STANDARDIZATION OF A CLOSED FIELD INTELLIGENCE TEST FOR RATS.

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PREFACE

The writer is indebted to Dr. H.E. Rosvold for invaluable counsel in the planning and carrying out of this experimental project.

For the cooperation of Messrs. Rishikof and Lansdell in providing the writer with necessary data, thanks are gratefully offered.

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INTRODUCTION AND STATEMENT OF PROBLEM

Some fifty years ago, Thorndike, (11), Small, (10), Kline, (5), and others, began systematically to study psychological aspects of animal behaviour. These early investigators used various kinds of mazes and problem boxes to describe the variables under examination.

Since these pioneer attempts, new mazes and problem boxes have been designed, and a great deal of the research carried on in the field of comparative psychology has involved mazes of one type or another. A different type of maze, designed by Hebb and Williams, (3), to evaluate rat intelligence, has provided the most recent improvement in animal testing apparatus.

This thesis reports the development of an improvement of the Hebb and Williams intelligence test, and presents measures of reliability and validity for the use of this procedure and apparatus.

The traditional procedure in the evaluation of rat intelligence is to test the animal's learning ability in a maze and infer from this behaviour the animal's level of intelligence. While the mazes and problem boxes used in this procedure vary greatly in design, they all have certain characteristic disadvantages. These inadequacies can be grouped under the following general headings.

Time consumed in using the apparatus

Traditional mazes and problem boxes are so designed that it is usually a matter of days before the subject is tested in a single problem situation. This very often forces experimenters to draw conclusions from observations of limited samples of behaviour. To increase the reliability of this type of maze by using ten or twelve such problem situations would generally involve a prohibitive number of man hours.

Space requirements of the apparatus

Alley mazes, elevated mazes, Carr square mazes, Hampdon Court mazes, require from 150 to 250 square feet of floor space. This space requirement often causes inconvenience in the laboratory resulting in the possibility of compromised experimental conditions.

Efficiency of recording behaviour in the test situation

From a fixed point in the experimental room it should be conveniently possible to thoroughly observe an animal's behaviour. This is important if the results are to be reliable. In using alley and elevated mazes of even moderate complexity, it is often very difficult to see accurately an animal's movements.

Automatic recording devices, such as used by Lashley and Skinner, can overcome this possible source of experimental error, but the expense involved in constructing tests with self scoring devices is often prohibitive.

Facility of problem variation

More reliable results in maze studies could be obtained if the animals were tested with longer series of test items over shorter periods of time. This would require apparatus so designed that the necessary problem variations could be made with a minimum expenditure of time, space, and effort.

The Lashley (7) mazes 1, 2, 3, 4, and the Watson (12) circular maze are less space consuming than other mazes, and are designed to make behaviour records very reliable; but they are of fixed design and structure, and therefore do not lend themselves to problem variations.

In 1930, Dashiell (2) reported some work on orientation and variability in rat behaviour. The apparatus described in this report was of a closed field design and indicated the possibility of such an apparatus as an improvement over contemporary maze designs.

In 1946, Hebb and Williams (3) described a method of rating intelligence in the rat, using a closed field apparatus similar to that described by Dashiell (2). The apparatus and procedure described by them significantly reduced the time, space, and difficulty of recording, as well as allowing for test item variation.

This closed field method of measuring intelligence in the rat has been put to experimental test in the psychology laboratory at McGill University. Twenty-four problems arranged in two equivalent sub-series of twelve each were used. Two problems were presented each day. The items in these series were of the same general type described by Hebb and Williams (3) in their report (p.61, fig. I-A to I-L).

The results of these studies indicated that the sub-test series of twelve items each did not yield satisfactory reliability indices. However, if the two sub-series were combined to form one twenty-four item test, the results were more reliable.

Since rating intelligence in experimental situations requires a test-retest design, a total of forty-eight test items would have to be employed, requiring twenty-four days of actual testing. In terms of time and effort, using the closed field test in this way is no improvement over traditional mazes.

It was felt that a twelve item test series could be developed which would yield a test-retest reliability as high or higher than that obtained with the twenty-four item series. To standardize such a series was the object of the experimental project which is the subject of this thesis.

