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The Effects of Shock Intensity and Response-Shock Interval upon Avoidance Learning of Rats in a Rotating Cage

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Compared to lever-press avoidance learning, easy and quick learning is expected when a running response which is a part of the "Species-specific defense reactions (SSDRs)" (1) i.e., fleeing, is used as an avoidance response (4,5). However, even in the running-wheel situation, some rats were discarded due to failure to respond (2). Rats might avoid a shock by crouching to the same pole of the grid, because a nonscrambled shock generated by a slipring commutator was used. This suggested the possibility of promoting avoidance learning if a scrambled shock is introduced. However, such studies using a running response in a rotating cage have been little attempted, because of the complexity of the mechanism to transmit a scrambled shock to the rotating grid.

Recently, ISO (3) attempted to improve the rotating cage, and reported effective Sidman-avoidance learnings in rats. A newly designed shock-transmitter mechanism was attached to the cage, and the scrambled shock was delivered on the grid. In the three experiments, response-shock (R-S) interval was 20 sec, shock-shock (S-S) interval was 5 sec, a shock duration was 0.5 sec and the shock intensity was 200 V AC. Then, in experiment 1, the magnitude of rotation to be counted as a response was tested in three times of 1 hr sessions. Rats learned more quickly in a quarter turn condition than a half condition. In experiment 2, the maintenance of learning over sessions was tested. Rats showed some superior maintenance of avoidance response without over-night decrement for consecutive 8 days. In experiment 3, the continuation of avoidance responses through a long session was examined. Avoidance responses were continued until the end of the session over 6 hours, and rats ran a mean of 1544 m with a mean of 42 shocks during 6 hours. Such results indicated the utility of the rotating cage for the avoidance learning in rats.

Then, in the present experiment, the effects of shock intensity and R-S interval which are the basic variables to affect the avoidance learning, on Sidman-avoidance learning in rats are tested using the same apparatus as ISO (3).
Method

Subjects: Thirty-six male 6-week-old Wistar rats, purchased from Kitayama Labesu Co., were housed individually and maintained on food (MF chow, Oriental Yeast Co.) and water ad libitum for 30 days. Their mean ±SD body weight at the start of the experiment was 328.3 ± 15.3 g.

Apparatus: Two identical rotating cage apparatus which were the same as ISO (3) were used. The cage was constructed with plexiglas, having inside width of 12 cm, and a diameter of 36 cm. The wheel required a force of approximately 20 g applied tangentially to start it moving. The wheel turned in either direction, but the continuous action of the same switch by the swinging of the wheel was prevented. A quarter turn for the circumferential running distance of 28.26 cm was needed to be one response.

The AC shock was charged with a 250 k ohm current-limiting resistor put in series with the grid. The rotating cage was placed in a wooden sound proof box, which was illuminated inside by a 100 V 10 W lamp.

Procedure: The rats were divided into 6 groups of the same mean body weight. Each group was assigned to one of six conditions (100-10, 100-20, 200-10, 200-20, 300-10 and 300-20) of three different shock-intensities (AC 100, 200 and 300 V) and two different response-shock (R-S) intervals (10 and 20 sec). All the rats underwent one habituation, two Sidman-avoidance training and one extinction sessions, and each session was separated by a week. In habituation, the rat was confined in the rotating cage for 60 min without shock, and operant level was recorded. In the avoidance-training sessions, the rat was put in the rotating cage and left there for 5 min as a warming-up period. Then, avoidance training was started and continued for 60 min. The shock-shock (S-S) interval was 5 sec. A shock duration was 0.5 sec. In extinction, after 5 min of warming-up period, avoidance re-training was conducted for 20 min. Then, 60 min of extinction was started. At the start of the extinction, no stimulus was changed except the omission of the shock.

Results

Figure 1 shows the cumulative records of two animals in both group 300-10 (No.77, left) and group 300-20 (No.71, right) as typical examples. The figures are presented in order of the sessions from top to bottom. In habituation (H), the rats responded well at
the first stage of the session, but the response was mitigated gradually in the course of time. In the first training (T1), both the rats responded hardly throughout the session. A greater number of responses were observed in the 10 sec R-S interval condition (left) than 20 sec condition (right). In the second training (T2), the tendency of respondings was the same as that in T1, and the rats maintained the avoidance responses which had been learned in T1 and less shocks were recorded in T2. In the fourth session, at first the rat experienced re-training (RT) for 20 min. Then, extinction (E) for 60 min was started continuously. In the RT, the rat responded as well as it did in T2. In the E, the response was reduced gradually with the lapse of time. In the 200 V condition the same tendency was observed but it was not evident in the 100 V condition.

