EFFECTS OF ELECTROCONVULSIVE SHOCKS ON THE PERFORMANCE OF THE RAT IN THE CLOSED FIELD TEST.

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Thesis submitted to the Department of Psychology in partial fulfilment of the requirements for the Degree of Master of Science.

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ILLUSTRATIONS

PREFACE

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INTRODUCTION AND HISTORICAL BACKGROUND

Introduction.

Since the introduction of electroconvulsive shock therapy into psychiatric practice, extensive research has been carried out to discover any deleterious effects of the shock. Learning and retention have received particular attention. Although the majority of the studies report no decrement in learning and retention in the rat after a series of electroconvulsive shocks, a few studies do indicate some impairment of these functions. In view of the conflicting results reported, it was felt that a more sensitive instrument was needed; the 'closed-field' test (10) appeared to be such an instrument. Accordingly, the basic studies on the effects of electroconvulsive shock--that is, the effects on learning and retention in both infants and adults--were repeated using this apparatus.

Historical Background

Early post-shock behavior. Stainbrook and Lowenbach (24) studied the immediate effects of shock on the behavior of rats in an over-learned, one-choice-point water maze, with one dark and one lighted alley. Fifteen minutes after the convulsion the rats showed a decrement in performance, slight in terms of errors, but pronounced in terms of time. The authors suggested that this may have been due at least in part to the chronic fright state which they observed in the rats after a few shocks.

Effect on learning. Eriksen (4) gave ten shocks, one per day, to a group of rats when age twenty-one to thirty days. Training on a maze was begun when age forty-one days. The convulsed group was significantly inferior to a control group.

Effect on retention. Duncan (3), Siegel (21), and Stainbrook (22) studied the effect on retention of a series of convulsions interposed between the original learning and re-learning. Siegel reports no loss on a simple running - to - food task, but Duncan and Stainbrook, using mazes, report very little retention by their experimental groups, as compared with their control groups. Duncan used a shock-control group, which received a non-convulsive shock in the hind legs. This group displayed much more emotional behavior than the convulsive shock group, but in retention differed little from the nonshocked controls.

Stainbrook suggests the "possibility that the errors of re-learning of the electroshocked animals were conditioned by the emotional behavior induced by the electroshock convulsions". Duncan, on the other hand, concluded that "the loss of the habit and probably also the curing of mental patients is due, not to the punishment or fear of electroshock, but to a direct action on cerebral tissue".

Effect on concurrent behavior. Horowitz & Stone (11) McGinnies (14), McGinnies and Schlosberg (15), Porter and Stone (17), and Sharp, Winder and Stone (20) studied the effect of daily shocks concurrent with learning introduced after a task had been more or less mastered. Deterioration of performance was demonstrated.

In regard to the importance of the emotional factor, Horowitz and Stone say, "although this factor cannot be ignored, the behavior of the animals in this study suggests that it was not a primary causal factor in the temporary disorganization of the discrimination habit".

McGinnies postulates that his rats "showed little or no impairment in retention of the habit but did exhibit a rather severe decrement in performance--this performance decrement may, however, have been aggravated by a partial failure in "availability of the habit--". He suggests that the "physiological stress caused by the convulsions" may cause the poor performance, by way of "generalized enfeeblement or indifference".

Porter's control group was etherized lightly before being shocked, so that no convulsion occurred. He found no appreciable change in the performance of these rats, and therefore concluded that it is the convulsion and not the current itself which caused the deterioration in performance.

This evidence suggests that under a variety of learning conditions, electroconvulsive shocks appear to be more or less deleterious to maze performances of rats. The decrements have sometimes been ascribed (a) to the rats' becoming emotionally sensitized, frightened or neurotic, and therefore disinclined to advance directly toward the goal, (b) to the reduction of general vigor, thereby making the rat unwilling or unable to expend the requisite amount of energy to solve the problem, and (c) to physiological alteration of cerebral functions, which are manifested by confusion and/or some degree of habit disintegration.

PURPOSE OF PRESENT EXPERIMENTS

The present studies were undertaken to ascertain the following:-

(1) The usefulness of the 'closed-field' test in assessing the effects of a series of electroshocks administered to the rat in infancy and adulthood.

(2) The permanency of the impairment of retention and learning which follows a series of electroconvulsive shocks.

RESEARCH DESIGN

A. Apparatus. The 'closed-field' test apparatus of the general design described by Hebb and Williams (10) was employed. It consisted of a box, 30" square and 3" high with the floor painted white and the walls black. An alley was constructed outside this area which allowed the rat to run up and reach the entrance, at the right hand corner, and follow a path, diagonally across, to the food box situated in the lower left hand corner. The box had a mesh-wire covering and the alley had a solid plywood cover. Figure 1 illustrates the apparatus. Barriers, painted black, were constructed to fit into this box so that they could be arranged into a variety of problem situations. Figures 2 and 3 illustrate two such problems. The rat, motivated for food (wet fox chow meal), had to learn the arbitrarily

Fig. 1. Closed-Field Apparatus. Front View. Entrance into alley at lower right hand corner. Goal at lower left hand corner.