PRELIMINARY STUDIES

The studies described below were carried out in order to make possible the standardization of a twelve-item closed field test of rat intelligence. Three successive tasks were undertaken.

A. All available data on performance of rats in the test were analyzed for the discriminatory capacity of the test items, and to determine the reliability of the original Hebb and Williams test.

B. Exploratory studies were designed which would determine the difficulty value of each item, demonstrate the effect of serial position, test some new items which differed qualitatively from any already in the test, and explore the possibility of an alternate form of the test.

C. The final task was to integrate the information gained from the analysis in A, and the experiments carried out in B, and on the basis of that integration to construct a new series of twelve problems that would yield reliable results.

A. ANALYSIS FOR DISCRIMINATION AND RELIABILITY.

(a) Sources of Data.

(i) castration study:

Twenty-one male and twenty female hooded rats, born and reared in the comparative psychology laboratory at McGill University, were used in this study. The animals were divided equally into control and experimental groups by a split litter method. At about seven days of age the experimental animals were castrated. When the animals were approximately one hundred days old the control and experimental groups were tested in the Hebb and Williams apparatus, using a series of twenty-four closed field problems arranged in two equivalent series of twelve each. The series were run concurrently, two problems being presented each day, eight hours apart.

(ii) extirpation study:

This was a study carried out by H.C. Lansdell (6) in which three types of brain extirpations were made on a group of fifty-two male hooded rats. At maturity, the rats were tested using the same procedure and apparatus as in the castration study described above.

(iii) electroconvulsive shock study:

This was a group of experiments carried out by J.R. Rishikoff (9). The subjects were one hundred and sixteen hooded rats of both sexes, approximately half of which were normal and half of which were electroshocked at various stages of development. They were all tested at maturity using a procedure and apparatus similar to those in the above two studies.

(b) Results.

The results shown in Table 1 indicate that when the two sub-series of twelve items each are combined as a single test series, the average test-retest reliability is .75. However, using the sub-series separately only yields an average test-retest reliability of .63. These measures are so low as to demand a modification of the test so as to increase the reliability.

TABLE 1

Reliabilities Obtained with Closed Field Test

Rho	N	Group	Method of Calculation
.79	52	48 op., 4 norm.	two 12 item tests
.88			combined as 24 item test
.56	20	10 cast., 10 norm.	two 12 item tests
.72			combined as 24 item test
.65	21	11 cast., 10 norm.	two 12 item tests
.79			combined as 24 item test
.60	37	23 shock., 14 norm.	two 12 item tests
.75			combined as 24 item test
.57	29	15 shock., 14 norm.	two 12 item tests
.73			combined as 24 item test
.64	13	shocked	test-retest, 24 items given twice
.71	14	normals	test-retest, 24 items given twice

(c) Analysis.

The raw data gathered in the above studies were transformed into answer patterns. A simple pass-fail scale was used, the dichotomy criterion being the median score obtained by the particular group on each item. Table 2 is an illustration of the type of answer pattern which was constructed.

TABLE 2

Sample Answer Pattern
(#signifies a pass, - signifies fail)

Test Item No.

