EFFECTS OF EARLY ENRICHED AND EARLY RESTRICTED ENVIRONMENTS ON THE LEARNING ABILITY OF BRIGHT AND DULL RATS

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Roderick Melvin Cooper

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ABSTRACT OF THESIS

Animal experimentation has demonstrated that the quality of infant experience can affect later mental functioning. Several experiments have shown that an early enriched environment improves the learning ability of rats while an early impoverished environment retards it. The subjects used in these investigations have been animals that possess only a <u>normal</u> degree of learning ability in contrast to the subjects of the present study. The present project was designed to test for the possibility of differential effects of early enhanced and impoverished environments on animals of superior and inferior learning endowment.

Forty-three rats served as subjects for the study. They comprised four experimental groups: a bright-enriched group, a bright-restricted group, a dull-enriched group and a dull-restricted group. The enriched animals lived in cages filled with play objects designed to provide a maximum of stimulation. The restricted animals lived in cages without such objects. All animals were weaned and placed in their respective environments at 25 days of age. At 65 days of age the animals began the training and testing regimen of the Hebb-Williams maze.

To facilitate the interpretation of results the scores of the animals used in the present experiment were

compared with the performances of bright and dull animals raised in a normal environment. It was found that the enriched and restricted environments had differential effects on the learning ability of the bright and dull rats. Bright animals showed no improvement in learning ability after a period of early enriched experience. This is in contrast to dull animals who benefited greatly from such experience. The extent of this improvement was such that the dull animals became equal to the bright animals in learning ability. On the other hand, dull animals raised in a restricted environment suffered no deleterious effects while bright animals were retarded to the level of the dulls in learning ability.

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CHAPTER I

THE PROBLEM AND INTRODUCTION

I. STATEMENT OF THE PROBLEM

Several experiments have been directly or indirectly initiated by D. O. Hebb of McGill University which show that the learning ability of adult animals can be affected by the quality of their early environment. These studies have shown that an enriched or stimulating environment in early life may improve learning ability while a restricted or unstimulating environment in early life may retard learning ability.

While this research has demonstrated that the quality of the early environment may affect the subsequent learning behaviour of animals possessing a normal heritage of learning ability, there still remains the possibility of differential effects on animals of superior and inferior endowment. The present study has been designed to test this hypothesis by using strains of bright and dull rats, in contrast to the animals of normal learning ability used in previous research. The object of the present investigation, therefore, is to test for possible differential effects of an early enriched and early restricted environment on the problem solving abilities of strains of bright and dull rats.

II. INTRODUCTION

"It has become increasingly evident that a fuller understanding of the effects of early experience upon subsequent behaviour is fundamentally important for a science of psychology and for the broader field of animal biology" (4, p. 256). Four recent summaries of studies dealing with the relationship between early environment and later behaviour testify to the prevalence of this conviction.

A summary by Thompson (53) includes research dealing with the effects of prenatal environment. Even at this early stage of development there are environmental factors influencing the future behaviour of the organism. A review by Beach and Jaynes (4) shows the numerous behavioural functions that have been studied at the animal level. Perceptual, feeding, reproductive, social and emotional as well as learning behaviour show the far-reaching effects of early experience on later functioning. In commenting upon studies at both the animal and human levels, Drever (11) concludes that there are certain basic perceptual and social skills which are established in early life or not at all. Bindra's summary (6) is more critical. He has pointed out that numerous studies are needed before certain theoretical issues are resolved and wide gaps in the existent literature can be filled.

D. O. Hebb is prominent among the investigators in this area. He believes that the organization of adult behaviour is largely determined by the quality of infant experience. He and his collaborators have published several animal studies that generally support his contentions. While the effect of various kinds of environments on animals of normal learning ability has been relatively well explored there is no systematic information available on the problem of how such environments would affect animals that vary in intellectual endowment. The present project has been designed to provide information on this problem by utilizing strains of bright and dull rats that are maintained for research by the Psychology Department of the University of Manitoba.

The thesis begins with a discussion of the historical background to the problem and goes on to present some of the more relevant findings in this area. Following this introductory section, the subjects, apparatus and procedure used in this experiment are described. The results are then presented with a discussion of their implications. Finally, the concluding section summarizes the results and discussion of previous sections.

III. HISTORICAL BACKGROUND

Human Studies

The problem of the effects of an early improved or impoverished environment on intellectual functioning has not been adequately answered at the human level. Although several comprehensive summaries (2, 29, 42, 61) indicate that considerable research has been carried out, the crucial experiment to clarify this highly controversial question has yet to be undertaken.

Several studies have reported a significant gain in performance on intelligence tests which were administered during or shortly after a period of enriched experience. For example, it was found that children six years and under made small but significant gains in IQ scores after being transferred from poor home environments to a model child city (46, 47). It was also found that the enriched environment must be provided early in life to have beneficial results since children seven years of age or older showed no improvement. Similarly, Kephart (30) reports that 16 mentally deficient boys showed a mean IQ gain of about 10 points after living in a special cottage in a training school. These retarded boys were stimulated to engage in constructive activity and encouraged to show ingenuity, initiative and original planning.

While these results appear to indicate that IQ scores may be increased after a period of enriched stimulation there are several negative studies that seem equally conclusive. Thus it was found that 141 children who participated in "a rich and vital school curriculum" showed no significant changes in IQ's (32, p. 70). Similarly, 111 dull-normal children failed to show any improvement after a two year curriculum designed to stimulate the intellectual activity of these slow learners (44).

The effects of an impoverished environment on mental functioning also remain indecisive. Wellman's conclusion (60) that the decrease in IQ of orphanage children during institutional residence was due to the "unstimulating" nature of their environment has been criticized on the grounds of biased sampling (18, 37). Asher (3) found that with increasing age Kentucky mountain children showed progressive losses in IQ scores. At age 7 he found a mean IQ of 84 that decreased to a mean IQ of 60 at age 15. In his study of canal boat children Gordon (cited by Neff, 42) found a similar decrease in IQ scores with age. While some interpret these results as showing that the impoverished environment has an increasing deleterious effect on intellectual performance as the child grows older (8, 63), others argue that this is the result of the tests being standardized on city children, the decrease in scores representing the increasing inappropriateness of the tests (29).