Figure 2 shows the mean number of responses per 60 min in the habituation (operant level), two avoidance trainings and extinction. In the trainings, a greater number of responses were recorded than in habituation. Analysis of variance [Type 3, Lindquist, (7)] on two trainings revealed that the main effect of shock intensity (I) was highly significant \[F(2/30) = 13.68, p < 0.001\], but the main effect of R-S interval (R) \[F(1/30) = 2.15\] and the interaction between I and R \[F(2/30) = 1.27\] were not significant. The
main effect of session (S) and the interaction between I and S were significant \[ F(1/30) = 29.38, p<0.001 \] and \[ F(2/30) = 3.77, p<0.05 \], respectively, but the interaction between R and S, and the interaction between all factors were not significant \[ F<1 \]. Except for the 100 V condition, in both the 200 V and the 300 V conditions, it seemed that the rats responded more frequently at 10 sec R-S interval than at 20 sec. Then, comparisons were made between the two R-S interval conditions with respective shock intensity and day. A significantly greater number of responses were recorded in the 10 sec condition only in T1 of 200 V \[ t(10) = 3.22, p<0.01 \]. For extinction, analysis of variance was performed. The main effect of shock intensity (I) was significant \[ F(2/30) = 17.07, p<0.001 \], but the main effect of R-S interval and the interaction between them were not significant \[ F<1 \] and \[ F(2/30) = 2.14 \], respectively. In extinction, all the groups in the 200 V and 300 V conditions showed significantly greater levels of responding than the operant level (200-10: \( t (5) = 6.73, p<0.005 \), 200-20: \( t (5) = 4.11, p<0.01 \), 300-10:
Avoidance Learning of Rats in a Rotating Cage.

$t(5) = 2.89, p < 0.05$ and $t(5) = 4.32, p < 0.01$. However, group 100-20 did not show a significant difference [$t(5) = 1.13$] and group 100-10 showed a lesser level of responses in extinction than the operant level [$t(5) = 2.60, p < 0.05$].

In the two trainings and one extinction, the rats ran hard. Figure 2 also indicates the running distance. During the training sessions, the running distance ranged from 200 m to 500 m in one hour. Such hard works reduced their body weight more than in the habituation. In habituation, the rats lost a mean ± SEM of 3.67 ± 0.45 g. In the two trainings and one extinction, the rats reduced their body weight by means ± SEM of 7.75 ± 0.44 g, 7.56 ± 0.45 g and 7.44 ± 0.56 g. The total body weight loss exceeded the total weight of urination and defecation (1.94 ± 0.52 g, 4.62 ± 0.65 g, 3.67 ± 0.50 g and 2.94 ± 0.32 g, respectively).

Figure 3 shows the mean number of shocks received during two trainings. Analysis of variance over this figure revealed that all the main effects were highly significant; the effect of R-S interval (R) [$F(1/30) = 40.89, p < 0.001$], the effect of shock intensity (I) [$F(2/30) = 7.31, p < 0.005$] and the effect of session (S) [$F(1/30) = 69.13, p < 0.001$]. The interactions between the R and I effects and between the I and S effects were

\[ \text{Figure 3. Mean ± SEM number of shocks received in the two training sessions (T1 and T2).} \]
significant \( F(2/30) = 6.31, p < 0.01 \) and \( F(2/30) = 4.15, p < 0.05 \), respectively]. But other interactions were not significant \( [R \times S : F(1/30) = 2.57 \text{ and } R \times I \times S : F < 1] \).

Figure 4 shows the mean percentages of interresponse times (IRTs) for each time unit (5 sec) during T 1 (white bars) and T 2 (black bars) in the 6 groups, respectively. The percentages of responses which have the same IRTs in T 1 and T 2 were compared for each unit of IRTs. The responses with longer IRTs increased in T 2.