Rat No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
38	-	#	-	#	#	#	#	-	-	#	#	-	#	#	#	#	-	#	#	#	#	#	#	-
33	#	#	-	#	#	#	#	#	-	#	#	-	#	#	#	#	-	#	#	-	#	#	#	#
37	#	#	#	-	#	#	#	-	#	#	-	#	#	-	#	-	#	#	-	#	#	-	-	-
28	-	#	#	-	#	#	#	#	#	#	#	#	-	-	-	##	#	-	#	#	-	#	#	#
19	#	-	-	#	-	-	-	#	-	-	#	#	#	#	#	#	#	#	#	#	-	#	-	#
1	#	#	#	#	#	#	-	-	#	#	#	#	-	-	-	#	#	-	-	-	-	-	#	#
27	#	-	#	-	#	#	#	#	-	-	-	#	#	-	#	#	-	-	#	-	#	-	#	-
26	#	#	#	-	#	#	-	#	#	-	#	-	-	-	-	#	-	-	#	#	-	-	#	#
36	-	#	-	-	#	-	-	#	#	#	-	-	#	#	#	-	#	-	#	#	#	#	#	-
24	-	#	#	-	#	#	#	-	-	-	#	-	-	-	-	#	-	-	#	-	-	#	#	-
5	#	#	-	#	#	#	#	-	-	-	#	-	#	#	-	#	-	#	#	#	-	-	-	-
35	-	-	#	#	#	-	-	-	#	-	-	-	#	-	-	#	-	-	#	-	#	-	#	-
8	-	-	#	-	-	#	#	#	-	#	-	#	#	-	#	-	-	-	-	#	-	-	#	#
25	-	-	#	-	#	#	-	#	-	-	-	-	-	-	-	#	-	-	-	-	-	-	#	#
7	-	-	-	#	-	#	#	-	#	-	-	#	-	-	-	#	-	-	-	-	-	#	-	#
6	#	-	#	-	-	-	-	#	-	-	-	-	-	-	-	-	-	-	#	#	-	#	#	#
3	-	#	-	-	-	-	-	-	-	-	-	-	#	-	#	-	-	#	#	-	-	-	#	-
4	-	-	-	#	-	#	-	-	-	-	-	#	-	-	#	-	-	-	-	-	-	#	#	-
29	-	#	-	#	-	-	-	-	-	-	-	-	#	-	#	-	-	-	-	-	-	-	#	#
34	-	-	#	-	-	-	-	-	-	-	-	-	-	-	#	#	-	-	-	-	-	-	#	-
2	-	-	#	-	-	-	-	-	-	#	-	-	-	-	-	-	-	-	-	-	-	-	#	-

Indices of Discrimination

Item No.	Index	Item No.	Index	Item No.	Index
1	.79	9	.64	17	.72
2	.72	10	.79	18	.72
3	.57	11	.93	19	.72
4	.57	12	.72	20	.72
5	.93	13	.72	21	.79
6	.79	14	.72	22	.57
7	.79	15	.57	23	.43
8	.72	16	.79	24	.64

Each completed answer pattern was divided into upper and lower thirds. An index of discrimination with a maximum value of one and a minimum value of zero was calculated using the following formula:-

$$\frac{X + Y}{A}$$

X is the number of passes in the upper third,
Y is the number of failures in the lower third,
A is the number of cases in the upper and lower thirds.

These indices were calculated for all the data described above and yielded an estimate of the discriminatory capacity of each item under several well-defined experimental conditions. Table 2 illustrates the indices which were calculated from the sample answer pattern.

B. EXPLORATORY STUDIES.

(a) Item Difficulty Study.

Thirty male hooded rats obtained from a local breeder were randomly divided into six equal groups. The twenty-four test items were then arranged in six random orders such that in no two orders did the same tests follow each other. Each group of animals was then tested on one of the random orders. The apparatus and procedure utilized was similar to that used in the discrimination studies.

The results of this exploration provided the following information:-

(i) An estimate of the difficulty of each item in various serial positions.

(ii) An indication that the unique structure of the immediately preceding item had no significant effect on an animal's performance in the next problem situation.

(iii) An indication that the most important single determinant of item difficulty was the overall position of an item in relation to the entire twenty-four item series which was presented.

(b) New Item Study.

Twenty-one mature hooded male rats born and reared in the comparative psychology laboratory at McGill were trained and tested on a series of twenty-two closed field problems. The series included eight problems which differed qualitatively from any in the Hebb and Williams test. This new type of problem, designed with an island barrier, is illustrated in Fig. 5, numbers 11 and 12.

The data from this study were converted into an answer pattern using the method described above. Indices of discriminatory capacity were calculated. Thus, it was possible to re-evaluate fourteen of the older items for difficulty and discriminatory capacity and also to examine the eight new type items for the same properties.

(c) Alternate Form Study.

The principal use of this intelligence test is as an experimental tool in the psychology laboratory. Therefore, it was felt that the final test should be so constructed as to encourage test-retest experimental designs. To this end, the possibility of an alternate form of the test was investigated.

