Bulletin of the Psychonomic Society
1989, 27 (2), 149-152

Free-operant discriminated avoidance in the rat

ARNOLD HYMAN
University of New Haven, West Haven, Connecticut

A procedure involving the use of free-operant discriminated avoidance in monkeys was replicated with white rats. Each rat was exposed to a series of avoidance schedules, in which the safe-stimulus duration was held constant and the warning-stimulus duration was systematically varied. Of the 6 rats in the study, 3 were exposed to the warning-stimulus durations in ascending order (shortest duration first), and 3 in descending order (longest duration first). The rats generally showed higher shock rates and lower response rates than the monkeys.

Brogden (1969) and Krieckhaus and Wagman (1967) appear to be the only reports in the literature that compare the performance of different orders of animals on an avoidance task. Brogden compared cats, dogs, and rabbits, whereas Krieckhaus and Wagman compared chickens, rats, and cats. Other reports compare the avoidance behavior of two or more species of rodents (e.g., Deni, Budzek, McDermott, Silvers, & Costantini, 1981), or two strains of rats (e.g., Powell, 1972).

In light of the differences in avoidance behavior among species found by Brogden (1969) and by Krieckhaus and Wagman (1967), a comparison of rats and monkeys would be of particular interest. No such reports have appeared to date. Consequently, in the present experiment rats were used in an attempt to replicate a study of avoidance behavior in the squirrel monkey (Hyman, 1971).

METHOD

Subjects

The subjects were 6 male Holtzman rats, ranging in weight from 284 to 440 g at the beginning of the experiment. They were housed in individual cages in a windowless room with a 12:12-h light:dark cycle; they were fed Purina Rodent Chow and given water on an ad-lib basis.

Apparatus

An experimental chamber manufactured specifically for rats by the BRS/LVE Co. (No. RTC-022) was employed. It was placed in a sound-insulated cubicle. The floor was a shock grid. The front contained a lever that activated a microswitch, three cuelights, a speaker, a Sonalert whistle (Model SC628), and a houselight. Grid shock was delivered by a shock source/scrambler (BRS/LVE No. SGS-004). White noise was piped into the experimental chamber. The warning signal (WrS) was created by passing 24V DC, attenuated by a 35-kΩ resistor, through the Sonalert. This resulted in a 2550-Hz tone, which raised the sound level in the chamber from 78-80 dB to 85-86 dB. Recording and control of the experiment were accomplished with a mixed system of electromechanical and solid-state modules.

Procedure

Free-operant discriminated avoidance was employed. A response (leverpress) postponed a due shock for the value of the response-shock interval (or cycle length). The time between two successive shocks if a response did not occur, sometimes referred to as the shock-shock interval, was in all cases the same as the response-shock interval. The response-shock interval was fractionated into the safe stimulus and the WrS. Following a response or a shock, the WrS onset occurred at the end of a time interval specified by the safe-stimulus value, and each shock followed an interval specified by WrS duration. A response during the safe stimulus postponed both the WrS and the shock, while a response during the WrS terminated it and postponed the shock.

Five avoidance schedules were employed. The safe stimulus was held constant at 4 sec throughout the study, while the WrS was assigned values of 16, 8, 4, 2, and 1 sec. Each change in WrS duration concomitantly changed the cycle length, which therefore assumed values of 20, 12, 8, 6, and 5 sec. Schedules will be referred to by WrS duration value. An attempt was made to replicate a procedure previously employed with monkeys (Hyman, 1971), in which all the subjects were exposed to all the WrS durations. For 3 subjects in that study (the ascending group), the durations were presented in ascending order (1, 2, 4, 8, and 16 sec); for the other 3 (the descending group), a descending order (16, 8, 4, 2, and 1 sec) was employed. An exact replication of this procedure with the rats did not prove to be feasible, largely because of the occurrence of stress reactions in the rats.[1] The principal modification made was to omit the 1-sec WrS for ascending group Rats 53 and 76, and to present it last to Rat 34. However, these 3 animals did receive their initial shaping with the 1-sec WrS. The descending group rats, Nos. 35, 51, and 52, were exposed to all WrS durations.