In reported cases of extreme isolation the effects of an impoverished environment also appear ambiguous. Davis (10) reports that a child who was incarcerated in a room for the first five years of life was unable to rise above the idiot level after two years of special treatment. On the basis of similar cases Davis concluded that there was little likelihood that the child would improve much further, the effects of isolation being relatively permanent. Unfortunately this and other studies (25, 36) lack conviction since the investigators were often forced to rely on the unsubstantiated judgments of unqualified observers. Because of this it is not known if such children were normal at birth or if the parents possessed normal intelligence. It is possible that these children were defective at birth and therefore their low intelligence might not have been due to the effects of isolation.

From this brief examination of typical results and the more comprehensive summaries of Jones (29) and Anastasi (2), it seems apparent that the effects of early environment on intellectual functioning are somewhat ambiguous.

Many reasons in addition to those already mentioned account for the lack of conclusive knowledge in this area (2, 29, 56). Problems connected with the nature of the experimental environment, the limitations of the testing instrument and the subjects themselves have led to faulty conclusions. For instance, a lack of any real contrast between experimental and control environments may explain the negative findings of some studies. Inherent in this problem is the question of what factors constitute a "stimulating" or "impoverishing" environment. Furthermore, psychological measurements are carried out in these studies by tests which are always subject to certain limitations. The failure to heed these limitations has led some investigators into faulty interpretation of their experimental results. Too little attention has been given to the variable of age in these studies. It seems possible that the age at which the enriched or impoverished experience occurred and the time at which the subjects were tested for possible effects might have accounted, in part, for the discrepancies in results. Moreover, no attention has been given to the possibility of differential effects of various environments on subjects differing in intelligence.

It seems evident that until such factors are taken into account the relationship between early environment and intellectual functioning will remain undefined at the human level. Meanwhile, more carefully controlled studies at the animal level provide an opportunity of obtaining a clearer picture about the effects of early environment on learning behaviour.

Animal Studies

While studies at the human level appear inconclusive there is a growing body of evidence at the animal level that testifies to the importance of early experience on later behaviour. Summaries compiled by Beach and Jaynes (4), Thompson (53), Drever (11) and Bindra (6), mentioned earlier, show the diversified behavioural functions that have been studied. Besides the general area of learning with which the present project is concerned, investigators have studied the effects of early experience on emotional, feeding, reproductive and social behaviour. The present survey will be limited to those studies most relevant to the problem under investigation. Such research deals with the effects of early environment in either improving or retarding learning behaviour.

Effects of Enriched Experience on Learning Ability

In 1949, Hebb (19) proposed a neurophysiological theory of behaviour out of which either directly or indirectly many of the studies mentioned below have followed. He drew a clear distinction between early and later learning, suggesting that early learning acts as a basis for perceptual skills and insights upon which later learning in part depends. Since, for Hebb, early learning was so important it would tend to follow that the more varied and enriched the experience of the organism in early life the better will be its future adaptive and purposeful behaviour.

In an attempt to provide experimental support for his theory Hebb embarked upon a series of studies (19,20). He found that animals raised as pets at home, where they had the freedom of the house, were superior to rats raised in ordinary laboratory cages on a complex series of maze problems. Further testing showed that the beneficial effects of the richer experience afforded by the home environment were permanent since several months later the difference between the pet and laboratory animals increased on further testing. Hebb concluded that "the richer experience of the pet group during development made them better able to profit by new experience at maturity . . . one of the characteristics of the intelligent human being" (19, p. 298).

In the laboratory Hymovitch (27) corroborated Hebb's investigation by raising rats in a "free-environment" or kind of "rat playground." The free environment consisted of a large cage where the animals had access to inclined runways, blind alleys, small enclosed areas, apertures, etcetera. Animals that were raised in this environment proved to be superior on the Hebb-Williams test to those who did not have such experience. Hymovitch also established that such experience is of little consequence if it is given in later life. He found, for example, that a period of enriched experience given after the animals had been subjected to a retarding environment was of no benefit while those animals subjected to an early enriched environment and then put into the retarding environment showed as superior a performance as those animals who had early and late free-environment experience. The retarding or "restrictive" environment consisted of "stove-pipe" cages that severely limited opportunity for perceptual experience.

One unexpected finding of Hymovitch's intensive study was the performance of a group of mesh-caged rats. These rats, one to a cage, were moved about in the free-environment box and to various positions about the laboratory. As adults these mesh-caged rats were indistinguishable on the Hebb-Williams test from the animals who had been given free run of the enhanced environment in the same period of time. This result led Hymovitch to conclude that the beneficial effects on problem-solving ability of an early free-environment were largely attributable to differential opportunity for visual perceptual learning. However, he did feel that non-visual perceptual learning was important since a group of blinded rats with free-environment experience did better on the maze test than a blinded group without free-environment experience.

The performance of Hymovitch's mesh-caged rats led Forgays and Forgays (13) to carry out a similar study. They reached essentially the same conclusions about the effects of early experience on later learning behaviour. They did differ on one important point, however. While Hymovitch had found no difference between his mesh-caged group and his free-environment group, they found that rats who had actual contact with the play objects were superior to those who only visually experienced them. Forgays and Forgays believe that this discrepancy may be due to different experimental procedures. This seems the likely explanation since Hymovitch's mesh-caged rats had the opportunity of experiencing visually not only the free-environment situation but also other parts of the laboratory to which they were moved. This difference in the two experiments may have provided more opportunity for visual experience and learning in the mesh-caged group of Hymovitch's study. This was then reflected in adulthood by equality with animals in problem-solving ability in a maze situation in which success is apparently closely related to the effective use of visual cues. Forgays and Forgays believe that, depending on the environmental conditions during their rearing, mesh-caged rats may be as superior in problem-solving ability as free-environment animals or as inferior as those animals raised in a restricted environment.

Experimental evidence on the effects of an early enhancing environment has also been contributed by Bingham and Griffiths (7). They found that rats raised in a large room supplied with an alley, an inclined plane board and swinging doors--objects that bore a resemblance to elements of the test situation--were superior to control animals on a Warner-Warden 12 cul-de-sac and on inclined plane mazes. That the superiority of the experimental animals was not due simply to direct transfer seems evident from the performance of a third group of animals. This group had play objects consisting of a broken chair, a box and a broken cage. In the test situations they displayed a superiority over the control animals equal to that of the other experimental group. This finding would seem to indicate that the particular elements constituting the enriched environment need bear no special relationship to the test situation for beneficial effects to occur.

