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# Maze-learning Ability of Young and Mature ddY Mice and *Mus musclus molossinus*-M Mice

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Maze-learning ability of young and mature ddY mice and *Mus musclus molossinus*-M mice (Mol-M) which was originally wild, now in the process of establishment as a strain in Nagoya University were examined using 16-unit T-maze for the 5 or 6 daily test trials. Six different scores; total score, total error, retrace error, blind path, total time and time for running between two check points for young and mature ddY decreased with every trial. Those scores for the young mice tended to be lower than those for the mature. The young and mature Mol-M mice exhibited the higher scores than those for the ddY mice. The performances of the young Mol-M mice in the maze became dull and slow with every test trial and that of the mature one was quick but ineffective to reach the goal through the trials.

## INTRODUCTION

Numerous studies on behavior have been performed. There are, however, still many basic problems to be resolved. It has been known that animal strain[1], age[2], method of animal care, apparatus for test[1], and complexity of problem[2,5] employed influence the results of experiments in the studies on behavioral effects of ionizing radiation.

The object of the present preliminary study was first, to compare the maze learning ability of ddY mice, established as laboratory animals in Japan with that of *Mus musclus molossinus*-M mice (abbreviation; Mol-M) which were Japanese wild mice in the process of establishment as a strain[3]. The latter may still keep wild characteristics because they are not completely established yet as laboratory animals. Second, an attempt was made to observe age differences in learning in the two kinds of

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mice. In addition, the paper outlines the 16-unit, standard multiple-T narrow-path maze constructed by the authors.

## MATERIALS AND METHODS

### 1. Animals

Animals were divided into 4 groups as follows; Group I: Mol-M (N=4) ♂♂♀♀, age at the beginning of the investigation; 9-week-old, (offsprings of the mouse in Group II), Group II: (N=1) ♂; 33-week-old, Group III: ddY mice (N=5) ♂♂♂♂♂; 8-week-old, Group IV: ddY mice (N=5) ♂♂♂♂♂; 21-week-old. Each animal was housed in a single cage for certain periods before investigation. The animals in Group I and II were housed in the cages 3 weeks before investigation, the animals in Group III, 4 weeks before it and the animals in Group IV, 17 weeks before it.

### 2. Diet restriction and training schedule

The daily food supply was restricted 1 week before training (approximately two-thirds of the normal intake). Practically, the animals in Group I and II (mean body weight; 10.9 g) were supplied 2.0±0.2 g of Oriental Chow pellets per day and the animals in Group III (mean body weight; 24.3 g) and Group IV (mean body weight; 40.9 g) were done 2.5±0.2 g Funabashi-Nojyo Chow pellets per day.

Preliminary trainings were given a trial on one section with food at one end for 2 days, on a T-unit of two sections with food at the right end of the T-arm for 1 day and on a T-unit of two sections with food at the left end of the T-arm for 1 day.

### 3. Reward

Successful maze runners were allowed a 30-second feed of the food in a goal box and then supplied 2.0 or 2.5±0.2 g of the stock chow pellet and water (ad libitam) in the home cages.

The methods for the diet restriction, training and reward were adopted from the methods described by McGregor and Newcome with some modification[4].

### 4. Maze

1) Type of maze:
Standard 16-unit multiple-T narrow-path maze(16-choice problems) was used as shown in Figure 1.

2) Sections of the maze:
The sections were constructed of gray vinyl chloride plates and were 60 cm long, 4 cm wide and 15 cm high (length of the 1st section was exceptionally 30 cm). The seventeen sections were

