THE RELATIONSHIP BETWEEN PHYSICAL EXERCISE AND LEARNING ABILITY

BY

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In view of the great emphasis placed upon physical exercise, especially in connection with the regular school program, it is timely that a study be made of the effect of this type of activity upon some of the higher mental functions. Comparisons of the grades of athletes and non-athletes have thrown little light upon the problem. Ryan[1] examined thirty-three publications in which the grades of athletes and non-athletes from forty-four institutions were compared, and he could come to no conclusion. Too many factors other than physical exercise affect the grades made by various students. It involves too much stretch of the imagination to infer differences in learning ability from difference in grades. In the face of this apparent inadequacy of grade analyses, an experimental attack upon the problem seemed most promising, and because of the extreme difficulty of maintaining adequately controlled conditions when using humans, white rats were selected as subjects.

The purpose of the investigation was two-fold, viz., (1) to ascertain the effect of various periods of compulsory exercise upon the ability of the white rat to learn, and (2) to ascertain the effect of various periods of forced exercise upon the ability of animal subjects to retain or remember the behavior patterns that they have learned.

SUBJECTS AND APPARATUS.

The 260 subjects used were select Wistar albino rats, weaned at one month, and placed under experimental conditions at sixty days of age. They were handled by the experimenter only, fed a varied diet, and throughout the study seemed to be in the best of health.

The exercise was imposed by the use of a wire cage, electrically driven at a rate which required each animal to run 4,500 feet per hour. As this drum was made in four compartments, each of which could accommodate two rats, it was possible to exercise eight subjects at once. The rats' learning ability was tested by having them solve an eight cul-

[1] RYAN, W. C. The Literature of American School and College Athletics. Carnegie Foundation for the Advancement of Teaching Bull. No. 24, 1929, p. p. xxix.

de-sac, elevated maze, similar to those used by Miles,[2] Vincent,[3] and Turner.[4] The runways of this maze were three centimeters in width and without walls. All of the turns were right angles, and each cul-de-sac was 24 centimeters long. The length of the correct pathway was 240 centimeters. Reliability coefficients of well over 0.85 indicated that the maze measured "something" with a high degree of accuracy.[5] This "something" we have called learning ability.

Preliminary Studies

Before the major problem could be attacked, it was necessary to investigate the relationship between maze-learning ability and the three factors: sex,[6] hunger, and initial ability.[7] The first minor experiment concerned itself with a comparison of the ability of male and female white rats to learn the maze. Females in one litter were compared to males in the same litter, conditions other than sex being kept as constant as it was possible to have them. Notwithstanding these precautions, the female subjects learned to solve the maze much more rapidly than did the males. These results tend to vitiate the conclusions of those comparative experiments wherein no precautions were taken to place an equal number of males and females in the control and experimental groups.

The second minor study was an attempt to determine the effect of inter-litter correlations in maze-learning ability upon experimental results. In other words, do some rat families have a certain average level of learning ability about which all members tend to group themselves, and which may be greater or less than that possessed by other families?

This proved to be true. Even though the subjects were from highly inbred Wistar stock, there was distinct evidence of family resemblances with respect to maze-learning ability. Brothers and sisters showed a decided tendency to group themselves about a family average. As Hubbert,[8] Burlingame and Stone,[9] Bagg,[10] Tolman,[11] and others have shown,

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[2] Miles, W. R. The Narrow Path Elevated Maze for Studying Rats. *Proc. Soc. Exper. Biol.* and *Med.*, 1927, *14*, pp. 454ff.

[3] Vincent, S. B. Function of the Vibrissae in the Behavior of the White Rat. *Behav. Monog.*, 1912, No. 5.

[4] Turner, C. H. Behavior of the Common Roach on an Open Maze. *Biol. Bull.*, 1913, *25*, pp. 348-361.

[5] Corey, S. M. The Reliability of the Elevated Skeleton Maze. *Amer. J. Psychol.*, July, 1930, *42*, 439-442.

[6] Corey. S. M. Sex Differences in the Maze Learning of White Rats. *J. Comp. Psychol.*, 1930, *10*, 333-338.

[7] Corey. S. M Equating Groups in Comparative Experiments. *J. Comp. Psychol.*, 1930, *10*, 287-294.

[8] Hubbert, H. B. The Effect of Age upon Habit Formation in the White Rat. *Behav. Monog.*, 1913-15, No. 11.

[9] Burlingame, M., and Stone, C. P. Family Resemblances in the Maze Learning of White Rats. *27th Yrbk. Nat. Soc. Sci. Study Educ.*, Part 1, 1927, pp. 89-99.

[10] Bagg, H. Individual Differences and Family Relationships in Animal Behavior. *Arch. Psychol.*, 1920, No. 43.

[11] Tolman, E. C. Inheritance of Maze Ability in Rats. *J. Comp. Psychol.*, 1924, No. 4, pp. 1-18.

some litters are distinctly superior to others. These findings call into question all previous comparative studies wherein no attempt has been made to guarantee equal initial ability in experimental and control groups. Positive results might be due, not to the experimental conditions imposed, but to differences in learning ability which existed before the experiment was started.

The third preliminary study verified the work of Holden,[12] Washburn,[13] Moss,[14] Stone,[15] and others in establishing a positive relationship between hunger and speed of learning. Some subjects were kept in a constant state of inanition during the training period, and their maze-learning performance was significantly better than that of a control group trained at the same time. It seems that inequalities in motivation have caused many conclusions to be drawn that are invalid. This is as true in studies of human learning as it is in the case of animals.