Although many investigators have confined themselves to the Hebb-Williams maze in testing for the possible effects of early enriched or impoverished environments, Forgus (14, 15, 16) has found that differences are upheld on other tests as well. Animals receiving complex visual-proprioceptive and complex visual stimulation were found to be more willing to encounter a problem situation than the control animals, and to excel the latter on tests of activity, emotionality and spatial problem-solving ability. This last test is similar to Maier's test of reasoning ability (35). Forgus (17) also found that rats who have had perceptual experience with specific two-dimensional forms in infancy are superior in form discrimination and generalization to rats who have had this experience only in later life. Luchins and Forgus (34) found that experimental animals were more capable of learning an indirect solution to a maze problem as well as being able to shift more readily to an indirect one than animals raised in ordinary laboratory cages.

It seems apparent from the above studies than an early enriched experience can have important beneficial results on a rat's later learning ability. Moreover, these gains, displayed in a variety of learning situations, seem to be fairly permanent.

Effects of Impoverished Experience on Learning Ability

Research has not been limited to an investigation of the effects of an early enriched environment on learning behaviour. Investigators have been equally concerned with the possible retarding effects of early environments that allow only a minimum of perceptual experience.

Hebb (19,20) found that rats blinded in infancy were inferior on the Hebb-Williams test to rats blinded at maturity. Apparently the loss of early visual experience in the group blinded in infancy accounts for the inferiority of these animals. Most interesting, however, was the fact that the two groups could not be differentiated on a simple test of rote learning, an observation that led Hebb to conclude that differences in early experience are more detectable by a test that resembles human intelligence tests (20). The Hebb-Williams resembles the Porteus maze test used to determine human intelligence (1, 63).

In a similar project, Wolf (62) sealed the eyes and ears of rats during infancy. He found that at maturity these animals had great difficulty in responding to visual and auditory stimuli when under the stress of competition. In the test situation visually deprived rats were inferior to acoustically deprived rats when the stimulus was visual and superior when the stimulus was auditory. This did not occur in a non-competitive situation. Wolf believed that the rats were showing behaviour similar to that of neurotic persons who lose highly developed skills in retreating to outmoded but previously serviceable forms of adaptation.

In his earlier mentioned experiment Hymovitch (27) found that rats raised in restrictive "stove-pipe" cages showed marked impairment on the Hebb-Williams test. The effects of such an environment are permanent since animals raised under restrictive conditions remained inferior even after a period of enriched experience. He was, however, unable to find a difference between early and late blinded animals as Hebb (19) had done previously. Forgays and Forgays (13) also found that rats raised in small laboratory cages with only a small mesh door and grill top permitting light to enter, were inferior on the Hebb-Williams test to animals allowed more perceptual experience. Similarly, rats raised in 2 x 6 x 4-inch "squeeze" boxes showed inferior performance on two mazes (7).

Experiments dealing with the effects of early environments on later cognitive abilities have not been limited to rats. Clarke and his associates (9) raised dogs in small restricting cages that allowed only diffuse light to pass in through the top. The dogs were fed by a special procedure so that they never saw their keepers. These animals when released showed permanent variations from normal emotional behaviour, a finding which is in agreement with related studies (38, 39, 40). Most important, however, for the present work was the nature of the intellectual impairment shown in this study and in ensuing projects by Thompson and Heron (55, 56). These dogs did more poorly than the controls on such simple tasks as circumventing a wire barrier or executing a "roll-over" test. Stereotypy was one factor contributing to the poorer scores made on a version of the Hebb-Williams test. The restricted dogs also did poorly on tests of delayed reaction and orientation. These intellectual deficits were enduring, appearing in dogs three years out of restriction. Most significant is the fact that Thompson and Heron found that the degree of intellectual retardation can be as great for dogs raised under slightly restricted conditions as for those reared in complete isolation. This may indicate that early perceptual experience is of greater importance to animals higher in the phylogenetic scale.

Chimpanzees have also been used to study the effects of early restricted experience (48). Animals deprived of light for the first twenty months of life and then subjected to a normal environment proved to be almost blind except for a few characteristic eye reflex movements. Moreover, these animals were very slow in learning to recognize objects that had been presented many times. These results have been supported by reports on congenitally blind humans given vision in adulthood (19) and comparisons of early with late-blinded individuals (12). Nissen, Chow and Semmes (43) restricted tactual and motor stimulation in a chimpanzee by placing cardboard cylinders around his legs and arms in early life. The effects of such restriction were evident in tactual-discriminatory and tactual-motor behaviour. Of interest is the fact that the chimpanzee when freed solicited stimulation even to the extreme of pencil-point jabs to which it responded with "pleasure panting." Similar findings have also been reported in the dog studies referred to above (38, 39, 40, 58).

It seems apparent from the studies mentioned above that early experience plays an important role in determining later intellectual ability. Restricted as well as enriched experience during early life can result in lasting effects in various psychological traits. In all of these experiments, however, only animals of normal learning ability have been used. No attention has been paid to the possibility that early environment may have differential effects on animals of superior or inferior endowment. The present project was undertaken to investigate this possibility. The specific hypothesis that was tested is that an early enriched and early restricted environment will have differential effects on the problem-solving abilities of strains of bright and dull rats.

CHAPTER II

EXPERIMENTAL METHOD

The Problem

The discussion of Chapter I revealed that an early enriched environment may improve the learning ability of rats while an early restricted environment may impair it. Previous investigators, it was pointed out, used normal animals as subjects in contrast to the animals employed in the present experiment. The present project was designed to test for the possibility of differential effects of an early enriched and early restricted environment on animals that vary in their inherited learning capacity. This will be done by using strains of rats that were selectively bred for brightness and dullness. The possibility of differential effects of the environments will then be measured by the performance of the animals on the Hebb-Williams test of maze learning.

The Subjects

The animals used as subjects in this experiment were bright and dull rats from strains of animals developed in a selective breeding project by C. F. Wrigley at McGill University. This work has since been continued by W. R. Thompson of Queen's University and by the Department of Psychology, University of Manitoba.