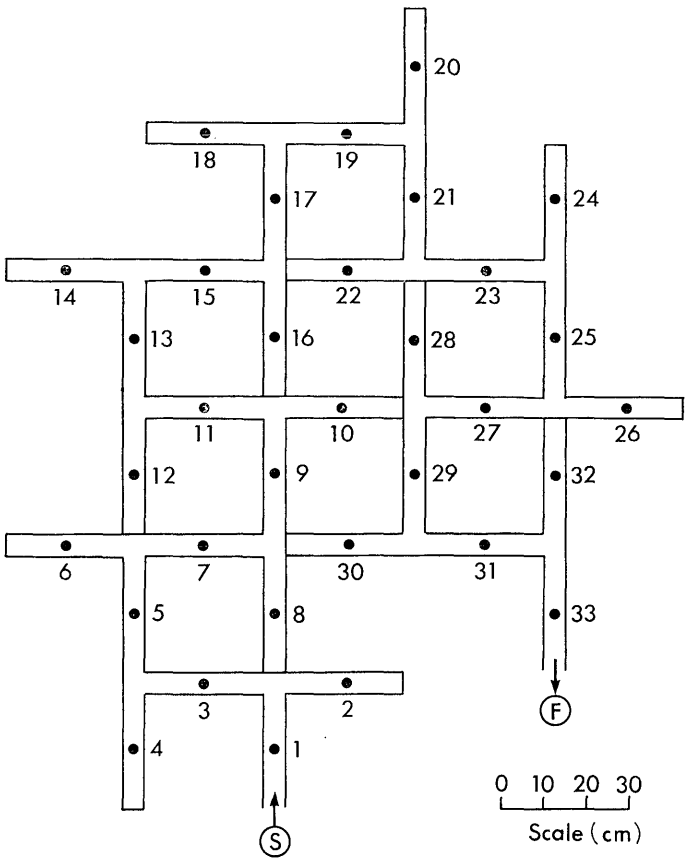


**Fig. 1.** Pattern of the multiple-T maze. Numbers indicate sections of the maze. Black dots indicate photoelectric cells.

jointed in T-form to make a true path of 510 cm and a total of 16 blind paths of 480 cm.

3) Goal box :
The goal box was constructed of wire-netting and was 20 cm long, 10 cm wide and 11 cm high with an entrance being 3.5 cm wide and 11 cm high.

4) Electronic device for scoring errors :
The bottom surfaces of their sections were illuminated by fluorescent lamps (intensity of illumination on the bottom surface was about 800 *l*x). A cadmium sulfide photoelectric cell was placed on the bottom surface at the middle of the half part of the each section. Passings of a mouse over the photoelectric cells intercept the light and they changed the resistance of the photoelectric cells and subsequently changed electric current of the circuit. The changes of the current were amplified and worked the relaies of the counter. The special circuits of the counter allowed to count separately the number of times an animal made the six kinds of per-

formances as follows; *turn to the right*, *turn to the left*, *run straight* without turn at the choice point (forward or backward, either), *retrace and turn backward* (right or left, either), *retrace type A* (retrace in a vertical arm of T-unit) and *retrace type B* (retrace in a horizontal arm of T-unit).

5) Assessment of maze-learning ability

Six different kinds of score were used to assess maze-learning ability.

(1) *Total score* indicated the total number of scores counted by the counter. Thus, it means the sum of scores for turn to the right, turn to the left, run straight, retrace and turn backward, retrace type A and retrace type B. (2) *Total error score* indicated the number of scores excepting those for right and left correct turns. In other words, it means the sum of scores for run straight, retrace and turn backward, retrace type A and retrace type B. (3) *Retrace error score* indicated the number of scores for three types of retrace and turn backward, retace type A and retrace type B. (4) *Blind path score* indicated the number of scores for the straight runs which were caused by entering of an animal into blind paths. Where an animal failed to reach the goal of the maze, the each scores (1), (2), (3) and (4) were estimated using the mean values of the scores and time obtained where it completed a run by the following equation.

$$\text{Estimated score (1), (2), (3) or (4)} = \frac{\text{mean score (1) (2) (3) or (4) where an animal complete a run}}{\text{mean time taken for an animal complete a run (sec)}} \times 1200 \text{ (sec)}$$

(5) *Time score* denoted either the time taken for an animal complete a run on the maze or, where it failed to do so, the maximum time it was permitted to stay on the maze (1200 sec). (6) *Time for running between two check points* indicated the time taken for an animal to run from a check point to another one. practically, this was calculated by dividing "time score" by "total score". In this calculation, the total score means actual score which an animal made even where it failed to complete a run on the maze for the maximum time.