Eight sessions of steady-state data were collected for each subject at each WrS duration to which that subject was exposed, with two exceptions (see Table 1). A minimum of the first eight sessions at each cycle length was routinely set aside as transition behavior. More time was allowed if trends continued to appear in response rate or proficiency ratio.

At the end of the experiment, several of the rats were re-exposed to the initial schedule to which they had been assigned, in order to find out if the original proficiency ratios could be recovered. In the descending group, rats 35 and 51 were re-exposed to the 16-sec WrS. However, this was not possible for Rat 52, because of a stress reaction. Of the ascending group rats, Rat 53 was re-exposed to the 2-sec WrS, but Rat 76 was not, again because of a stress reaction. As stated above, Rat 34 was assigned the 1-sec WrS in lieu of a recovery attempt.

The rats were initially trained to press the lever by the standard shaping procedure. The schedule used for training the descending group was the first one assigned to that group in the experiment—the 16-sec WrS schedule. However, the ascending group, as previously stated, was trained with the 1-sec WrS in order to give them some experience with that schedule.

At the beginning of training, the shock intensity was set at a level of 0.5 mA in order to reduce stress and preclude freezing on the part of the rats. As training progressed, the current was increased by .125-mA steps, until the target level of 1.0 mA was reached. When ac-

This research was supported by a Summer Stipend and other funds from the University of New Haven. The author wishes to thank John Gianutsos, Michael York, and Thomas Mentzer for their critical reading of the manuscript. Technical assistance was rendered by Andrew Kaplan, Sherry Lantz, Steven Jex, and Ellen Kulak. The secretarial assistance of Beverly Blanchard is gratefully acknowledged. Reprint requests should be sent to Arnold Hyman, University of New Haven, 300 Orange Avenue, West Haven, CT 06516.

quisition of the barpress was complete, 1-h sessions were used for the remainder of the study. The rats were run once a day, 5 days per week, at about the same time each day. The start of the session was signaled by turning on the houselight, the end of the session by turning it off.

RESULTS

Performance Measures

The mean response rates for each rat at each schedule are shown in Table 1. Functions based on the combined means for both groups are plotted in Figure 1. The functions were similar for both groups of rats. Response rate was inversely related to WrS duration.

The proficiency ratio, given in two decimal places, represents the proportion of potential shocks that have been avoided. The formula for proficiency ratio is written as follows: (maximum no. shocks − shocks received)/maximum no. shocks. The maximum number of shocks represents the number of shocks that a rat would receive during a 1-h session if it did not respond at all.

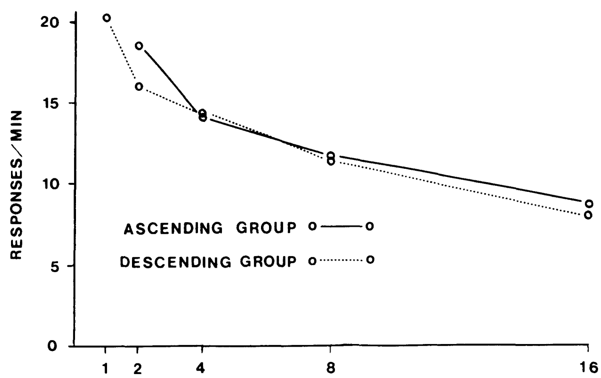

Figure 1. Responses per minute as a function of warning-signal (WrS) duration. Each point represents a group mean for all steady-state sessions.

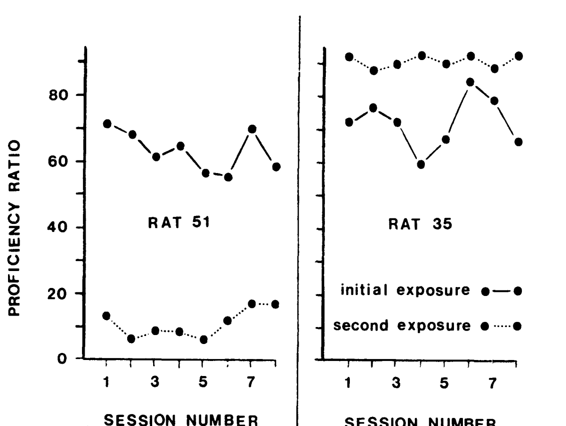

Figure 2. A comparison of the proficiency ratios for the initial exposure and second exposure to the 16-sec warning-signal (WrS) duration, for Rats 51 and 34. Each point represents the ratio for a single-state session.