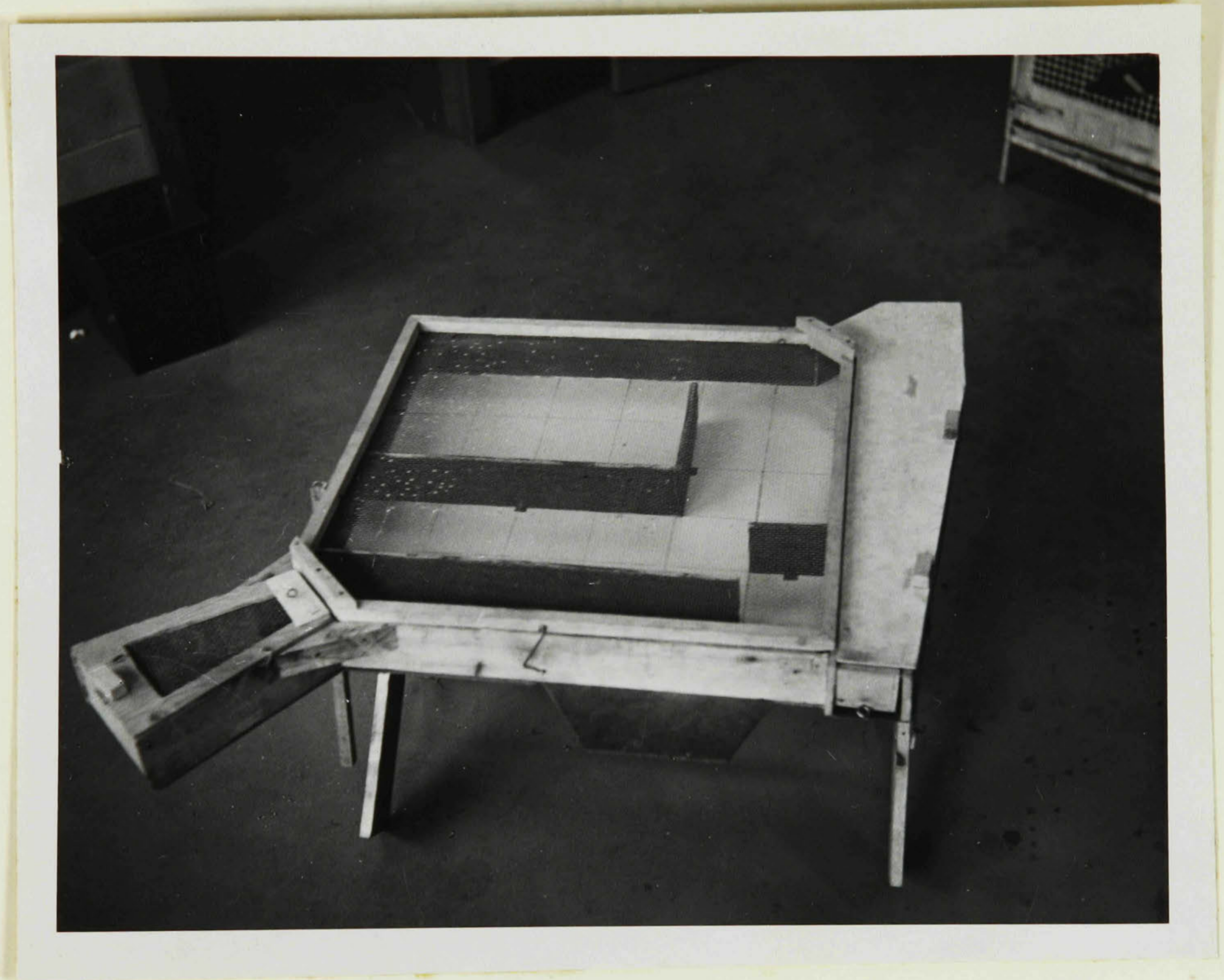

Fig. 2. A problem-solving situation for the rat arranged in the Closed-Field.

Fig. 3. A side view of the Closed-Field with a problem situation.

set up "correct" path from start to goal for each individual problem. Error zones, i.e. arbitrarily set up deviations from the "true path", were set for each problem. Figure 4 illustrates the six training and twenty-four test problems; the error zones are designated by lower case letters.

The test apparatus was elevated on a treadle 24" from the floor always in the same position in the room. The experimenter maintained the same position relative to the box during training and testing periods.

B. Animals. One hundred male and twenty-eight female hooded rats of the stock maintained by the Royal Victoria Hospital, Montreal, were employed. Throughout each experiment they were fed wet fox chow meal twice daily. Quantity of food was adjusted to keep each rat at about 85 per cent of its normal weight.

C. Equating of groups. The animals were divided randomly into control and experimental groups.

D. Shocking period. A series of fifteen shocks, one per day was administered to the animals shocked and tested as adults, and a series of ten shocks, one per day, to the animals shocked in infancy and tested as adults.

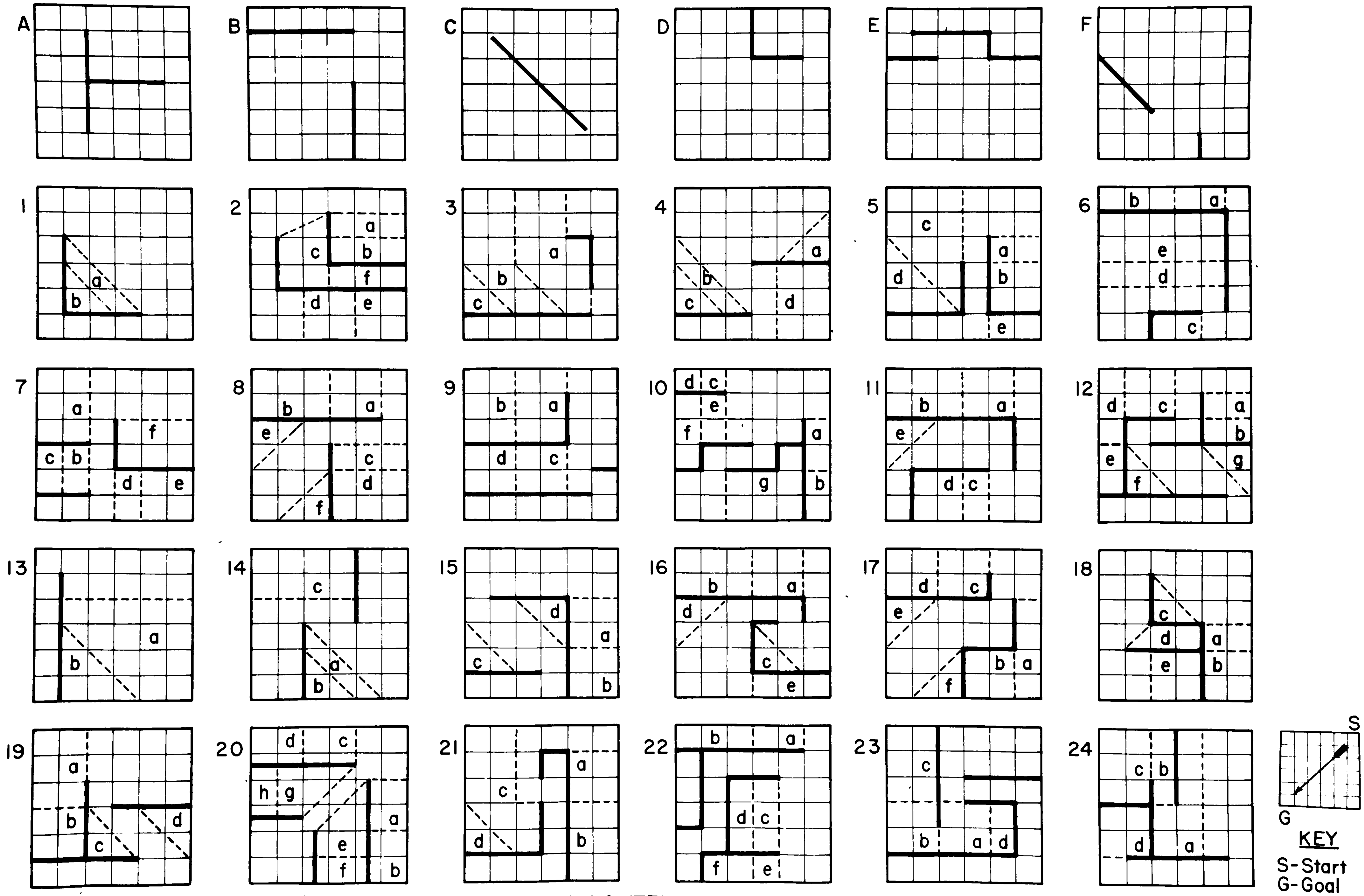

FIG. 4. CLOSED FIELD TRAINING ITEMS AND TEST PROBLEMS

The shocking apparatus was the same as designed by Hayes (9). It had a current regulating circuit that gave an alternating current output of 50 milliamperes for a duration of one-fifth of a second. This produced a convulsion with pronounced tonic-clonic phases, as described by Golub and Morgan (8). Figures 5, 6 and 7 illustrate the three phases of the convulsion. The padded alligator clip electrodes which were attached to the ears of the animals were immersed in a sodium bicarbonate solution to minimize resistance.