## RESULTS

1. Mean total score

Mean total scores obtained by the young mice in Group I and the mature mouse in Group II for the 6 daily test trials were given in Table 1 and 2, and Figure 2. The mice in both groups did not show consistent scores for all test trials. The young mice, however, made lower scores

on Trials from 1 to 4 than mature one. Those scores were on the same levels as those for animals in Group III and IV. On Trials 5 and 6, the mice gave high scores which were about twice as much as the animals in Group III and IV made. On the other hand, the mature mouse gave high scores which were also about twice the scores of the animals in Group III and IV on Trials 1, 2, 4 and 6 and low scores, on the same levels as those for animals in the latter groups on Trials 3 and 5. It can be said, therefore, that the tendency of the scores for the young mice were low in early phase, on the same levels as those for animals in Group III and IV, high in late phase of the test trials, twice as much as the animals in Group III and IV made, and those for the mature one were high through the trials with low scores on some trials.

Mean total scores obtained by the young in Group III and mature

**Table 1.** Total score, total error score, retrace error score, blind path score, time score, time for running between 2 check points for young Mol-M mice (Group I).

| Trial number | 1 | 2* | 3* | 4 | 5* | 6* |
|---|---|---|---|---|---|---|
| Number of animals | 4 | 4 | 4 | 4 | 4 | 4 |
| Total score | 34.5±2.0** | 61.3±5.7 | 37.5±9.8 | 39.0±3.6 | 96.3±17.1 | 75.1±20.1 |
| Total error score | 15.0±1.1 | 31.4±3.4 | 14.7±1.5 | 17.8±2.6 | 46.3±7.6 | 36.6±9.3 |
| Retrace error score | 6.0±0.9 | 14.4±1.7 | 5.4±2.8 | 7.0±1.8 | 19.5±3.1 | 17.2±4.0 |
| Blind path score | 9.0±0.7 | 17.0±1.9 | 9.3±2.6 | 10.8±1.1 | 26.8±4.7 | 19.4±5.5 |
| Time score (Scc) | 387.1±83.4 | 781.6±141.5 | 460.9±217.7 | 409.1±114.8 | 964.1±204.3 | 744.6±233.1 |
| Time for running between 2 check points (Sec) | 11.5±2.7 | 13.3±2.6 | 17.8±8.8 | 9.8±2.2 | 24.3±7.2 | 22.9±8.5 |

* : There were the animals failed to reach the end of the maze; Trial 2(1/4), 3(1/4), 5(3/4), 6(2/4)

** : Standard error

**Table 2.** Total score, total error score, retrace error score, blind path score, time score, time for running between 2 check points for mature Mol-M mouse (Group II).

| Trial number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Number of animals | 1 | 1 | 1 | 1 | 1 | 1 |
| Total score | 87 | 89 | 44 | 98 | 24 | 94 |
| Total error score | 49 | 49 | 19 | 56 | 8 | 52 |
| Retrace error score | 22 | 23 | 8 | 17 | 1 | 24 |
| Blind path score | 27 | 26 | 11 | 39 | 7 | 28 |
| Time score (Sec) | 592.4 | 499.8 | 175.8 | 150.0 | 45.8 | 292.2 |
| Time for running between 2 check points (Sec) | 6.8 | 5.6 | 3.9 | 1.5 | 1.9 | 3.1 |

mice in Group IV for the 5 daily test trials were given in Table 3 and 4, and Figure 2. The scores for both young and mature mice decreased with every trial except that the score for young mice on the 5th trial was higher than that on the 4th. In addition, the young mice showed lower scores from the initial to the 4th trial than the mature mice except for the higher score than the mature ones on the 5th trial. However, differences between the young and mature ones were not statistically significant.