The procedure which was employed to obtain these two strains of animals was as follows. Large numbers of hooded rats of the normal laboratory strain were tested on the maze and a record was kept of the error score of each animal. These scores indicated that the animals were not of uniform ability. Some rats made a great many errors on the maze while others made very few. The experimenters picked out the brightest and dullest rats in the group and began a program of selective breeding. The rats of poorest ability were mated with each other, using brother-sister pairs whenever possible, and the rats of superior ability were similarly intermated. When the offspring of these animals were mature, they too were tested on the Hebb-Williams maze. Again, the brightest and dullest animals were selectively intermated and their offspring were later tested on the maze. By the end of the sixth generation there were two groups that differed markedly in learning ability, (52). Further studies have shown that the strains do not differ significantly in weight, emotionality and motivation (51, 54, 57). The indications are that the animals differ only in learning ability as measured, unconfounded by other factors.

Forty-three animals were used in the present experiment. They were direct descendants of Thompson's F_7 dull and bright groups and represent the thirteenth generation of these strains. At 25 days of age the young bright and dull rats were separated from their mothers and placed in the experimental environments. On a split-litter basis, twelve bright rats were placed in an enriched environment while thirteen were placed in a restricted environment. They were kept in these environments for a period of 40 days, or until they were 65 days of age. They were then tested on the maze. Thus, there were four groups of rats, a bright-enriched group, a bright-restricted group, a dull-enriched group and a dull-restricted group.

Experimental Environments

The four groups of animals were placed in four cages that occupied a grey painted room 12' x 6' x 8'. At one end of the room a window allowed only homogeneous light to pass through. A large rectangular cardboard partition, suspended from the ceiling, divided the room lengthways. Two restricted cages were placed on one side of the partition while the enriched cages were placed on the other side. The side of the partition facing the restricted cages was grey, matching the colour of the room. The side of the partition facing the enriched cages was white with "modernistic" designs painted upon it in black and luminous paint. The partition was so placed that animals in the restricted environments were unable to see the enriched cages (see Figure 1).

The four cages, each measuring 40" x 25" x 13", were

Figure 1. Photograph of partition separating enriched and restricted cages.

covered with one-half inch wire mesh. Two of these cages, containing the enhanced environments, were filled with such objects as the following: ramps, mirrors, swings, polished balls, marbles, barriers, slides, tunnels, bells, "teeter-totters," and springboards, in addition to food boxes and water pans. Some of the objects were painted white and black, while all were so constructed that they could easily be shifted to new positions in the cage (see Figure 2). The restricted environments were identical to the enriched cages in size and mesh coverings but contained only a food box and a water pan (see Figure 3).

Test Apparatus

The selection of bright and dull rats in the selective breeding project was made on the basis of their scores on the Hebb-Williams maze. This maze, also known as a "closed-field test of intelligence," was suggested by D. O. Hebb and K. Williams in 1946 (21). Their aim was to devise a measure of animal intelligence similar to measures of human intelligence, being based not on a single measure but on a number of problems of varying complexity. They argued that the ordinary fixed maze patterns commonly used in animal experimentation could be a measure of timidity, of need for food, or a complex of these with intellectual factors but not necessarily a measure of learning ability.

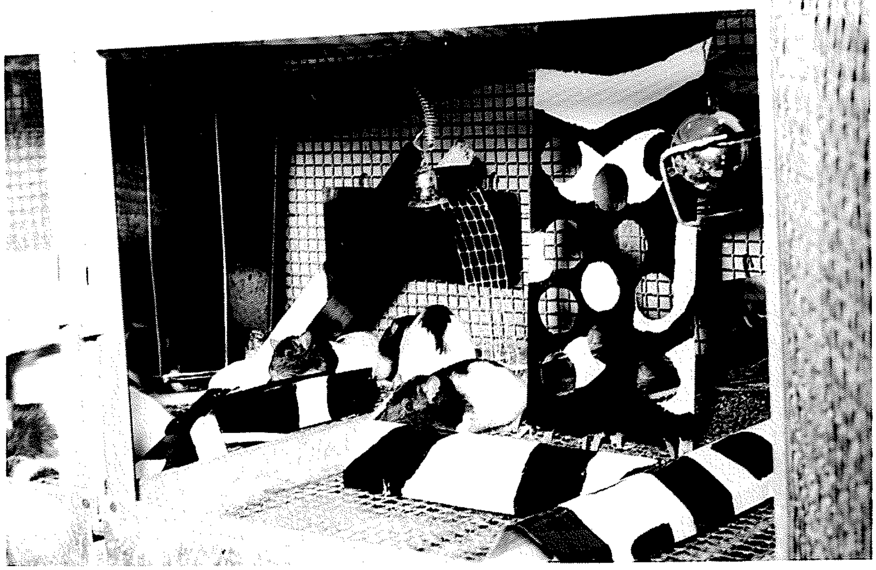

Figure 2. Photograph of enriched cage.

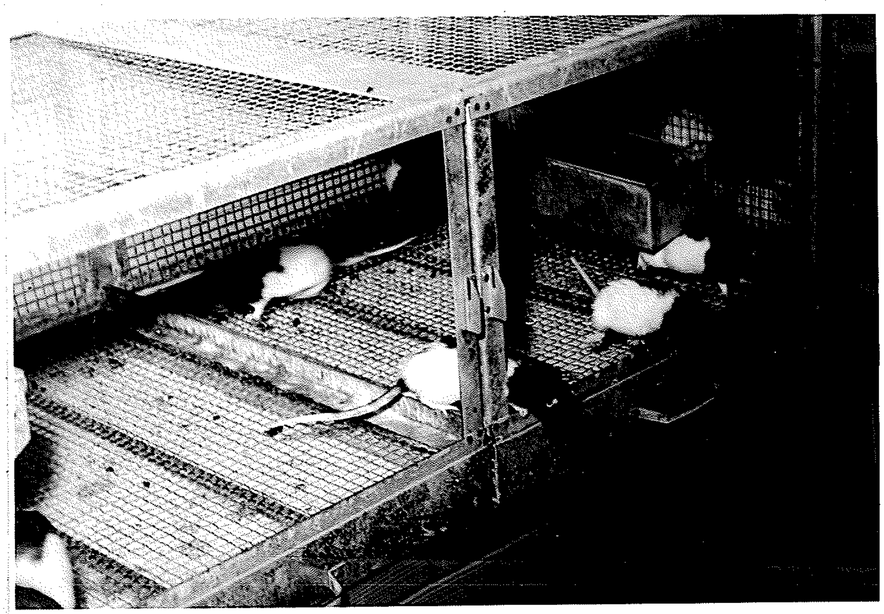

Figure 3. Photograph of restricted cage.