A group of twenty-one male hooded rats born and reared in the comparative psychology laboratory at McGill were divided into two groups of ten and eleven.

Group A was tested on eight closed field problems and then retested on the mirror image reversals of these problems.

Group B was tested first on the mirror image reversals and then on the original problems. Figure 1 gives an example of a mirror image reversal.

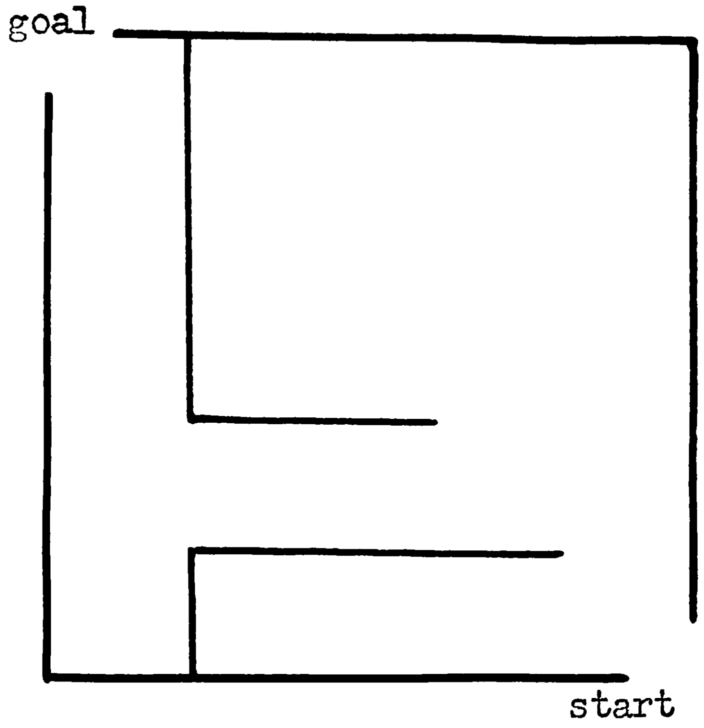
The test-retest reliability for the two groups were .85 for group A and .77 for group B.

These results indicated that the mirror image reversal technique would be satisfactory in the construction of an alternate form of the test.

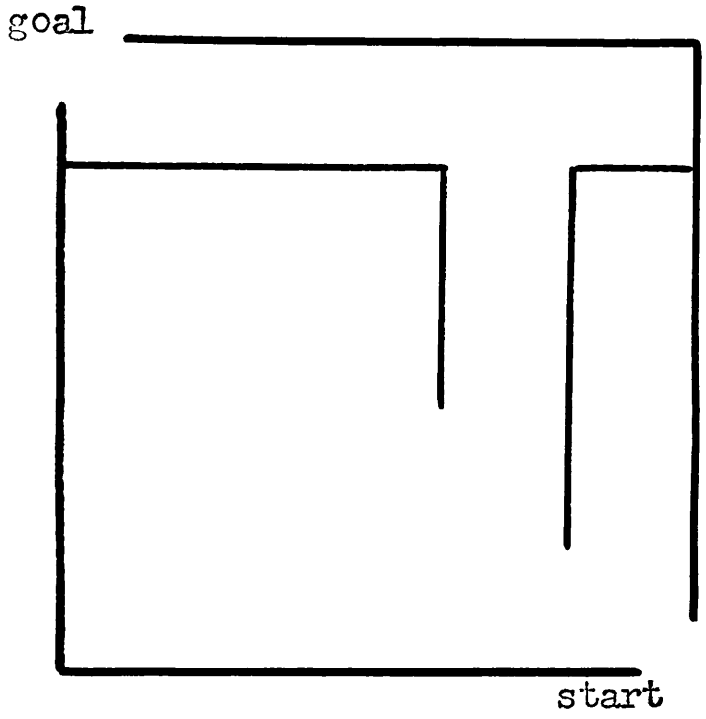
C. CONSTRUCTION OF THE NEW TEST SERIES.