Table 1
Responses per Minute: Rats

WrS Duration (sec)	Ascending Group 76	Ascending Group 34	Ascending Group 53	Descending Group 35	Descending Group 52	Descending Group 51
1				22.4	21.9†	16.2
2	6.6*	31.4	17.5	17.9	19.6	10.8
4	8.4	17.2	16.5	12.4	13.4	17.4
8	7.2	14.6	10.9	10.6	10.5	13.2
16	8.3	8.8	9.2	8.4	6.9	8.7

Note—Each entry is the mean response rate for the eight steady-state sessions unless otherwise indicated. *Based on four sessions. †Based on six sessions.

This measure has been adapted from a similar measure called "proficiency of avoidance" by Hurwitz and his coworkers (Hurwitz & Bounds, 1968; Hurwitz & Herrmann, 1984). It permits direct comparison of performance efficiency among the different avoidance schedules employed in the study.

Individual proficiency ratios for each schedule are listed in Table 2. The results are mixed: two different patterns may be seen. Rats 51, 52, 53, and 76 had higher ratios for the "easier" schedules—those with longer WrS durations. Rats 51 and 76 show this to a very marked degree. For the other two rats, 34 and 35, the ratio was not related to WrS duration. Also note that the pattern shown by a particular rat was not determined by the order in which the WrS durations were presented (ascending or descending).

In most sessions where the proficiency ratio was very low, notably with Rats 51 and 76, it was combined with a substantial, or even high, response rate. This combination occurred because of a recurrent pattern of responding: the animal pressed the lever, sometimes several times, just after receiving a shock, and then did nothing until immediately after the next shock, when it again responded, and so on.

Regarding the recovery attempts at the end of the experiment, the main focus was on the proficiency ratio. The exposure of Rat 34 to the 1-sec WrS duration will also be considered here, since it constituted a return to a short WrS after exposure to long warning stimuli. The results were mixed. In the descending group, in which the 16-sec WrS was re-employed, Rat 51 showed markedly lower proficiency ratios during the recovery attempt as compared to the initial exposure, while Rat 34 showed a modest increase in proficiency (see Figure 2). In the ascending group, the proficiency ratios of Rat 53 were not significantly different in the second exposure to the 2-sec WrS from what they were in the initial exposure. The proficiency ratios of Rat 34 for the 1-sec WrS were in the same range as they were for all the other schedules to which he was exposed. The Mann-Whitney *U* test was used to test all the recovery data.

Stress Reactions

Rat 51 developed what may be called an "experimental neurosis," for lack of a better term, during his exposure to the 2-sec warning stimulus. For the 1st session

Table 2
Proficiency Ratios: Rats

WrS Duration (sec)	Ascending Group			Descending Group		
	76	34	53	35	52	51
1				.73	.47†	.14
2	.14*	.80	.69	.81	.57	.19
4	.24	.75	.71	.74	.69	.76
8	.26	.79	.87	.77	.67	.77
16	.60	.77	.80	.73	.73	.64
Recovery attempts		.72	.71	.91		.11

Note—Each entry is the ratio for the eight steady-state sessions unless otherwise noted. *Based on four sessions. †Based on six sessions.

Table 3
Responses per Minute: Monkeys

WrS Duration (sec)	Ascending Group			Descending Group		
1	25.3	48.1	68.3	29.7	26.4	25.7
2	20.4	32.2	73.2	30.3	19.5	30.3
4	17.2	15.5		32.7	17.5	
8	16.4	18.8	64.1	27.5	16.8	27.2
16	12.8	17.5	20.1	18.1	12.0	18.1

Note—Each entry represents the mean rate for the eight steady-state sessions for one animal. Missing entries indicate that no data are available.