The maze, designed by Hebb and Williams and standardized by Rabinovitch and Rosvold (45), differs from all other mazes in that the animal has to solve a number of problems rather than just a single problem, which is the usual procedure. It is similar to the Porteus maze used in the appraisal of human intelligence (1, 63).

The present form of the maze consists of a box four inches high and thirty inches square, having an entrance box at one corner and a food compartment in the corner diagonally opposite. Fourteen separate barriers of lengths varying from five to twenty-five inches make it possible to set up any one of the six practice problems or twelve test problems used with the maze (see Figure 4). The walls and barriers of the maze are made from ½" x 4" dressed lumber, painted black to contrast with the white floor. Thirty-six five-inch squares are outlined in black on the floor of the maze to facilitate the placing of barriers and to define error zones during the test situation (see Figure 5).

Experimental Procedure

The four groups of animals were kept in the experimental environments from the time of weaning at 25 days of age until the age of 65 days when testing on the Hebb-Williams maze was begun. They were also kept here during the entire period of testing. Since one of the restricted cages stood closer to the window, the animals were shifted every three

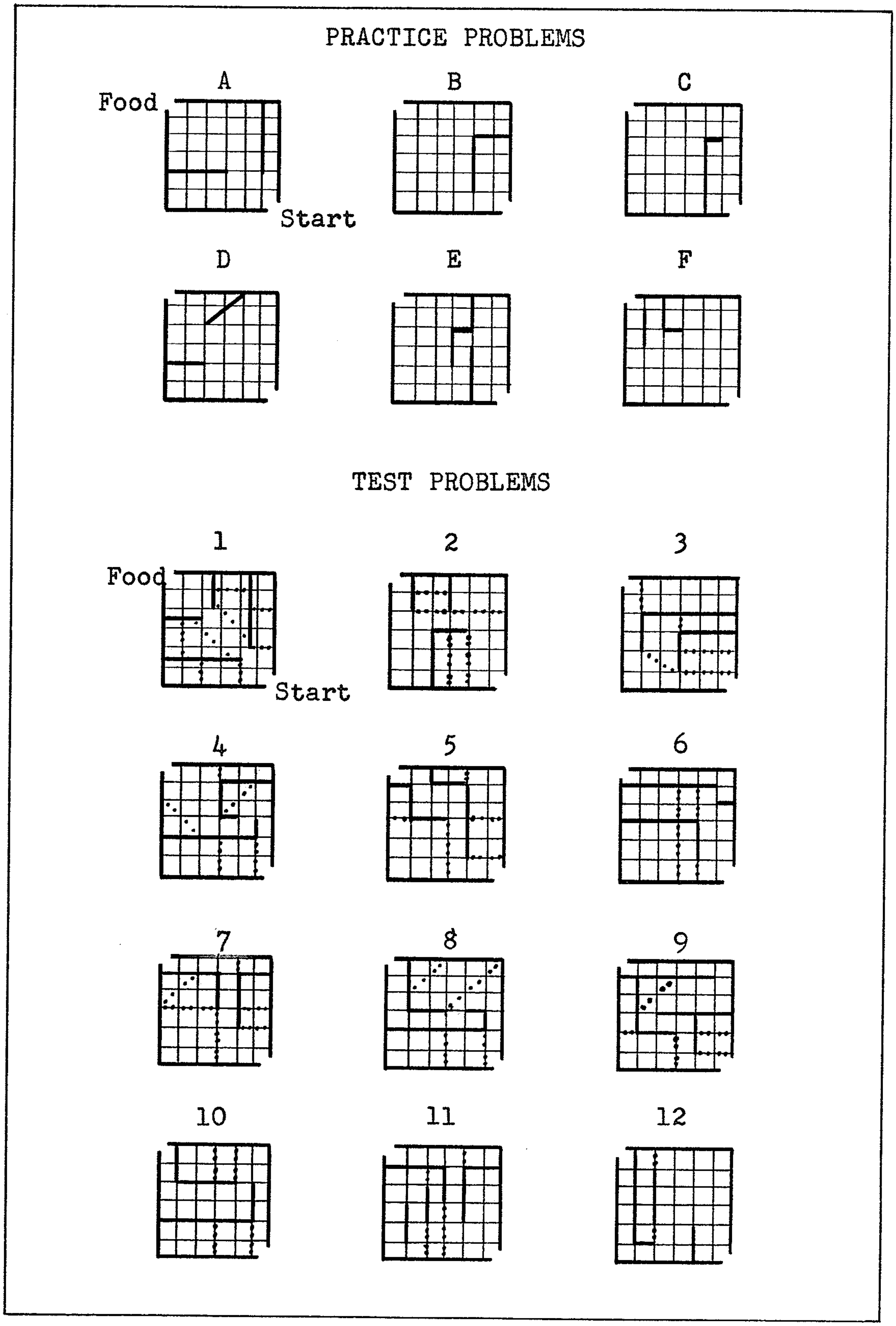

Figure 4. Floor Plan of Training and Test Problems.