E. Emotional factors. Porter and Stone (17) have suggested that a period of ten days is necessary for recovery from the emotional effects of shock. Further, they point out that if, after this period any decrements are shown on testing the animals, they can be assumed to be permanent. In this research, twenty-four days recovery were allowed before the beginning of the training period in the 'closed-field' apparatus, at which time two qualified observers were called in to view the performance of the animals, and when the observers could not distinguish the controls from the experimental animals, testing was begun.

F. Preliminary training. As indicated in items A to F of Figure 4, six different arrangements of the barriers were used to accustom the animal to the 'closed-field' box. Twice daily, seven hours apart, the hungry animals

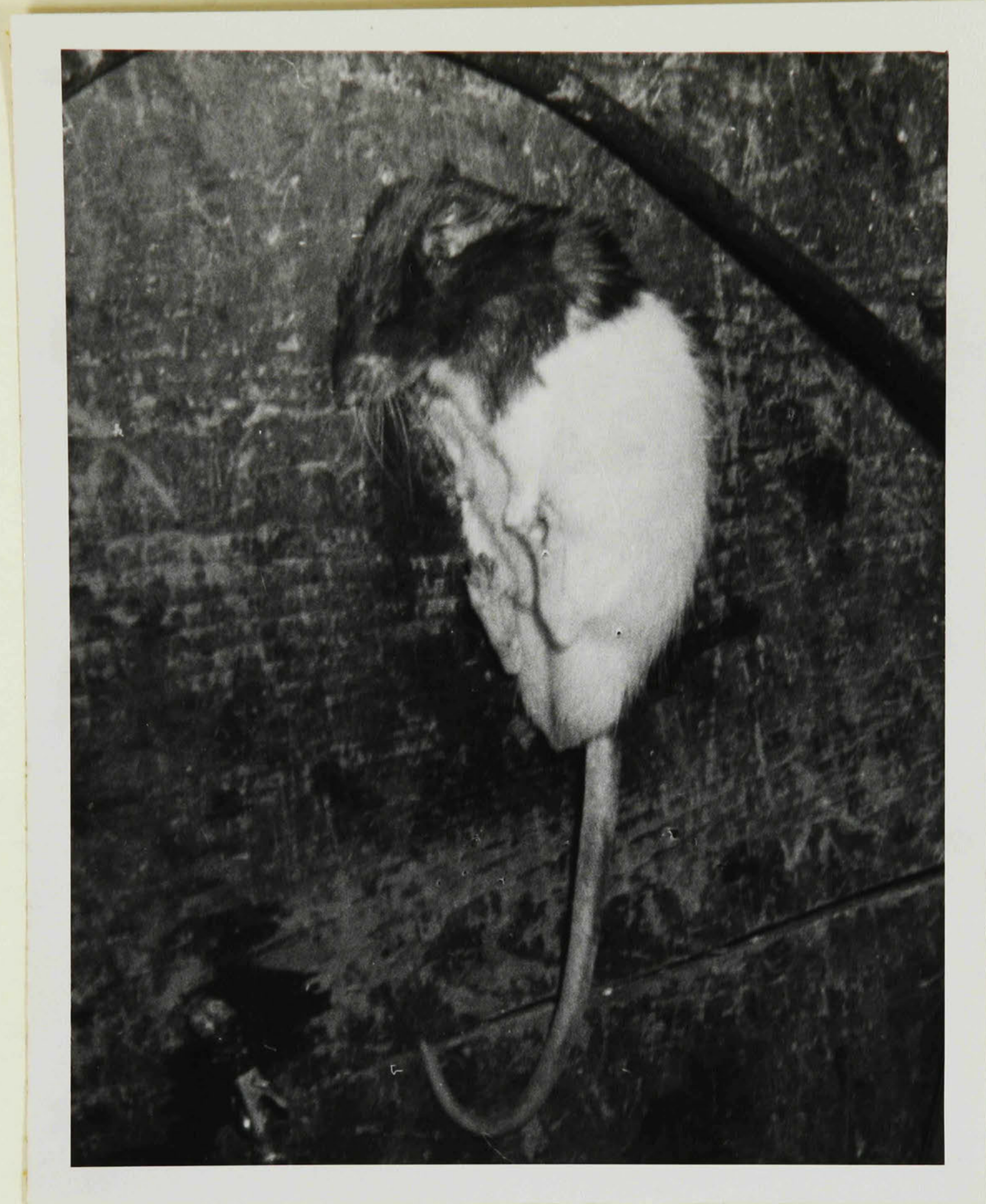

Fig. 5. Tonic phase after administration of electro-convulsive shock.