The main objective of the studies reported in this paper was to devise a series of closed field problems with a high

FIGURE 1



ORIGINAL TYPE



MIRROR IMAGE REVERSAL

test-retest reliability, but short enough to be used conveniently. To this end, it was decided to construct a twelve problem test. The guiding principles in the selection of items to be used in the series were the following:-

1. The test should include a wide variety of problems, making it possible to sample a wide range of behaviour.
2. The series should have a wide range of difficulty, progressing from very easy to very difficult items. This would make the test effective in discriminating extremes of intelligence.
3. The problem solutions should not favour any one location of the closed field apparatus.
4. The items should have high discriminatory capacity and high test-retest reliability.

The studies discussed thus far yielded information which was integrated into one or more of the above test selection principles. Of the twenty-four original Hebb and Williams closed field problems, the ten which best conformed to the guiding criteria were selected. The study which investigated the island type problems yielded two other satisfactory items. This gave a twelve problem test. The mirror image reversals of these problems constituted the alternate form of the test series.

APPARATUS AND PROCEDURE

The Closed Field apparatus consists of an entrance alley, an open field, and a food box. Entrance alley and food box are at opposite corners of the field. Figures 2, 3, and 4 describe the details of the apparatus.

The floor is cut out of $\frac{1}{4}$" plywood and left unpainted. The walls of the box are painted black and made from stock $\frac{1}{2}$" x 4" dressed lumber.

There are thirty-six five inch squares outlined in black on the floor of the open field. These serve to define the error zones and also act as markers for placing the barriers.

The barriers used to set up the problems are painted black and are made from stock $\frac{1}{2}$" x 4" lumber. They are constructed so that set on edge they reach exactly from the floor of the box to the screen. They are made according to the following specifications:

3 barriers each 5" long

4 barriers each 10" long

3 barriers each 15" long

2 barriers each 20" long

2 barriers each 25" long

A small piece of sheet metal, 2" x $\frac{1}{2}$", is nailed to the bottom of each barrier so that the barrier stands on edge.

FIGURE 3.

Closed Field Apparatus

FIGURE 4.

CLOSED FIELD APPARATUS

To prevent the barrier from moving once the screen is fastened down, a 3/4" brad with head cut off is put into the top of the barrier at each end, sharp point up, so that it engages the mesh of the screen.

Finally a collection of error sticks is used. These are slender pieces of wood about ¼" square, laid on the screening above, and corresponding to the error lines. They prevent mistakes in the rapid counting of errors as the rat makes his runs, serving to remind the experimenter which of the various lines on the floor mark of error zones in the problem being used.

Preliminary Training

The essential in the preliminary training is to teach the rat where food can be found, adapt him to the apparatus and to handling, and establish the habit of eating in the food-box, so that when he is put into the entrance alley he will go to the food without fear and with a minimum of exploratory behaviour, in spite of changes in the position of barriers.

After about nine to twelve hours of food deprivation and some handling, the rats are put into the apparatus in groups of four. These exposure periods last half an hour and occur twice daily. Moist Purina ground food is put in the food box and the animals allowed to eat for a total of an hour or so each session. They receive no food in the living cage. It was found convenient here, and particularly during the later testing, to have a special feeding place other than the animal's living cage in which feeding can be completed after the animals are taken out of the apparatus. During this and the succeeding training procedures the training problems A-F, as shown in figure ~~6~~ 5, are set up in the box and changed each exposure period.

As soon as the animals are eating well and give the impression of being adapted to the apparatus, they ~~should be~~ are run individually, still with as much handling as possible. In these individual preliminary runs, the rat is put into the entrance alley and allowed to go to food. Time is recorded from the moment the animal enters until he takes his first bite of food. When he has taken a few bites he is replaced in the entrance alley and timed again. This process is repeated nine times, twice daily, until all the animals reach the same criterion of adaptation to the apparatus; namely making nine runs to food in sixty seconds, time on each trial being scored from the moment the rat is dropped into the entrance alley until it takes the first bite of food. When an animal is not running as well as ~~he~~ it should, less total food should be given, otherwise the animal is allowed to eat for a total of about fifteen minutes after completing the runs. To save time, it was found essential to have a place in which a rat that had finished his training or test trials could be put to eat the remainder of his food while the next animal was being tested.