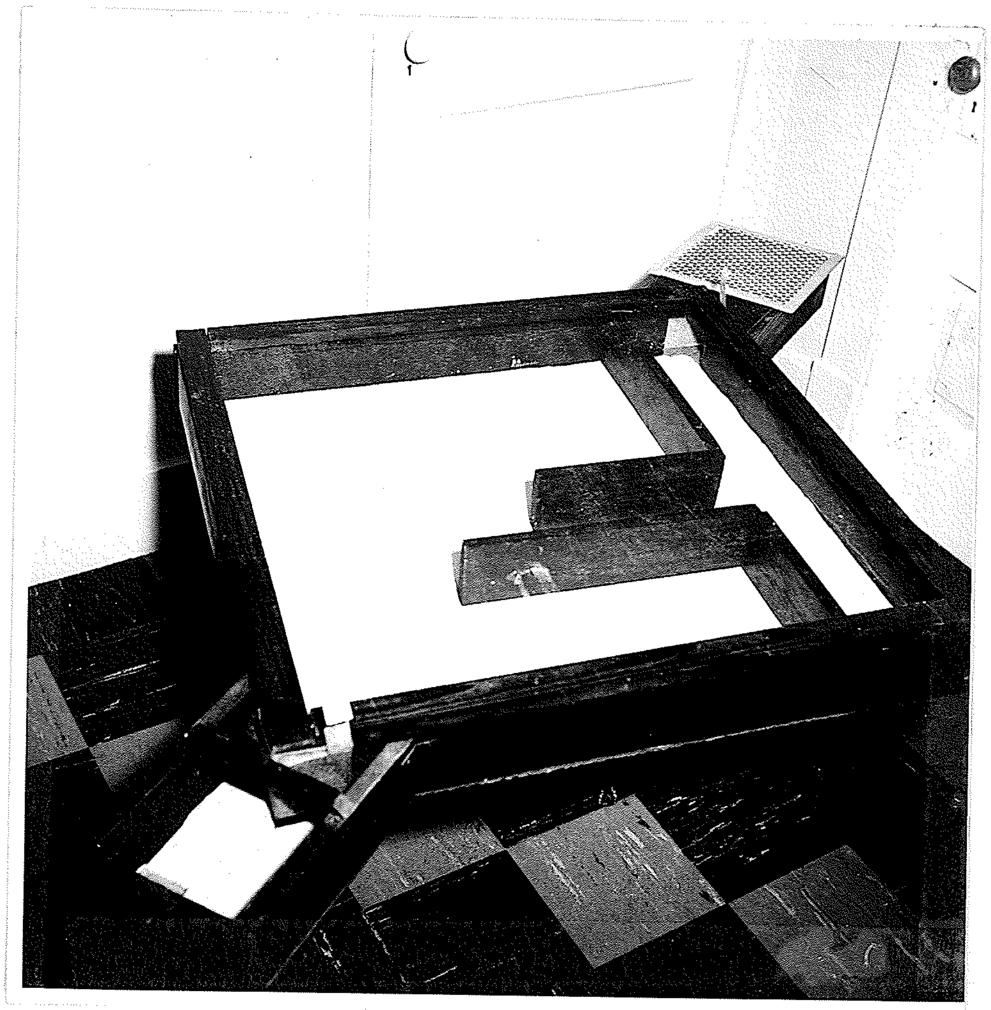

Figure 5. Photograph of Hebb-Williams maze.

or four days from one cage to the other. This was also done for the enriched animals. In addition, the objects in each of the enriched cages were moved about at random every three or four days. During these moving periods and while the cages were being cleaned, all animals received the same amount of handling.

Maze adaptation sessions. After eight hours of food deprivation the rats were placed six or seven at a time in the entranced box of the maze and allowed to find their way around the barriers of the first adaptation problem (Figure 4, Problem A) to the food compartment. Two adaptation sessions of 45 minutes each were given daily, with practice problem A set up in the first period, problem B in the second, and so on, until the animals appeared well-adapted to the apparatus.

Preliminary trials. Completion of the adaptation sessions was followed by series of timed runs on the six practice problems. The rat was placed in the entrance box and time was recorded from the moment it passed through the entrance box until it reached the food in the food compartment. The animal was then allowed to take one or two bites of food, after which it was replaced in the entrance box and again allowed to go to the food, being timed as previously. This was repeated nine times on each practice problem, twice a day, until all the animals were able to make nine runs on the problems in sixty seconds on two consecutive occasions. Rats slow to reach the criterion were given less food, more handling and more trials each day, while those reaching the criterion early were given fewer trials in each session. It has been found that the extra runs do not influence subsequent scores and that the precocious animals are not more likely to do better than the others on the subsequent test problems (45). This preliminary training is used to reduce emotional and motivational differences between the animals.

Test problems. Upon completion of the preliminary training, the 12 test problems shown in Figure 4 were then administered two per day for six days. In the test sessions an animal was given eight runs on the first problem and was then permitted to eat moist mash for twenty minutes before being returned to its home cage. After a delay of about eight hours, the same procedure was repeated for problem two. This was continued in morning and evening sessions until the twelve test problems had been completed. Error scores for each trial were recorded for every animal.

Scoring procedure. An error was recorded each time the rat's two forefeet crossed one of the error zones indicated by the broken lines in Figure 5. Where a blind alley contained two error zones (two broken lines), two errors were scored if the animal crossed the second error line. If an animal emerged from an error zone with both forefeet, but then turned and went back, a further error was scored. The total number of error zones entered by an animal in the twelve test problems was that animal's score on the test.

CHAPTER III

EXPERIMENTAL FINDINGS AND DISCUSSION OF RESULTS

I. RESULTS

Individual error scores for each animal are given in Tables 1, 2, 3 and 4 of the appendix.

For purposes of statistical analysis and interpretation of the data the performance of the restricted and enhanced animals will be compared with that of bright and dull animals that were raised in a normal laboratory environment. These comparative scores were made by animals that formed two control groups in an experiment by Hughes and Zubek (26).

Effect of the Enriched Environment

In Table I are recorded the mean error scores for

TABLE I

MEAN ERROR SCORES FOR BRIGHT-ENRICHED, DULL-ENRICHED AND BRIGHT AND DULL ANIMALS RAISED IN A NORMAL ENVIRONMENT

	Enhanced Environment	Normal Environment
Bright	111.2	117.0
Dull	119.7	164.0

the bright-enriched group, the dull-enriched group and the scores made by bright and dull animals raised in a normal environment. A study of the figures contained in this table reveals that the average number of errors made by the bright animals in the enriched environment is only slightly below that of the bright animals raised under normal conditions (111.2 vs 117.0). This differences is not statistically significant ($t = 0.715$, $p > .4$). On the other hand, the error scores of the dull animals raised in an enhanced environment are considerably below those of animals reared in a normal environment (119.7 vs 164.0). This difference of 44.3 errors is statistically significant ($t = 2.52$, $p > .02 < .05$). These results indicate, therefore, that an early enriched environment can improve considerably the learning ability of dull animals while having little or no effect on that of bright animals.

Effect of the Restricted Environment

Table II summarizes the mean error scores for the bright-restricted group, the dull-restricted group and the scores of the normally raised bright and dull animals. It is seen that the bright-restricted group made many more errors than the normally raised bright animals. The difference of 52.7 errors is statistically significant ($t = 4.06$, $p < .001$). On the other hand, there is no significant difference between the normally raised dull animals and the restricted dull animals ($t = 0.280$, $p > .7$). Thus the dull animals did not suffer from their early restricted experience while the bright animals were significantly retarded in learning ability.