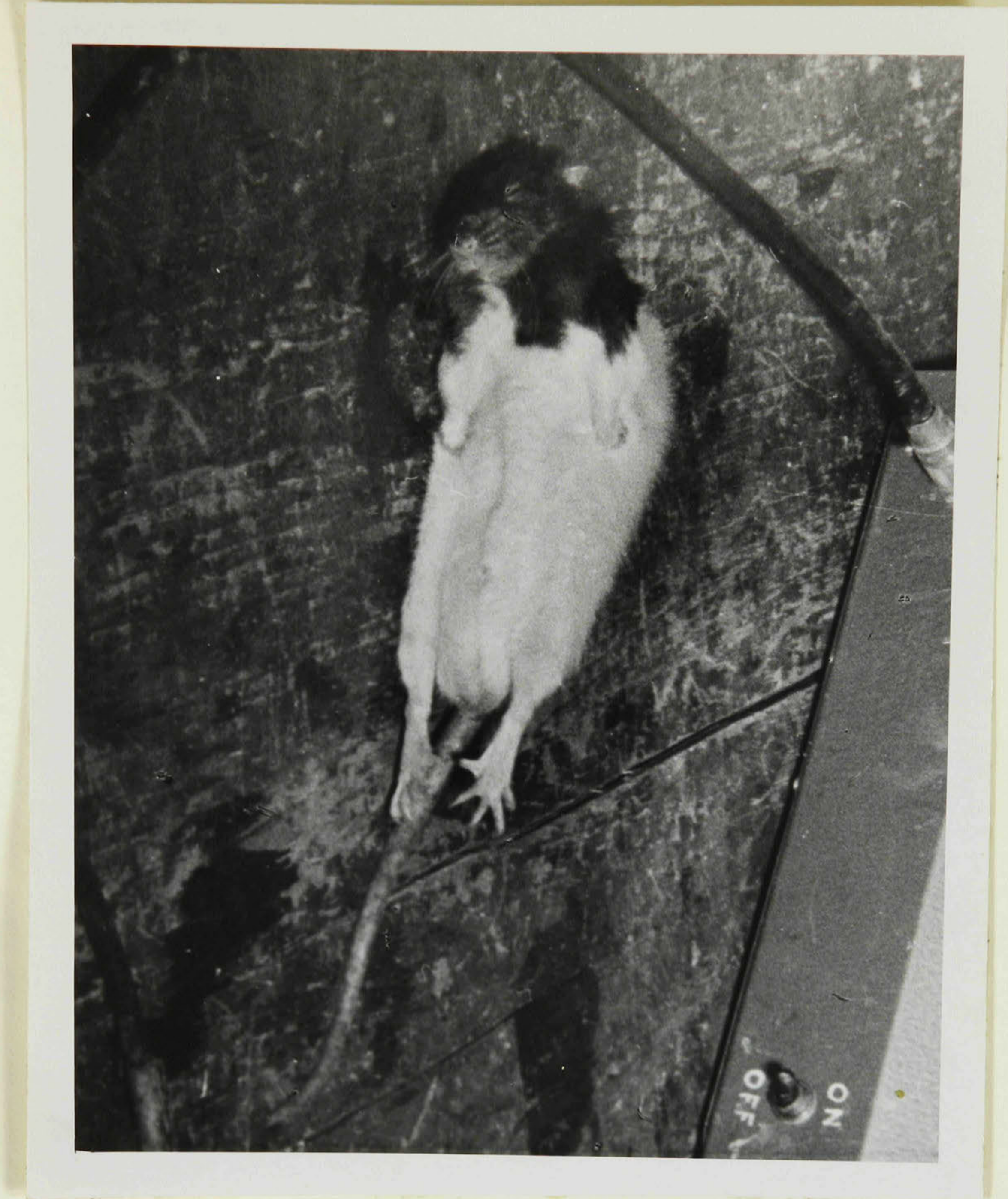

Fig. 6. Clonic phase after administration of electro-convulsive shock.

Fig. 7. Demonstrates the "Malleability" of the rat after shock.

were placed, four animals at a time, in the apparatus for half-hour exposures. When the animals were observed to have achieved a 'start - to - goal' orientation, criterion running was attempted. This consisted in having the animal make ten consecutive runs in the training item within sixty-nine seconds. If the animal reached criterion on two consecutive training items, it was considered ready for testing. This was usually achieved after ten days of training. Figure 8 shows training situation 'C' in the 'closed-field'.

G. Testing period. Each animal was run on two items per day, each item seven hours apart. The arrangement of the barriers in each of the twenty-four items is indicated in Figure 4. Errors and errorless runs were scored. An error was counted when the animal had placed its fore-paws over a line of a zone deviating from the true path, indicated by a, b, c, etc. in Figure 4. Time scores were also taken. Time was measured from the moment the animal was placed in the alley-way until it reached the food in the goal box. Experimental and control animals were run in random order. Table 1 gives the experimental schedule for the experiments.

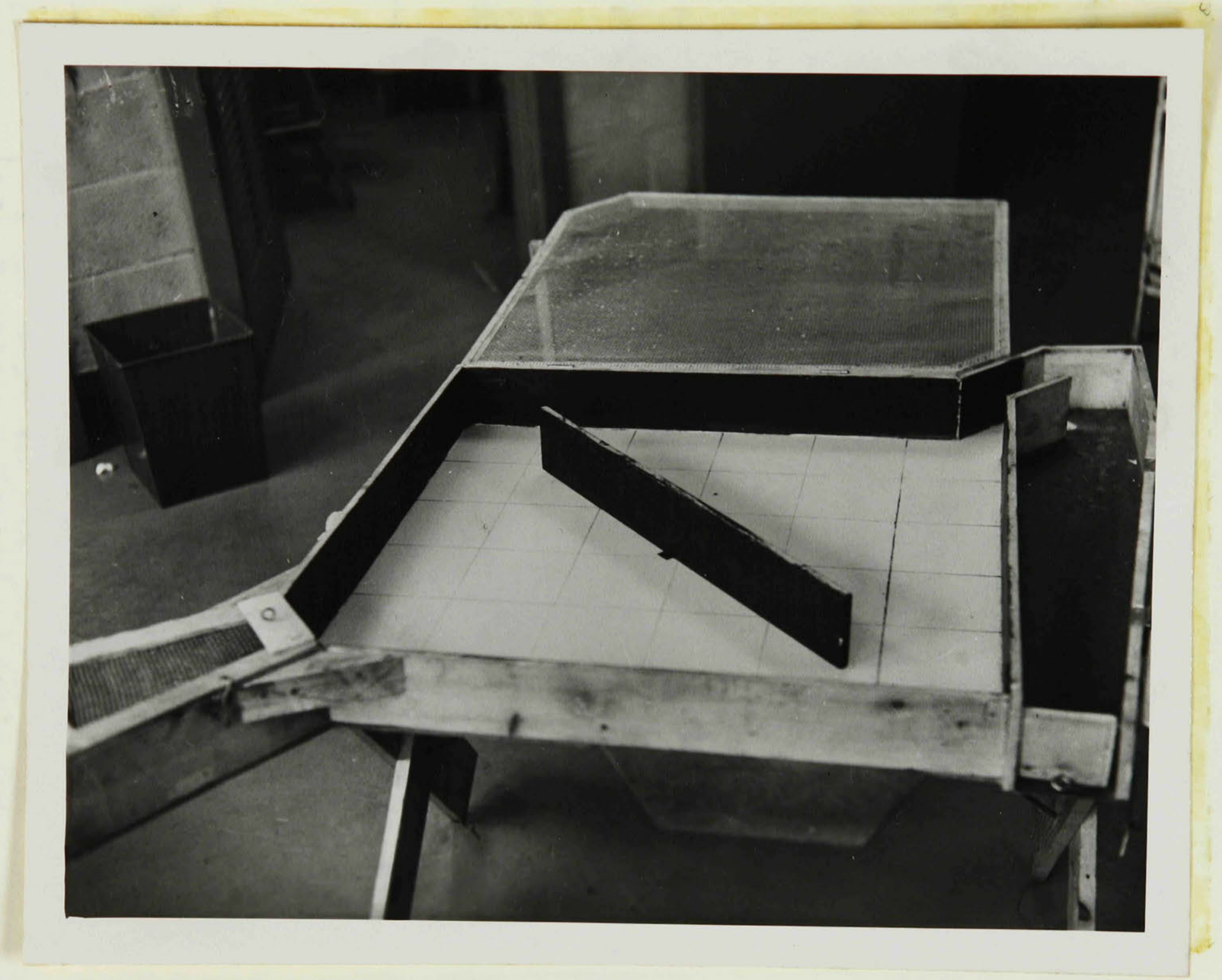

Fig. 8. Training situation "C" in the Closed-Field.

TABLE I

RESEARCH DESIGN

EXPERIMENT I - INITIAL LEARNING

Experimental Group	N 15	15 Shocks	24 days Recovery	10 days Training	12 days Testing	
Control Group	14	15 Pseudo Shocks	24 days Recovery	10 days Training	12 days Testing	

EXPERIMENT II - INFANT STUDY

Experimental Group	N 33	10 Shocks	74 days Recovery	10 days Training	12 days Testing	
Control Group	27	10 Pseudo Shocks	74 days Recovery	10 days Training	12 days Testing	

EXPERIMENT III - RETENTION STUDY

Experimental Group	N 14	12 days Testing	15 Shocks	24 days Recovery	10 days Training	12 days Testing
Control Group	13	12 days Testing	15 Pseudo Shocks	24 days Recovery	10 days Training	12 days Testing

EXPERIMENT I

The first experiment termed here 'initial learning' employed a group of thirty-four hooded male rats, mean age one hundred and ten days. Five animals were eventually discarded--two because of middle ear disease and three because of death due to paralysis. The remaining twenty-nine were randomly divided into two groups, fifteen in the shock group, fourteen in the pseudo-shock group.