2. Mean total error score, mean retrace error score and mean blind path score

Mean total error score, mean retrace error scores and mean blind

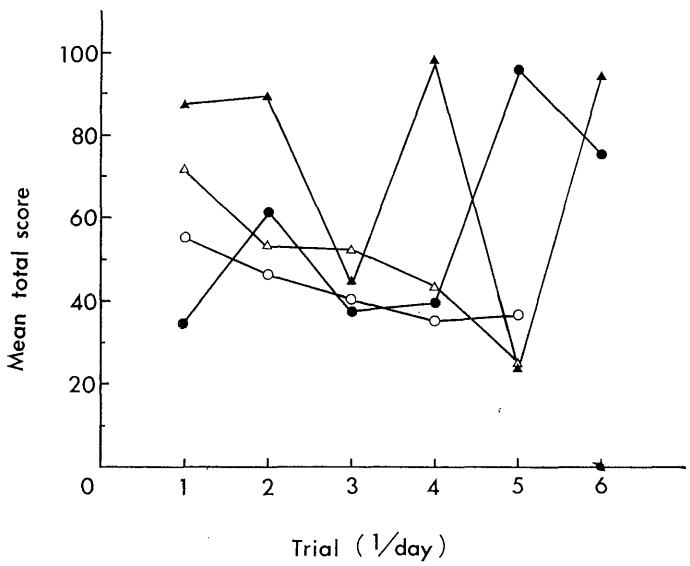


**Fig. 2.** Mean total scores obtained by Mol-M and ddY mice.
● Young Mol-M (Group I), ▲ mature Mol-M (Group II),
○ Young ddY (Group III), △ mature ddY (Group IV).

**Table 3.** Total score, total error score, retrace error score, blind path score, time scoee, time for running between 2 cheek points for young ddY mice (Group III).

| Trial number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Number of animals | 5 | 5 | 5 | 5 | 5 |
| Total score | 55.0±15.3* | 45.8±8.4 | 39.8±7.5 | 35.2±4.0 | 36.6±5.7 |
| Total error score | 29.0±10.6 | 23.0±5.5 | 18.8±2.0 | 15.8±2.4 | 16.4±3.9 |
| Retrace error score | 11.4±5.3 | 15.0±5.0 | 6.8±2.6 | 7.6±1.7 | 4.8±1.6 |
| Blind path score | 17.6±5.6 | 13.6±2.2 | 12.0±2.4 | 9.8±0.8 | 11.6±2.3 |
| Time score (Sec) | 237.9±52.1 | 192.3±34.5 | 130.9±16.8 | 112.1±9.0 | 126.0±22.4 |
| Time for running between 2 check points (Sec) | 4.6±0.4 | 4.2±0.6 | 3.6±0.4 | 3.3±0.4 | 3.5±0.6 |

* Standard error

**Table 4.** Total score, total error score, retrace error score, blind path score, time score, time for running between 2 check points for mature ddY mice (Group IV).

| Trial number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Number of animals | 5 | 5 | 5 | 5 | 4 |
| Total score | 71.8±16.2* | 52.6±11.1 | 52.0±21.6 | 43.0±10.8 | 24.5±3.5 |
| Total error score | 39.4±10.7 | 26.6±7.9 | 26.6±14.0 | 20.0±7.7 | 7.3±2.4 |
| Retrace error score | 18.4±6.1 | 11.6±3.8 | 12.6±8.9 | 9.2±3.7 | 2.3±1.1 |
| Blind path score | 21.0±4.7 | 15.0±4.2 | 14.0±5.2 | 10.8±4.0 | 5.0±1.4 |
| Time score (Sec) | 261.5±51.5 | 171.2±33.1 | 141.5±51.6 | 132.2±32.5 | 84.9±26.0 |
| Time for running between 2 check points (Sec) | 3.9±0.5 | 3.3±0.3 | 3.0±0.2 | 3.1±0.4 | 3.1±0.5 |