TABLE II

MEAN ERROR SCORES FOR BRIGHT-RESTRICTED, DULL-RESTRICTED, AND BRIGHT AND DULL ANIMALS RAISED IN A NORMAL ENVIRONMENT

	Restricted Environment	Normal Environment
Bright	169.7	117.0
Dull	169.5	164.0

<u>Extent of the Effects of Enriched and Restricted Environments</u>

A study of Table III below shows the extent to which the bright animals were retarded as a result of their period of impoverished experience and the extent to which the dull animals were improved by their period of enriched experience. Although the bright-enriched animals averaged 8.5 errors less than did the dull-enriched group, this difference is not significant ($t = .819$, $p > .5$). Thus, dull animals become equal in learning ability to bright animals after undergoing a period of early enriched experience. The difference between the bright and dull-restricted groups is also not significant ($t = .008$, $p > .9$), a finding which indicates that bright animals after undergoing a period of early impoverished experience become as retarded in learning ability as dull rats.

TABLE III

MEAN ERROR SCORES FOR BRIGHT-ENRICHED, BRIGHT-RESTRICTED, DULL-ENRICHED AND DULL RESTRICTED ANIMALS

	Enriched Environment	Restricted Environment
Bright	111.2	169.7
Dull	119.7	169.5

Summary of the Results

Figure 6 below summarizes graphically the results of the present experiment. From the figure it can be seen that there is very little difference in learning scores between bright and dull animals that have been raised in restricted or enriched environments. This is in contrast to the clear difference in performances of those animals when raised in a normal environment. The curve of the dull rats illustrates that these animals benefited from the enriched environment to the extent of becoming equal to the brights in learning ability.

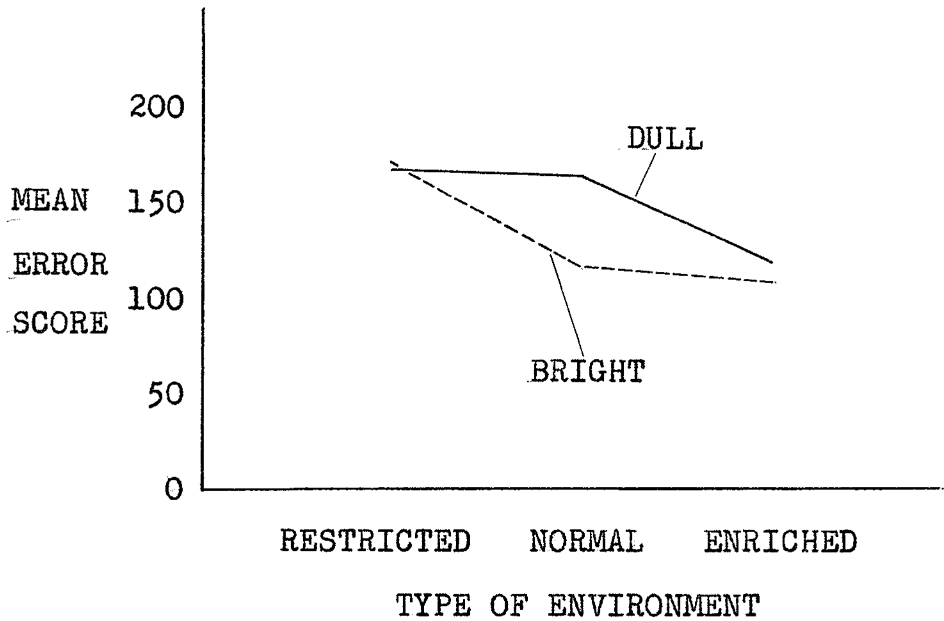

Figure 6. Mean error scores of bright and dull animals in restricted, normal and enriched environments.

II. DISCUSSION

In the preceding section it was shown that a period of early enriched experience produces little or no improvement in the learning ability of bright animals. This is in contrast to dull animals which benefit greatly from such experience. The extent of the improvement is such that the dull animals become equal to the bright animals in learning ability. On the other hand, dull animals raised in a restricted environment suffer no deleterious effects while bright animals are retarded to the level of the dulls in learning ability.

Past studies on the effects of early experience on later learning behaviour have used animal subjects of normal learning ability while the present experiment has utilized animals that vary in their inherited capacity for learning. While it was felt that the two extremes of environment would have differential effects on the bright and dull animals, it was expected that the bright-enriched animals would show a superior performance over the dull-enriched animals. Theoretically it might be expected that the bright animals, with their presumably better cerebral functioning, would better utilize the extra experience afforded by an enriched environment, while the dull animals with their presumably inferior cerebral functioning would not be as effective in utilizing the added stimulation. Although the bright-enriched group did somewhat better (8.5 less errors), the difference is not statistically significant. This different, although not significant, does suggest that there may be a real difference in learning ability between the groups but the twelve problems of the Hebb-Williams test were inadequate in revealing it. It is possible that the ceiling of the test was too low to differentiate the animals; that is, the problems may not have been sufficiently difficult to "tax" the ability of the bright rats. This has happened on tests of human intelligence like the Stanford-Binet (1). Adults of varying ability achieve almost similar IQ scores on this test but clear differences emerge on tests of greater difficulty. It might also be mentioned that it is relatively more difficult for the bright animals to show an improvement in learning as compared with the dull animals. For example, it would seem more difficult for the bright rats to improve their error scores from 120 to 100 than it would be for the dull animals to improve their scores from 160 to 140.

While these criticisms tend to weaken the present results with respect to the performance of the bright-enriched animals, it seems reasonable that they should be accepted until future experimentation should prove otherwise.

So far, the discussion has been concerned with the somewhat puzzling effects of an enhanced environment. The effects of a restricted environment are not so difficult to accept. In this environment the bright animals, even with their superior learning capacity, would be expected to show an inferior performance. This is because learning is both a function of experience as well as one of capacity. Consequently, under conditions that limit experience extensively, the superior learning capacity of the bright animals is never fully utilized and the animals perform far below their usual level of ability. On the other hand, much of a decrement would not be expected in the dulls since they are already functioning at a low level of intellectual capacity.