The experimental group was then administered the series of fifteen electroconvulsive shocks at the rate of one per day. The control group received the same type and amount of handling, including the placement of the electrodes on the ears, but received no shock. On the twenty-fifth day after the last shock, preliminary training in the 'closed-field' test was begun. Criterion was reached by all animals on the tenth training day and the twenty-four item test was then presented at the rate of two items per day.

Results of Experiment 1. Figures 9 and 10 give means of error and time, respectively, on each of the twenty-four items. The shocked group's performance on the 'closed-field' test was significantly inferior to that of the control group. This difference was significant for errors at the 1 per cent level of confidence, the F ratio being 8.69. Appendix 1 gives the pertinent data for this analysis.

It may be concluded that learning ability, under

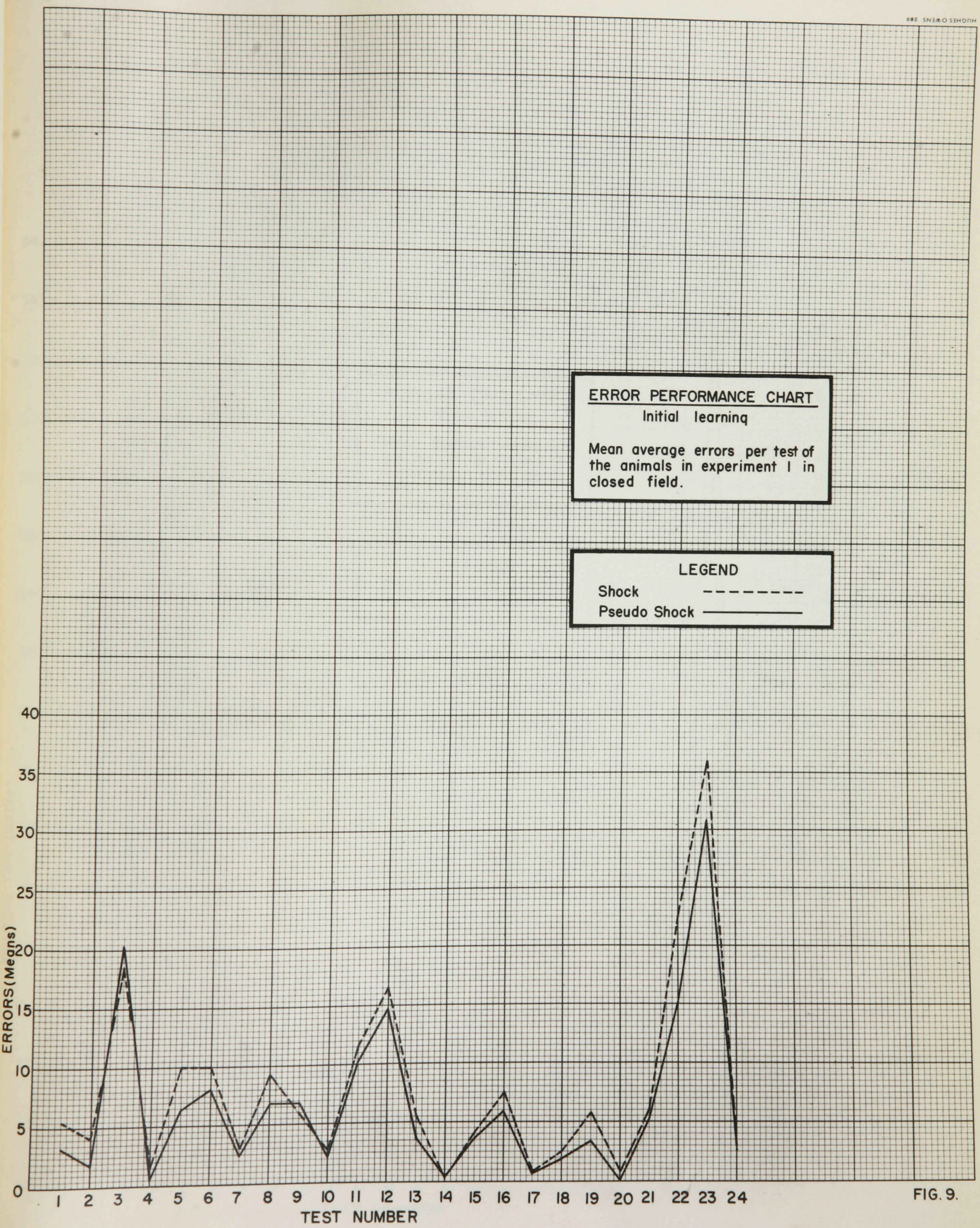
ERROR PERFORMANCE CHART
Initial learninq
Mean average errors per test of the animals in experiment I in closed field.
LEGEND
Shock
Pseudo Shock
ERRORS (Means)
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TEST NUMBER

FIG. 9.

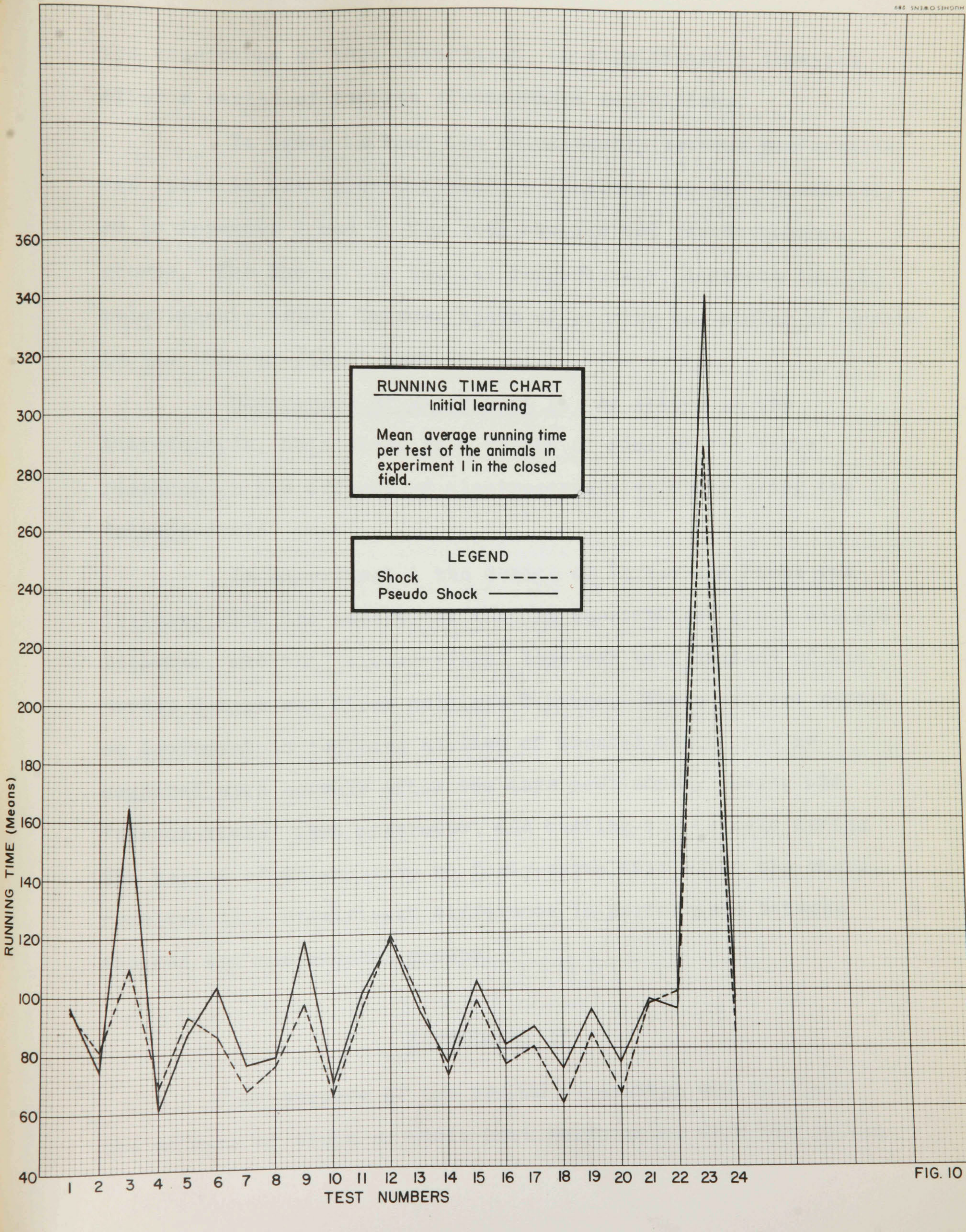
HUGHES OWENS 289
RUNNING TIME CHART
Initial learning
Mean average running time per test of the animals in experiment I in the closed field.
LEGEND
Shock
Pseudo Shock
RUNNING TIME (Means)
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
TEST NUMBERS

