aspects of the previous act in the solution of the problem are relatively slow learners and exhibit the greatest disturbance when this time interval between the stimulus and the response is increased.

FUNCTION OF VISION

The group of eight rats contained three blind animals. The records of the two groups were compared. The individual records are so variable and the numbers in each group are so few that it is impossible to make assertions with any degree of confidence. In general the group differences that exist are so small that they may well be due to chance or individual differences. Consequently the data as given justify the following negative conclusions. 1. The presence of vision did not influence the rate of learning. 2. No differences in the type of curve were apparent. 3. There were no manifest differences as to the interrelation of the R and the L habits. 4. No assertions can be made as to any differences of ability in mastering the initial choice for each day, or as to the relation between this choice and the day's success. 5. No differences were manifested in the mode of attack, or the ability to adapt the alternate choices to the objective sequence. 6. The groups did not differ as to the relative reliance which they placed upon the two sets of guiding stimuli. 7. No assertions can be made as to any differences of ability in solving the problem of increasing intervals of delay. It is of course possible that some of the above conclusions will need revision provided larger groups of animals are tested.

Two differences were detected. 1. The blind animals were somewhat the slower in movement and expended more time in making each run. The average time values per run were 6 and 7.2 seconds for the normal and the blind animals respectively. 2. In the later stages of mastery, the normal rats frequently turned immediately after entering the blocked path. The blind rats did not manifest this type of behavior. When wrong choices were made, the blind animals did not correct their mistake until actual contact with the closed door was effected. This differential behavior indicates that the normal animals frequently used visual data in reacting to a blocked pathway.

SUMMARY

All rats succeeded in learning to make alternate choices between two exits. The problem proved to be rather difficult for these animals.

The problem is a complex one consisting of four components which are stated in their order of importance. 1. The rat must learn to adapt its alternate choices to the given order of presentation. 2. The system of making alternate choices must be acquired. 3. The rat must resist the tendency of developing a position preference. 4. There is the final difficulty of choosing correctly in the initial trial of each day's test,—of getting the day's sequence started correctly.

These four aspects of the problem constitute to some extent independent difficulties in the early stages of mastery; progress in mastering one component does not necessarily depend upon the animal's ability to overcome the other difficulties. The four factors were mutually related in the case of some individuals, but there is no *necessary* dependence inasmuch as they were unrelated with some animals.

Animals differ greatly in their rate of progress in mastering each of these component elements of the problem. The curve of learning for the problem as a whole may be regarded as a combination of the four curves representing the mastery of the four components. The complexity of the problem, the independence of its parts, and the variability of the animals in mastering each part make possible a wide range of individual differences in rate and method of learning.

The final co-ordination consists of an association between each act and the sensory aspects of the preceding act as well as a distinctive motor attitude resulting from the same. The relative efficiency of the two stimuli in determining each choice varies with the individual. The problem was mastered quickest

by those animals that relied mainly upon the factor of motor attitudes in making their choices. This fact suggests the hypothesis that the speed of learning is to some extent a function of the degree of temporal contiguity between the terms to be associated. Since the animals relied in part upon the sensory aspects of the preceding act, we are forced to conclude that a rat can establish an associative nexus between a stimulus and a response separated by a time interval of 16.5 seconds, provided that relatively constant sensori-motor conditions prevail during that interval.

The rate and mode of learning are apparently not dependent upon vision. Rats with vision exhibited the greater speed of movement and occasionally corrected their wrong choices in terms of visual stimuli from the closed doors.