**Figure 4.** The percentages of interresponse times; the number of interresponse times (IRTs) in each time unit (5 sec), divided by the total number of IRTs during each session and multiplied by 100. White bars indicate the distribution in training 1 and black bars indicate the distribution in training 2.
Discussion

As a running response is a part of the SSDRs (1), i.e., fleeing, the rats achieved easy and quick learning during the single 1-hr session and maintained it over one week without decrement. Then, it is proved that the present rotating cage was effective over a wide range of experimental variables which affected the avoidance learning in rats. In most of the lever-press situations, rats frequently failed to avoid shocks even after many training sessions (SIDMAN 9,10), and number of shocks received was usually expressed in terms of a minutely value (e.g., KURIBARA et al. 6). In the present situation, the shocks received counted far less and, therefore, could be expressed in terms of an hourly value. The number of shocks received as shown in Fig. 3 represented more clearly the development of learning than the number of responses shown in Fig. 2. In the 20 sec R-S interval condition, all the animals learned avoidance responses well and the mean number of shocks received in the second training session was reduced to less than 15 per hour (100 V: 12.8 shocks, 200 V: 4.8 shocks and 300 V: 7.0 shocks).

The effect of R-S interval was not distinctly determined, though SIDMAN (9,10) reported that the number of responses increased with a decrease in the R-S interval except only in the condition of 200 V on T1. Continuous running in all the groups might have concealed the effect. However, the effect of R-S interval on the number of shocks received was significant, demonstrating a higher frequency of shocks in the 10 sec groups than 20 sec groups. The shock intensity produced a significant effect, demonstrating a higher frequency of avoidance responses in the intermediate 200 V condition, while the development of avoidance learning was retarded in the high shock intensity condition in the shuttle box (SHISHI and IMADA, 8). In the 100 V condition, the rats received a greater number of shocks. This is because responses occurred after exposure to some shocks at some S-S intervals after termination of the R-S interval. This effect was observed in the analysis of the IRT distributions shown in Fig. 4. With the 200 V and 300 V shocks, most of the rats responded with one shock after termination of the R-S interval.

The IRTs in Fig. 4 also indicate that the rats acquired timing behavior. Compared to T1 (white bars), the responses with longer IRTs than R-S interval decreased in T2 (black bars). Then instead of a decrease in the responses which have 0-5 sec IRTs, the percentages of responses with 5-10 sec IRTs increased.

The present avoidance responses were characterized by quick learning with a little individual differences and long preservation over a week. These characteristics would be useful in the applicatory fields of avoidance behavior. Continuous response with running a distance of more than 300 m for 1 hr under the avoidance schedule indicates that this
situation may be used as a tool for animals to exercise.

REFERENCES

1. Bolles, R.C. Species-specific defense reactions. In F.R. Brush (Ed.), Aversive conditioning and learning. 1971, New York: Academic Press.

2. Bolles, R.C., Stokes, L.W., & Younger, M.S. Does CS terminataion reinforce avoidance behavior. Journal of Comparative and Physiological Psychology, 1966. 62, 201-207.

3. Iso, H. On some improvement of the rotating cage apparatus for avoidance training and a series of pilot experiments using the revised apparatus with rats. The Annual of Animal Psychology, 1984, 34, 61-73, (in Japanese).

4. Keehn, J.D. The effect of warning signal on unrestricted avoidance behavior. British Journal of Psychology, 1959, 50, 125-135.

5. Keehn, J.D. Running and bar pressing as avoidance responses. Psychological Reports, 1967, 2, 591-602.

6. Kuribara, H., Okuzumi, K., & Tadokoro, S. Analytical study of acquisition of free-operant avoidance responses for evaluation of psychotropic drugs in rats. Japanese Journal of Pharmacology, 1975, 25, 541-548.

7. Lindquist, E.F. Design and analysis of experiments in psychology and education. 1953, Boston: Houghton Mifflin Company.

8. Shishimi, A., & Imada, H. The effects of US intensity upon avoidance conditioning in the shuttle-box. Japanese Journal of Psychology, 1972, 43, 167-175, (in Japanese).

9. Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. Science, 1953, 118, 157-158.

10. Sidman, M. Avoidance behavior. In W.K. Honig (Ed.) Operant behavior: Areas of research and application. 1966, New York: Appleton Century Crofts.

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Abstract

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Sidman-avoidance learning of Wistar rats as a function of shock intensities (100, 200 and 300 V AC) and response-shock (R-S) intervals (10 and 20 sec) was examined in a newly designed rotating cage [ISO (3)]. The shock-shock (S-S) interval was fixed at 5 sec with a shock duration of 0.5 sec. One habituation, two avoidance trainings and one extinction were continued for one hour each. Such sessions were split weekly. All the rats learned avoidance responses easily, especially well in the condition of 20 sec R-S interval with a shock intensity of 200 V.