FIG. 10

the conditions of this experiment, is significantly impaired after a series of fifteen electroshock convulsions.

In order to test the relationship between performance and speed in the 'closed-field', a Spearman Rho was calculated, as in Appendix 2 and 3, for both shocked and pseudo-shocked groups. The Rho of .41 and .42 respectively, indicate that no relationship exists between speed of running and number of errors in the 'closed-field' test.

Discussion of Experiment 1. As stated in the introduction, this study is a report of some of the basic research on the effects of electroconvulsive shock using the 'closed-field' test.

In Experiment 1 the design of Porter and Stone was followed with the exceptions that an anesthetized group was not included, and the 'closed-field' test was used instead of the Warden U-type and Stone multiple T mazes. These writers report no decrement in learning ability of shocked adult rats as compared with normals after ten days post-shock. Using the 'closed-field' test apparatus, and testing the animals during the period of thirty-five to forty-seven days after the shock, resulted in a significant difference in performance between shocked and non-shocked groups.

EXPERIMENT II

The purpose of the second experiment was to study the effects of shock on adult test performance when the shocks had been administered in late infancy.

The experimental group comprised nineteen males and fourteen females, and the controls fourteen males and thirteen females. They were all chosen at random from a group of sixty infants. One shock per day was given to the experimental group during late infancy--that is, from twenty to twenty-nine days of age inclusive. The controls were handled similarly except that they were not shocked. Both groups were weaned at twenty-six days of age. At one hundred and four days of age, all animals began their preliminary training and they reached criterion after ten days. They were then run on the twenty-four test items, according to the routine described for Experiment 1.

Results of Experiment 11. Figures 11 and 12 give the curves for the mean errors and time on each of the twenty-four items of the test for experimental and control animals. The overlapping of the curves indicates that there are no differences between the groups. The F ratio of .000 computed as in Appendix 4, indicates that the difference in errors between the two groups is not significant.

Discussion of Experiment 11. Eriksen, Porter and Stone (5) gave groups of young rats, twenty days of age, ten daily electroconvulsive shocks, and after a ten day recovery period in one case, and a twenty day recovery period in the other, the rats began to learn the Stone multiple T-maze. The experimental groups were slightly but significantly inferior to control groups in terms of trials and errors. Furthermore, "............recovery from the effects of electroconvulsive

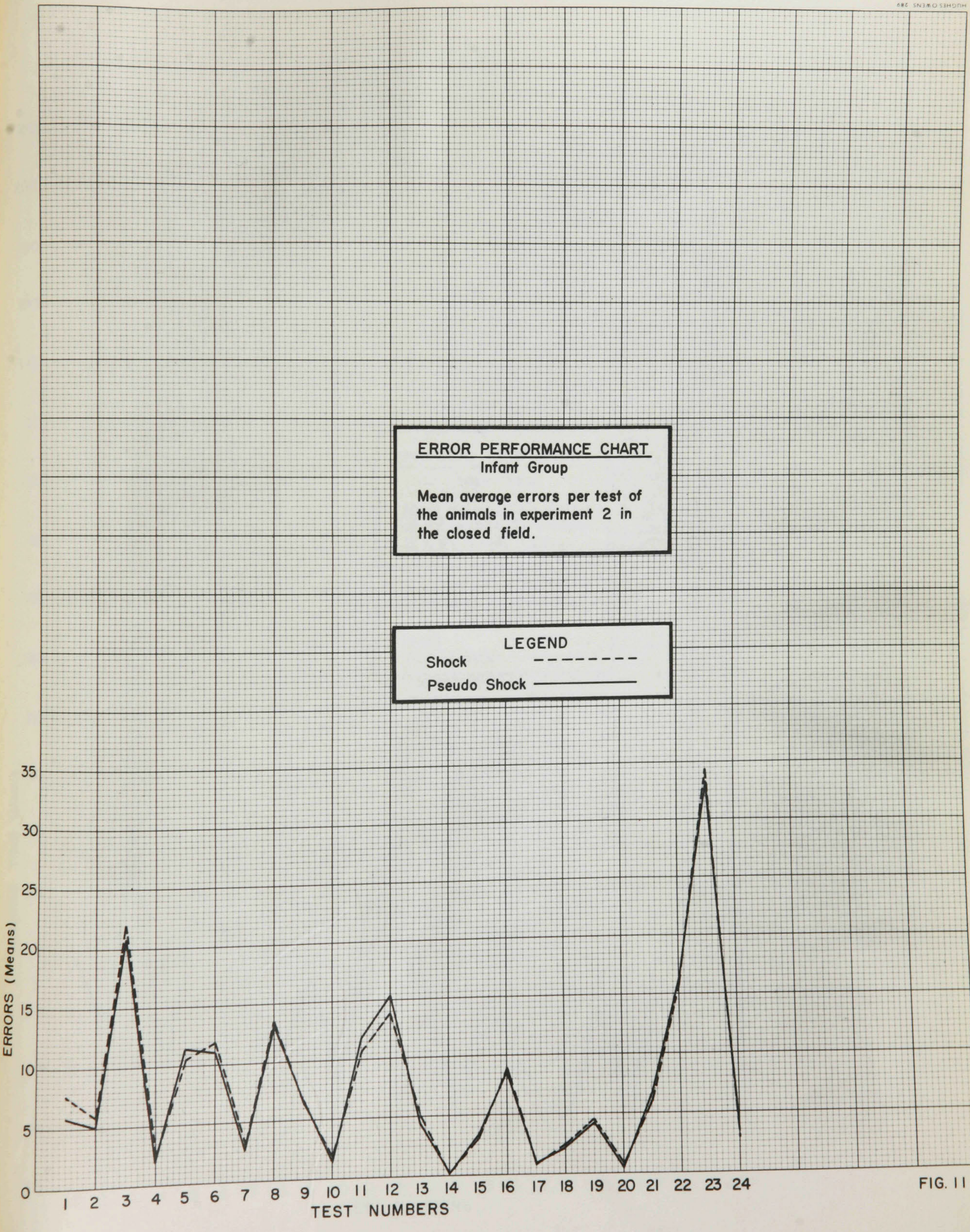
ERROR PERFORMANCE CHART
Infant Group
Mean average errors per test of the animals in experiment 2 in the closed field.
LEGEND
Shock
Pseudo Shock
ERRORS (Means)
0
5
10
15
20
25
30
35
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TEST NUMBERS