* Standard error

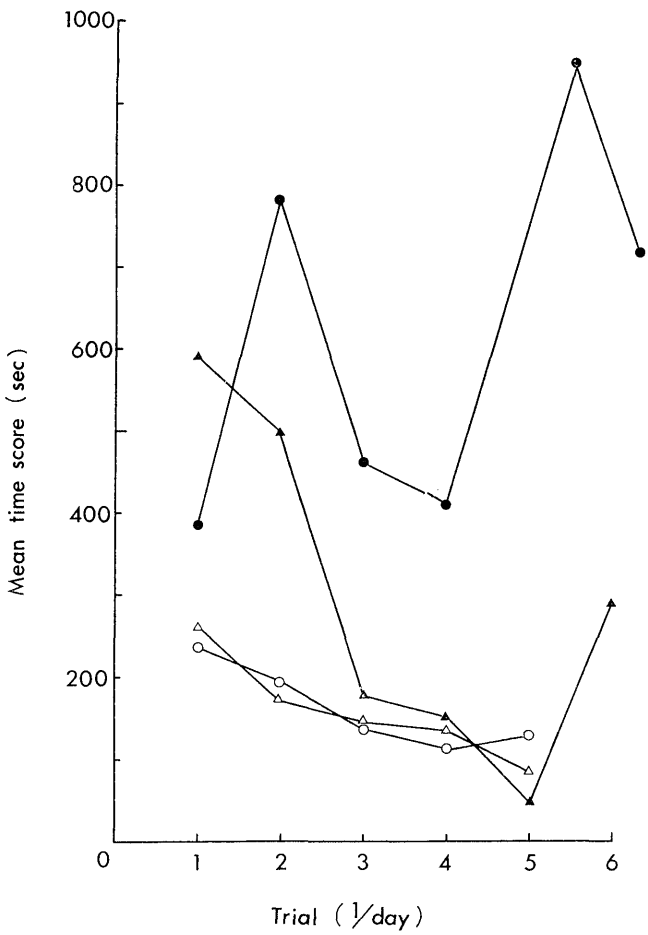


**Fig. 3.** Mean time scores obtained by Mol-M and ddY mice.
● Young Mol-M (Group I), ▲ mature Mol-M (Group II),
○ Young ddY (Group III), △ mature ddY (Group IV).

path scores obtained by Group I, II, III and IV for the 5 or 6 daily test trials were given in Table 1, 2, 3 and 4. The three types of errors plotted as a function of trials (learning curves) were not shown as Figures, because the patterns of those learning curves did not different basically from that for mean total scores.

3. Mean time score

Mean time scores obtained by the young mice in Group I and the mature mouse in Group II for the 6 daily test trials were given in Table 1 and 2, and Figure 3. On the initial trials, the mice in both group I ant II made higher score than the mice in Group III and IV. The mean score for the young mice was 1.6 times and that for the mature mouse was 2.3 times as much as the scores for the young and mature mice of Group III and IV respectively.

After the 2nd trial, the scores for the young mice increased and reached to a score, 744.6 sec, about 7 times the score of the mice in Group III on the final trial, though the scores on Trials 3 and 4 fell to the level of that on the initial trial. The scores for the mature mouse markedly decreased to the levels of those for Group III and IV

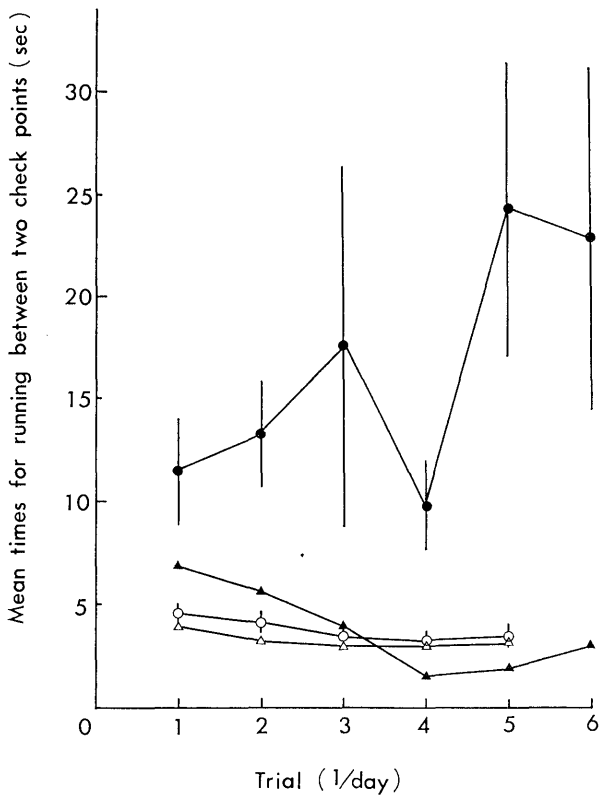


**Fig. 4.** Mean times for running between two check points obtained by Mol-M and ddY mice.
● Young Mol-M (Group I), ▲ mature Mol-M (Group II),
○ Young ddY (Group III), △ mature ddY (Group IV)
Vertical bars indicate standard error

after Trial 2 with relative increase of the score on the final trial.