It can not be expected that all rats will meet these requirements at the same time; those that do not should be given less food, extra handling, and extra runs in the apparatus, so that the group as a whole can be brought up to criterion. This criterion is two occasions of nine runs in sixty seconds. Reduced numbers of runs, 3 or 4, should be continued for those animals that meet the criterion earlier than the rest. These extra preliminary runs do not seem to influence the subsequent test scores.

At no point is the same training test used on succeeding occasions; the sequence A-F should be repeated as necessary. Seven to ten days were usually required for this adaptation and preliminary training.

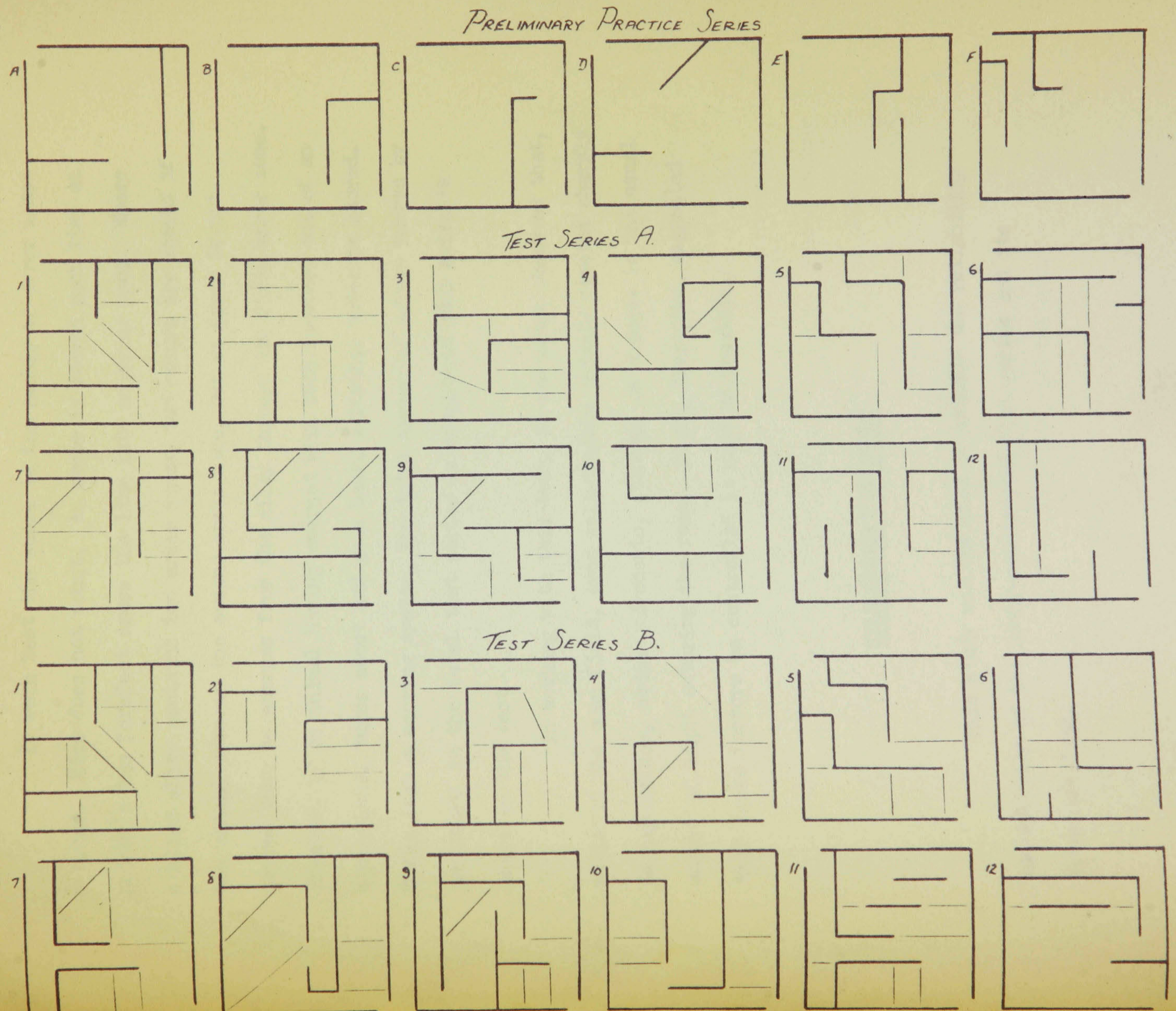
Testing

When the animals have reached the criterion of nine runs in sixty seconds on two occasions, they are ready for testing. Figure 5 gives the plan of the test problems.

The test has two forms, series A consisting of the twelve problem situations and series B the mirror image reversals of the problems in series A.

The animals should be given eight runs in each problem situation at about nine a.m. each day, then allowed to eat for about a total of fifteen minutes and returned to their living cages. Approximately eight hours later the same procedure is repeated with the next problem; this continues until the twelve test items have been completed. No days should be missed and it is necessary that all conditions be kept as constant as possible

FIGURE 5.


PRELIMINARY PRACTICE SERIES
A
B
C
D
E
F
TEST SERIES A.
1
2
3
4
5
6
7
8
9
10
11
12
TEST SERIES B.
1
2
3
4
5
6
7
8
9
10
11
12

throughout the training and testing period.

In each test the score is the number of error zones entered. Time does not count. An error is scored each time an animal's two forefeet cross the line into an error zone. Where a blind alley contains two error zones, two errors are scored if the animal crosses the second error line, but an error is not scored when he emerges from the alley through the first error zone. However, if an animal having emerged with both forefeet out of an error zone, turns about and goes back, a further error is scored. Using such a scoring system, the total number of errors scored by an animal in the total test series is considered that animal's score on the test.

In working with this test, it was often observed that, while in the open field, even well-trained animals reacted sharply to any noises, sudden movements, shadows, or changes in the usual amount of light entering the room. It is, therefore, suggested that these factors be controlled as much as possible.