FIG. 11

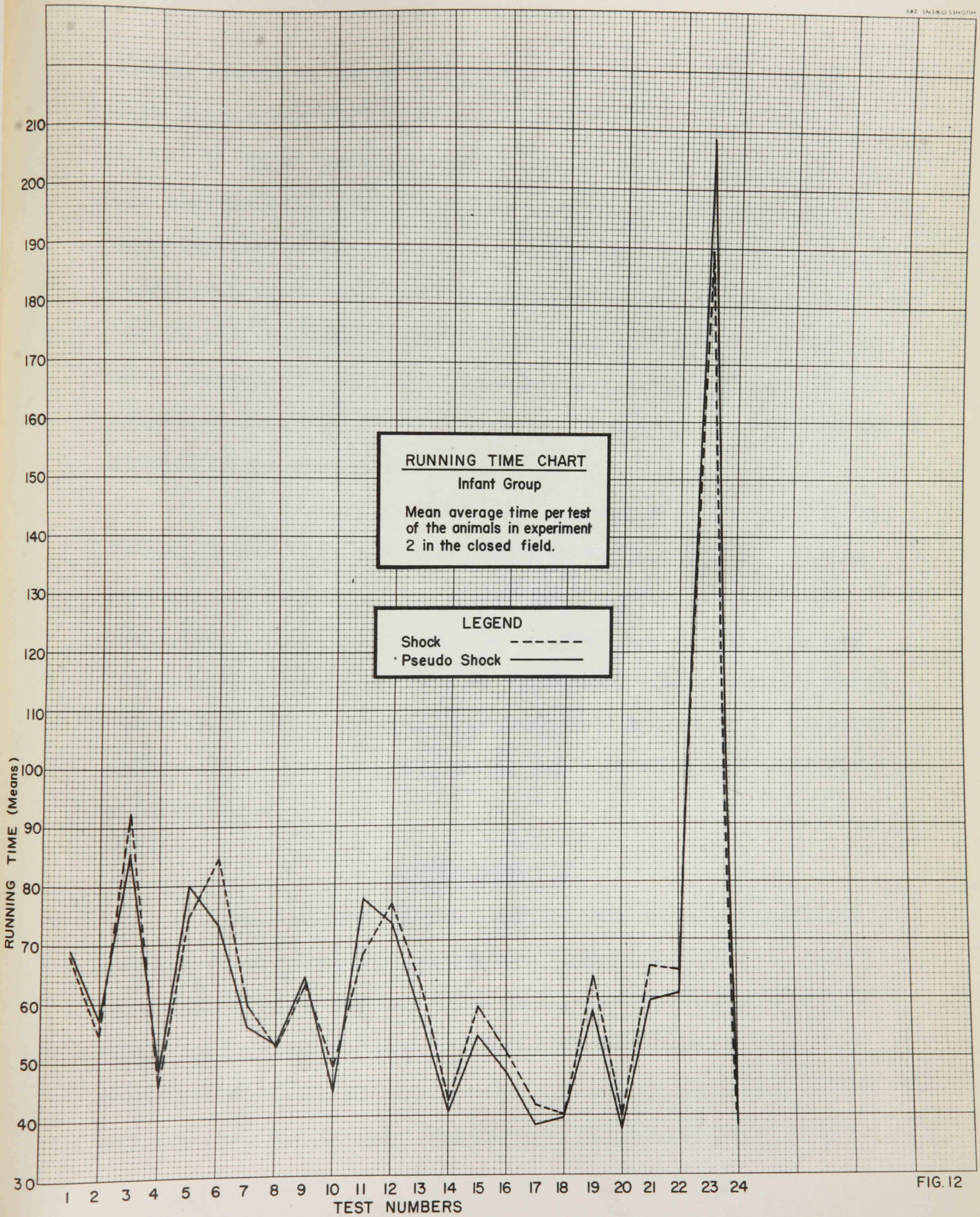
RUNNING TIME CHART
Infant Group
Mean average time per test of the animals in experiment 2 in the closed field.
LEGEND
Shock
Pseudo Shock
RUNNING TIME (Means)
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TEST NUMBERS

FIG. 12

shocks seemed to be as complete after ten as after twenty days post shock". (5, p.154)

In a further study by Porter, Stone and Eriksen (18) the experimental conditions were the same as their previous experiment with the exception of the recovery period which was lengthened from seventy-four to ninety days. Again, they report a difference in performance between their controls and experimental groups. They suggest that if a decrement is evidenced after ten days recovery, then this decrement can be assumed to be permanent.

In our experiments, we followed the procedure of the second experiment, that is, allowing eighty-four days before testing was begun, (seventy-four days recovery and ten days training). The results of this 'infant' experiment with the two reported above, are not in agreement. Their studies using the Stone multiple T-maze, resulted in a decrement in learning ability; the present study using the 'closed-field' test reveals no difference.

EXPERIMENT III

This experiment was carried out to investigate the ability of the test to demonstrate retention loss as a result of shock. Twenty-seven hooded rats received random orders of the twenty-four test items in the 'closed-field' test. They were then divided into two groups equated on the basis of their performance, yielding an experimental group of fourteen and a control group of thirteen. The experimental animals received fifteen shocks, one per day, the control group was handled in the same manner, except that they were not shocked. All animals then received twenty-four days of recovery, and ten days of preliminary training, after which they were presented with the twenty-four test items in the same random order as before shock and pseudo-shock sessions.

Results of Experiment 111. In this experiment, six random orders of the twenty-four test items of the 'closed-field' were used. Table 2 gives error scores for the two groups. The significance of the difference between the errors of the two groups is just below the 5 per cent level of confidence.

Discussion of Experiment 111. Porter and Stone (17) in their retention study, report no decrement after a forty day post shock interval as tested on the Stone multiple T-maze.

Muhlhan and Stone (16) using the Dashiell-type of water maze, report no decrement in performance between shock and non-shock groups after sixteen days post shock. Braun, Russel and Patton (2) report a decrement as late as sixty days post shock using the Lashley III maze.

Animals tested on the 'closed-field' test during the interval of thirty-five to forty-seven days post shock, demonstrated a difference in retention between shocked and non-shocked groups. This finding supports the one in Experiment 1 which showed the 'closed-field' test to be sensitive enough to detect deficiencies in the ability of the

TABLE 2

RETENTION STUDY

	Pre-shock Scores				Post shock Scores					
	Score	M	Std.Dev.	$Std.Dev._m$	Score	M	Std.Dev.	$Std.Dev._m$	Diff. of means	$Std.Dev._{dm}$
N-14 Shock	2423	173.1	26.4	7.3	2111	150.8	34.5	9.5	22.3	11.9
N-13 Control	2407	186.9	17.8	5.1	1721	132.4	30.9	8.9	54.5	10.3
		-13.8				18.4			32.2	15.7

$$C.R. = \frac{D}{Std.Dev._{dm}} = \frac{32.2}{15.7} = 2.11$$

P = .045

adult rat to learn the problems.