Mean time scores obtained by the young in Group III and the mature mice in Group IV for the 5 daily test trials were given in Table 3 and 4, and Figure 3. The scores for both young and mature mice decreased with every trial. On all taials, differences between young and mature group were not significant.

4. Mean time for running between two check points

Mean times for running between two check points obtained by the young mice in Group I and the mature mouse in Group II for the 6 daily test trials were given in Table 1 and 2, and Figure 4. This value for the young mice on the initial trial was higher than those for the mature one and the mice in Group III and IV. The values increased with every trial from Trial 2 except those on Trial 4 and 6 (decrease of the value was slight on Trial 6). On the other hand, the values for the mature mouse decreased rather markedly with every trial and reached to the lower value than those for the mice in Group III and IV on Trial 4 and then slightly increased on Trial 5 and 6.

Mean times for running between two check points obtained by the young mice in Group III and the mature mice in Group IV for the 5 daily test trials were given in Table 3 and 4, and Figure 4. The values for the mice in both groups were lower than those for the mice in Group I and II on the initial trials and then decreased very slightly during the early trials. During the later trials, those values did not change. Age difference were not statistically significant. However, the differences between Group I and Group III were statistically significant.

## DISCUSSION

Maze-learning ability of young and mature ddY mice and Mol-M mice were examined using 16-unit T-maze for the 5 or 6 daily test trials.

For the young and mature ddY mice, six different kinds of scores decreased with every trial. Although those scores for the young mice tended to be lower than those for the mature, differences between those for both mice were not statistically saignificant. GOODRICK[2] claimed that the complex maze, 14-unit T-maze was useful to obtain age differences between mature-young and aged rats. The rats used in his experiment were 6-month and 26-month-old. The present study may support his findings because the young mice tended to learn a 16-unit T-maze better than the older mice, although difference of age between the both was only about 3 months.

The yound and mature Mol-M mice did not show the consistent scores through all test trials. For both mice, the six different kinds

of scores tended to be higher than those for ddY mice. However, the total scores for the young mice were on the same levels as those for ddY mice in the early phase of test trials. In addition, the time scores for the mature mouse decreased to the same level as those for ddY mice, although those for the young increased through test trials.

Time for running between two check points on the maze showed remarked differences between young, mature Mol-M mice and ddY mice. This value for the young Mol-M mice on the initial trials was markedly higher than those for the mature one and the ddY mice. In addition, the value for the former animals mostly increased with every trial. On the other hand, the value for the animals in the latter three groups decreased in the early phase and mostly did not change in the later phase of test trials.

The results indicated that the performance of the young Mol-M in the maze became dull and slow with every test trial and that of the mature one was quick but ineffective to reach the goal, although the young and mature ddY mice learned a 16-unit T-maze effectively. It cannot be decided, however, that the intelligence of the Mol-M mice is low, by the inferior performance in the maze. It seems likely that the mice, which still keep wild characteristics, possibly perform according to the motivations different from those of well established laboratory mice such as a hunger motivation. The prominent exploratory behavior of the mature Mol-M mouse may result in the inferior performance in the maze. The motivation to hide or stay at a place may overwhelm the hunger motivation in young wild animals. The change of social pattern, living in a single cage from living as a colony, may influence their behaviors in the maze.

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## REFERENCES

1) FURCHTGOTT, E.: *Psychol. Bull.*, 160 : 157, 1963.
2) GOODRICK, G. L.: *J. Gerontol.*, 27 : 353, 1972.
3) NISHIMURA, M., KONDO, K., NAKAMURA, H. and WATANABE, T.: *Proc. ICLA Asian Pacific Meeting on Laboratory Animals*, 187, 1971.
4) MCGREGOR, J. F. and NEWCOMBE, H. B.: *Radiat. Res.*, 17 : 465, 1962.
5) URMER, A. H. and BROWN, W. L. : *J. Gen. Psychol.*, 97 ; 67, 1960.