The preliminary experiments sufficed to call attention to the following considerations: (1) extreme care should be exercised lest the experimental and control groups have unequal initial ability, and (2) every attempt should be made to have the motivation equally strong for the control and experimental groups.

Experimental Technique

With these precautions in mind the study proper was begun. Three different experimental groups of thirty-one subjects each were used. These are called the I-, III-, and V-hour groups, respectively, the Roman numerals representing the number of hours of exercise imposed daily. Each experimental group had its own control of equal size, and composed of rats from the same litters and of the same proportion of males and females. In this manner the two groups were of as nearly the same initial ability as it was possible to have them.

Attempting to guarantee equal motivation in the control and experimental groups involved numerous difficulties. The following techniques were finally adopted:

(a) The control and experimental animals were fed the same amount of the same kind of food. This was necessarily so because in each nest cage there was one litter, including an equal number of control and exercised animals.

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[12] Holden, F. A. Study of the Effects of Starvation on Behavior by Means of the Obstruction Method. *Comp. Psychol. Monog.*, 1926, No. 17.

[13] Washburn, M. F. Hunger and Speed of Running as Factors in Maze Learning. *J. Comp. Psychol.*, 1926, No. 6, pp. 181-187.

[14] Moss, Fred. A Study of Animals Drives. *J. Exper. Psychol.*, 1924, No. 7, pp. 165-185.

[15] Stone, C. P. *in* Thorndike, E. L. Adult Learning. p. 142.

(b) No food was placed in the nest cage until the exercised subjects had been removed from the rotating cage and put with the control half of the litter. Hence all subjects began feeding at the same time.

(c) The food was removed from the nest cage four hours prior to maze running. Both the control and exercised groups experienced an equal period of deprivation from food before being placed on the maze.

(d) The daily order of procedure for the exercised subjects was: (1) testing on the maze, (2) exercise in the rotating drum, and (3) feeding. This was done in order that the unusual effect of the exercise might be as far removed in time as possible from the maze running.

During experimentation each subject was given five trials on the maze per day. The norm of mastery was five consecutive errorless runs. Speed of learning was judged in light of the following four criteria: (1) number of errors made, (2) number of trials required, (3) total number of seconds spent on the maze, and (4) total number of seconds spent actually running the maze, and called "active time."

Fourteen days after the maze was learned it was relearned. The exercise ceased for the experimental animals with the day on which the subject finished his fifth consecutive errorless run. The criteria for speed of relearning were the same as those for learning.

After the data were all in, each exercised group was compared with its control with respect to the following particulars: (1) learning scores in terms of errors, time, trials, and active time; (2) variability of learning scores; (3) location of errors; (4) number of errors repeated on any one day; (5) number and location of retracements; (6) speed of relearning as measured by the four criteria mentioned above; and (7) correlation between learning and relearning scores.

This list seems to exhaust the possibilities wherein the two groups might differ in such a way as to indicate unequal learning performances. They are compared with respect to the speed and quality of their learning. In all comparisons, the measure of central tendency was a mean, and of variability, a standard deviation. The significance of any difference between scores made by the exercised and control groups was judged by using the standard error of the difference. If the difference were three times its standard error it was considered to be statistically significant.

Conclusions

1. Judging the ability of the exercised and control subjects by their error, trial, time, and active time learning scores, it appeared that (a) in a majority of instances the exercised subjects were superior,

(b) in no instance was the difference between the performance of exercised and control subjects statistically significant, and (c) the superiority of the exercised animals did not increase consistently with increased exercise.

2. With respect to variability of learning scores it appeared that (a) the learning scores of the exercised subjects were insignificantly less variable, and (b) there was no constant tendency for the variability to decrease regularly as the exercise was increased.

3. The difference in the percentage of errors made on any one cul-de-sac by exercised and control subjects was negligible.

4. One group was as apt to repeat its errors on the same day as was the other.

5. There was no significant difference between the groups with respect to the number of retracements made while learning the maze.

6. There was no significant difference between the control and exercised subjects with respect to the location of the retracements made while learning the maze.

7. There was no significant difference between the two groups with respect to the error, time, active time, and trial scores made while relearning the maze.

8. No consistent and significant difference in the relationship between learning and relearning scores was noticeable for the two groups.

Implications of the Study

This study was an attempt to attack a problem in human learning by a preliminary experimental analysis of animal behavior. Such an approach is neither new or unjustified. The most completely stated theories of learning have sprung from researches on infra-human subjects. Thorndike, Watson, Washburn, and Köhler have had success in applying to human behavior the principles discovered or verified while working with animals. This problem was particularly susceptible to inferential exploration. It was an attempt to ascertain the effect of forced exercise upon kinesthetic learning. Little defense is needed for the statement that higher vertebrates stand in close proximity to each other with respect to physiological functioning. It is well known that drugs which affect the nervous system of man in a particular manner have a similar effect upon many of the higher vertebrates. This is true of strychnine, and alcohol. It seems reasonable, therefore, that factors which affect the muscular learning of the white rat would affect the kinesthetic learning of man in much the same way. And inversely, if compulsory physical exercise has no significant effect upon the maze-

learning ability of the white rat, it will probably not affect the muscular learning of man.

The latter of these two possibilities seems to be true. It is somewhat startling that the strenuous exercise imposed on the five-hour group (approximately five miles of running per day) did not affect the ability of the experimental subjects to learn the maze. It appears that forced exercise, apart from hunger, bears no relationship to the learning ability of the sixty-day-old albino rat, no matter on what basis one seeks for a difference in performance. It is suggestive then, at least, that physical exercise, apart from the relationship which it may bear to motivation, would have no noticeable effect upon the muscular learning of man.