STANDARDIZATION STUDY

This study was designed to examine the reliability and validity of the newly-constructed test series and its alternate form.

Procedure

A group of twenty-eight male hooded rats from the colony maintained in the comparative psychology laboratory at McGill University were divided into three groups and treated as follows:-

(a) Nine rats were reared in cages measuring 9" x 10" x 12", three per cage.

(b) Ten rats were reared similarly to those above. At about the age of ninety days these rats underwent cortical extirpation operations. No specific cortical area was excised. None of the animals showed any observable physical defects at the time of testing.

(c) Nine rats were reared in a free environment very similar to that described by Hymovitch (4).

When the animals were one hundred and fifty days old, they started in the closed field apparatus according to the schedule described above. The entire group reached the required criterion after eight days of preliminary training. This amounted to thirteen exposure periods of thirty minutes each and three individual run sessions.

The animals were then tested with test series A, two test problems eight hours apart, each day. No days were missed. In six days the test series was completed and the animals returned to their regular feeding schedule.

For three days the rats were fed and watered; nothing else was done to them. On the fourth day, the entire group was retrained in the closed field apparatus. This preliminary training took two days. It commenced with two exposure periods of thirty minutes each, followed the next day by two criterion run sessions. Training problems A,B,C,D, were used in bringing the group to criterion. The rats were then tested as previously except that this time test series B was used.

Results

A. Validity.

It has been shown by Lashley (7), and others that intelligence, as measured by behaviour in various traditional types of mazes, is impaired by cortical damage.

Hymovitch (4) has shown that rat intelligence, as measured by the Hebb and Williams test, is significantly improved by rearing in a free environment as opposed to a very restricted one. He has further reported a strong tendency for the free environment rats to be superior to animals reared in normal living cages, such as were used in the present experiment.

If it can be shown that the test developed in this thesis can discriminate ~~between~~ animals with damaged cortex, validity may be claimed for the test. The results of this experiment as shown in table 3, using the new test series, enable us to make this claim.