What is the physiological mechanism or mechanisms underlying these changes in learning ability? Several investigators have propounded theories to explain the relationship between the nature of sensory stimulation and learning behaviour. Perhaps the most systematic of these theories is that of Hebb (19). Hebb has suggested that neural patterns or "cell assemblies," which he considers to be the physiological basis of learned behaviour, are built up over a period of time through varied stimulation coming through specific sensory pathways. This stimulation is especially effective if it occurs during infancy. Others (28, 53), also believe varied stimulation coming through non-specific projection pathways (e.g., thalamic-reticular system) aids in the learning process by keeping the brain in an alert state. In a recent revision of Hebb's theory, Milner (41) has pointed out that newly discovered neurophysiological information indicates that non-specific stimulation would likely play a part in the building of Hebb's cell assemblies. Thus at the neurophysiological level varied stimulation seems to play a dual role in the learning process. It may act directly on cerebral cells to form cell assemblies or may aid learning by keeping the brain "primed," or in an alert state.

From the foregoing it would appear that varied stimulation has an important role in establishing the physiological components (e.g., cell assemblies) underlying learned behaviour. From this the following assumption would seem to be tenable; viz. that a certain level of varied stimulation is necessary if learning (that is, establishment of cell assemblies) is to occur with maximum efficiency. Moreover it could also be assumed that the initial difference in learning ability between the bright and dull rats in some way reflects an underlying neurophysiological difference in their capacity to "utilize" stimulation. On the basis of these contentions, the following theory is an attempt to explain how the different levels of stimulation found in the restricted, normal and enriched environments acted upon the superior brains of the bright rats and the inferior brains of the dull rats to produce the results of the present experiment.

In a normal environment the level of stimulation is adequate enough to permit the building up of cell assemblies (or some other neurophysiological unit underlying learned behaviour) in the superior brains of the bright animals. It is not great enough, however, to permit them to be built up easily in the inferior brains of the dull animals. In a restricted environment the level of stimulation is so low that it is inadequate for the building up of cell assemblies even for the superior cerebral apparatus of the bright rats, with a consequent retardation in learning ability. On the other hand, the dulls are not retarded further since the level of stimulation provided by the normal environment was already below the threshold for the establishment of cell assemblies. In the enriched environment the level of stimulation is great enough to reach the higher threshold of the dull animals and consequently there is an improvement in learning ability. The brights show little or no improvement since the extra stimulation is largely superfluous, the stimulation provided by a normal environment being adequate for the building up of cell assemblies.

Such a theory is open to several criticisms. For instance, the assumption that the bright and dull rats differ somehow in their inherited capacity to utilize stimulation is open to some question. Futhermore, as pointed out above, certain inadequacies of the Hebb-Williams test make the performance of the bright-enriched rats doubtful. While it is realized that such a theoretical interpretation rests upon an inadequate foundation, it does seem to best fit the experimental data in the light of present neurophysiological knowledge.

CHAPTER IV

SUMMARY AND CONCLUSIONS

I. SUMMARY OF THE STUDY

Numerous experiments have been carried out to study the effects of early enriched and early impoverished environments on later intellectual functioning. At the human level, the results of such research have been indecisive because of the contradictory conclusions reached by different investigators and because of weaknesses in experimental design. On the other hand, animal experimentation has clearly proven that early experience affects later mental functioning. Several experiments have shown that an early enhanced environment improves the learning ability of rats while an early impoverished environment retards it.

The subjects used in previous investigations have been animals that possess only a normal degree of learning ability. The present experiment was designed to test for the possibility of differential effects of early enhanced and restricted environments on animals of superior and inferior learning endowment. The subjects in this experiment were bright and dull rats, selectively bred on the basis of their ability to learn the test problems of the Hebb-

Williams maze.

Forty-three rats served as subjects for the study. Twelve bright rats and nine dull rats were placed in two enriched environments while thirteen bright rats and nine dull rats were placed in two restricted environments. Thus there were four groups of animals, a bright-enriched group, a bright-restricted group, a dull-enriched group and a dull-restricted group.

The enriched environments consisted of two large cages filled with play objects such as tunnels and swings, designed to provide a maximum of stimulation. The restricted environments consisted of cages identical in size to the enriched cages but containing no play materials. All the cages were housed in a small room that had minimal stimulating properties. The enriched cages were separated from the restricted cages by a partition.

The animals were weaned and placed in these environments at 25 days of age. At 65 days of age the animals were introduced to the training and testing regimen of the Hebb-Williams maze.

To facilitate the interpretation of results, the scores of the animals used in the present experiment were compared with the performances of bright and dull animals raised in a normal laboratory environment. It was found that the bright animals showed no improvement in learning ability after a period of early enriched experience. This is in contrast to dull animals who benefit greatly from such experience. The extent of this improvement is such that the dull animals become equal to the bright animals in learning ability. On the other hand, dull animals raised in a restricted environment suffer no deleterious effects while bright animals are retarded to the level of the dulls in learning ability.

II. CONCLUSIONS

Within the limitations set by the design of the present experiment the following conclusions seem warranted: Early enhanced and early restricted environments have differential effects on the later learning ability of bright and dull rats. A period of early enriched experience will improve the learning ability of dull rats but not of bright rats. The extent of the improvement is such that the dull rats become equal in learning ability to the bright rats. On the other hand, a period of early restricted experience will retard the learning ability of bright rats but not of dull rats. The extent of this retardation is such that the bright rats become equal to the dull rats in learning ability.

A P P E N D I X

TABLE 1

ERROR SCORES OF BRIGHT ENHANCED ANIMALS

Rat No.	Error Score
20	112
23	89
25	116
26	124
27	130
29	124
33	103
35	102
36	112
38	119
47	103
50	101
Sum	1335
Mean	111.2

TABLE 2

ERROR SCORES OF DULL ENHANCED ANIMALS

Rat No.	Error Score
0	122
4	130
6	123
7	91
9	122
11	78
12	110
14	155
16	146
Sum	1077
Mean	119.7

TABLE 3

ERROR SCORES OF BRIGHT RESTRICTED ANIMALS

Rat No.	Error Score
21	189
22	138
24	141
28	281
30	172
31	128
32	149
34	160
39	161
40	189
41	169
42	181
51	148
Sum	2206
Mean	169.7

TABLE 4

ERROR SCORES OF DULL RESTRICTED ANIMALS

Rat No.	Error Score
1	144
2	165
3	151
5	162
8	114
10	177
13	158
15	230
17	225
Sum	1526
Mean	169.5

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