The test problems were of such a nature as to give results contradictory to those of Porter and Stone (17) in the shocked adult rat, and Porter, Stone and Eriksen (18) in the shocked infant rat tested as an adult. Except for the testing instruments the procedures of the present experiment were essentially similar to theirs.

THEORETICAL CONSIDERATION OF RESULTS.

The experiments using the 'closed-field' test after a series of electroconvulsive shocks indicates the following: If shock interferes with problem solving ability, the 'closed-field' test does not reveal it in an animal shocked in infancy and tested as an adult, but does reveal it if the animal is both shocked and tested as an adult. Three variables which may have been responsible for producing this deficit in learning and retention of the 'closed-field' test, but not of the Warden U-type maze or Stone multiple T-maze are general emotional reactions associated with the convulsive episodes, the electroconvulsive technique employed, and the methodology and procedure of the investigations.

The experimental design of this study controlled the possible effects of emotional factors by testing at a time when the shocked animals could not be distinguished from the control animals on a basis of emotional behavior. The electroconvulsive in learning ability. With the adult, on the other hand, the process may not be reversible and thus a deficiency becomes evident in the inferior performance on the 'closed-field' test. If this is the case, however, it is difficult to account for the deficits demonstrated in the infant studies of Porter, Stone and Eriksen (18).

Nevertheless, the purpose of this experiment is fulfilled in demonstrating the usefulness of the 'closed-field' test in assessing deficits in performance.

Although this study did not set out to demonstrate that electroconvulsive shocks result in damage to cerebral cortical tissue, it may be that such is the case. Histological studies of the brains of the shocked rats were not undertaken. Nevertheless, Ferraro, Roizin, and Helfand (6) have claimed reversible chemical and structural changes resulting from shock. Lansdell (13) using the 'closed-field' test with rat brain-operates has indicated that this apparatus does reveal deficits correlating with the lesions. Rabinovitch (19) also found his operated rats to be inferior to normal animals in performance on this apparatus. Since the deficits in performance which result from ECS in the present study are not attributable to emotional differences, not to differences in techniques, it is possible that they are the result of brain damage.

SUMMARY AND CONCLUSIONS

This report has described certain experiments which were conducted to determine the decrements in learning and retention following a series of controlled electroconvulsive shocks. All learning and retention tests were conducted in the 'closed-field' test apparatus. The animals used were all of Royal Victoria Hospital, Montreal, strain.

Experiment 1 - Initial Learning. Twenty-nine adult rats, mean age one hundred and ten days, fifteen were administered fifteen electroconvulsive shocks, one per day. After twenty-five days of recovery training was begun in the 'closed-field' test, and on the thirty-fifth day after last shock, testing on the twenty-four items of the test began with two items being presented per day. The convulsed group was significantly inferior to the control group in error performance in the test.

Experiment 11 - Infant Study. The purpose of this experiment was to study the effects of shock on adult performance when the shocks had been administered in late infancy.

From a group of sixty rats, random division was made of experimental and control groups. One shock was given per day to the experimental group during late infancy--that is from twenty to twenty-nine days of age. At one hundred and four days of age, the animals were trained and run on the 'closed-field' test. No difference between experimental and control animals in error performance was found.

Experiment 111 - Retention Study. To ascertain the ability of the 'closed-field' test to demonstrate retention loss as a result of shock, twenty-seven male hooded rats received six random orders of the twenty-four test items. After being equated on the basis of their performance in these orders, they were divided into control and experimental groups. Fifteen shocks, one per day, were administered to the experimental animals, and after the customary twenty-four days recovery and ten days training the twenty-four item-test was presented to the animal in the same random order as before shock and pseudo-shock sessions. This experiment indicated a retention loss in the experimental animals.

The findings are interpreted as indicating that,

(1) if ECS effects problem solving ability, the 'closed-field' test does not reveal it in an animal shocked in infancy and tested as an adult, but does reveal it in the animal that is both shocked and tested as an adult.

(2) The decrements, if evidenced, are permanent.

(3) The decrements may be due to brain damage.

APPENDIX I

STATISTICAL ANALYSIS WITH F RATIO, USING ERRORS

	INITIAL LEARNING - EXPERIMENT I		
	GROUPS		
	EXPERIMENTAL	CONTROL	
N	15	14	
TOTAL ERRORS	2907	2196	
MEAN ERRORS	193.8	156.9	
SUMS OF SQUARES	584,025	354,42	
TOTAL SUM OF SQUARES	40,499		
BETWEEN SUM OF SQUARES	985.94		
TOTAL MEAN ERRORS	176.00		
F RATIO	8.69		

APPENDIX 2

RHO between errors and time scores in shocked group.

Animal #	Rank (Time)	Rank (Errors)	d	d^2
20	8	14	6	36
21	13	7	6	36
24	6	6	0	0
25	15	15	0	0
29	10	13	3	9
30	7	10	3	9
34	14	12	2	4
35	2	11	9	81
36	9	2	7	49
5	1	3	2	4
6	4	1	3	9
8	12	4	8	64
12	5	9	4	16
13	3	5	2	4
15	11	8	3	9

$$P = 1 - \frac{6\Sigma d^2}{N(N^2-1)}$$

$$= 1 - \frac{1980}{15(224)}$$

$$= 1 - \frac{1980}{3360}$$

$$= \frac{3360-1980}{3360}$$

$$= \frac{1380}{3360}$$

$$= .41$$

APPENDIX 3

RHO between errors and time scores in pseudo shocked groups.

Initial learning.

Animal #	Rank (Time)	Rank (Errors)	d	d^2
23	7	13	6	36
26	5	3	2	4
28	13	8	5	25
32	$11\frac{1}{2}$	14	$2\frac{1}{2}$	$6\frac{1}{4}$
33	10	5	5	25
37	3	1	2	4
39	$11\frac{1}{2}$	6	$4\frac{1}{2}$	$20\frac{1}{4}$
2	2	2	0	0
3	9	7	2	4
4	14	12	2	4
9	4	9	5	25
10	8	10	2	4
14	1	11	10	100
16	6	4	2	4

$$P = 1 - \frac{6Ed^2}{N(N^2-1)}$$

$$= 1 - \frac{1569}{2730}$$

$$= \frac{2730-1569}{2730}$$

$$= \frac{1161}{2730}$$

$$= .42$$

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APPENDIX 4

STATISTICAL ANALYSIS WITH F RATIO, USING ERRORS

	INFANT GROUP - EXPERIMENT II	
	GROUPS	
	EXPERIMENTAL	CONTROL
N	33	27
TOTAL ERRORS	6353	5138
MEAN ERRORS	192.6	190.3
SUMS OF SQUARES	1,269,123	1,002,026
TOTAL SUM OF SQUARES	70,431	
BETWEEN SUM OF SQUARES	78.8	
TOTAL MEAN ERRORS	191.5	
F RATIO	.000	

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