TABLE 3

Results of Validity Studies

Group	N	Mean Score
operates	10	159.5
normals	9	102.2
free env.	9	88.0

The mean score difference between the operates and normals is significant at better than the one per cent level of confidence. The mean score difference between the normals and the free environment animals is significant at the ten per cent level of confidence.

The report by Hymovitch (4) indicates that the Hebb and Williams test is sensitive enough to discriminate animals on the basis of free or restricted environments, and early or late experience. The work by Lansdell (6) indicates that the test can measure the differential effects of cortical lesions in various parts of the cortex. Rishikoff (9) has indicated that using the Hebb and Williams test, it is possible to measure the effects of electroconvulsive shock on intelligence.

These studies point to the validity of the Hebb and

Williams approach to the measurement of intelligence in the rat.

The agreement of the data obtained using the new test series with the results obtained using the old test series supports the probability that both test series are measuring the same properties.

B. Reliability.

The important objective of this entire experimental project was to establish a reasonably high test-retest reliability for a test series of twelve items. Table 4 shows the reliabilities obtained with the new test. They are significantly greater than the average reliabilities obtained with the previous test series used as a twelve item test, and as a twenty-four item test.

TABLE 4

Test-retest Reliabilities

Rho	N	Group
.84	28	10 op., 9 norm., 9 free env.
.80	18	9 norm., 9 free env.

These results indicate that the new test series is a significant improvement over the old one and furthermore establishes the close field intelligence test as a reliable instrument. Other advantages, such as the time saving procedure, the space conserving apparatus, the efficient recording of errors, and the facility of problem variation, make it a very useful and practicable test of rat intelligence. Its validity is apparent from the fact that it is sensitive to the effect of agents which have been shown to alter intelligence.

DISCUSSION

The standardized intelligence test for rats described in this thesis compares very favourably with any maze test available as a reliable instrument for the evaluation of rat behaviour. Miles (8) reporting some work in which he compared the elevated maze with an alley maze of the same pattern indicates a reliability of .75 for the elevated maze and .73 for the alley maze. Burlingame and Stone (1) reporting on the multiple-T maze, obtained a reliability of .78. The original studies using the closed field test (3) report an average reliability of .76. The standardization studies described in this paper achieved reliabilities of .84 and .80. These results clearly indicate the closed field intelligence test series developed here to be a reliable research instrument, probably more so than either the elevated, multiple-T, or original Hebb and Williams intelligence tests.

It is generally agreed that intelligence refers to the aggregate capacity of an organism to deal effectively with the various aspects of its environment.

Is this capacity made up of independent abilities? Is there a significant common factor? To what degree, if any, is there an integration of specific with common factors? These are questions which remain unanswered, as does the basic question of what is the possible nature of a common or specific factor in intelligence. Nevertheless, the evaluation of human intelligence, by psychologists and others, is an everyday practice. While a real understanding of what we mean is unavailable, it is possible to evaluate intelligence quantitatively by the measurement of the behavioural results of intelligence.

Any attempt to measure intelligence at the human or subhuman level must recognize that it is a general capacity to do many things rather than a restricted ability to do certain things. At the human level, reliable measures of intelligence are based on performance on a large number of different tasks. Animal studies, on the other hand, have used learning scores on one task as the index of intelligence. This restriction adds to the difficulty of making comparable measures between human and infra-human intelligence.

The closed field test described in this paper bases its quantitative score on a number of qualitative analyses of performance on many different problems. This is a deliberate attempt to evaluate rat intelligence as a more general and integrated phenomenon and in this way to accomplish the measurement of a capacity in the rat which more closely approaches our concept of intelligence in the human.

Therefore, it may be said that this thesis has served to develop a highly reliable, valid, and practicable test of rat intelligence, using methods comparable to the better methods of testing human intelligence.

SUMMARY

The nature of the items and the measure of reliability and validity for a test of rat intelligence, using methods comparable to tests of human intelligence, is described. Advantages in ease of administration, practicability of the apparatus, saving in time, and dependability of results ~~is~~ are claimed.

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