Table 4
Proficiency Ratios: Monkeys

WrS Duration (sec)	Ascending Group			Descending Group		
1	.99+	.99+	.99	.98	.95	.93
2	.99	.99+	.99+	.99+	.99+	.95
4	.99+	.99+		.99+	.99+	
8	.99+	.99+	1.00	.99+	.99	.99+
16	.99+	.99+	.99+	.99+	.99+	.99+

Note—Each entry is the ratio for one animal for the eight steady-state sessions. Missing entries indicate that no data are available.

on this schedule his proficiency ratio was .80. By the 10th session the ratio had fallen to .18. Periods of total nonresponding were observed, as well as the pattern previously described: pressing the lever just after receiving shocks. Two other stress reactions occurred.[1]

DISCUSSION

Table 3 shows the response rates of the monkeys in Hyman (1971). Ten separate comparisons can be made between these animals and the rats in the present study, for each of the 10 combinations of warning stimulus duration and presentation order.[2] With two exceptions, all of the monkeys at a particular combination had higher response rates than all of the rats for that same combination. The exceptions are in the 4-sec ascending combination and the 2-sec descending combination, for which the rat and monkey rates overlap. The exceptions do not form a pattern, and it can be safely stated that the monkeys generally had higher response rates than the rats. This was due in part to the warm-up effect, a period of decreased proficiency at the beginning of a session, which was observed frequently in the rats, but never in the monkeys.

Table 4 shows the proficiency ratios for each monkey. A comparison with Table 2 shows that in both groups, for all schedules, the rats have lower proficiency ratios than the monkeys. In fact, there is no overlap at all between any of the rat ratios and any of the monkey ratios. Again, the warm-up effect in the rats contributed to this result.

An attempt must be made to account for the low proficiency of the rats as compared to the monkeys. The generally higher rate of responding of the monkeys cannot be accepted as a causal factor; it is a correlate of the higher proficiency ratios. Furthermore, as with Rats 51 and 76, high response rates may even be paired with low proficiency.

Preparedness theory (Seligman, 1970) and the related concept of species-specific defense reactions (Bolles, 1970) suggest a possible analysis. One would postulate that it is not "natural" for a rat to press a lever to avoid a noxious stimulus; such a response is *unprepared* according to the Seligman classification. Although this analysis is not without controversy (see, e.g., Berger & Brush, 1975), it seems to be a useful theoretical framework for comparing rats with monkeys. Regarding the monkeys, the case can be made that the monkey is a naturally manipulative animal with a great deal of dexterity, for whom barpressing is a *prepared* response. Indeed, instances of tool utilization by nonhuman primates (though not specifically *Saimiri sciureus*) have been reported (Van Lawick-Goodall, 1970).

Another useful explanation for the rats' relative inefficiency centers on the issue of emotionality. It is well known that high levels of emotionality—in the present case, fear or anxiety due to the reception of shocks—disrupt or disorganize behavior (Navarick, 1979). The reception of a shock would adversely affect the rat's ability to avoid subsequent shocks, sending the rat into a vicious cycle of recurring shocks and increasing anxiety, leading to an inefficient performance. More specifically, what is disrupted is the rat's timing ability, referred to in earlier work as "temporal discrimination" (Anger, 1963; Sidman, 1954, 1966), and more recently as an internal clock (Church, 1984).

The superior performance of rats in discrete-trial as opposed to free-operant avoidance would support the notion that anxiety or fear was disrupting the rats' timing. In discrete-trial avoidance, the intertrial interval would, theoretically, give the rat some time to "calm down" after the reception of a shock. This would tend to minimize the destructive effects of fear or anxiety on the animal's timing ability on the next trial. No such opportunity is available to rats in free-operant avoidance. This analysis is supported by the findings of Berger and Brush (1975). Their rats learned barpress avoidance in a discrete-trial paradigm quite efficiently, without any shaping. Most notable for the present discussion, a relatively long, 5-min, intertrial interval was used, and a conspicuous "safety" signal—flashing lights—was present throughout the entire intertrial interval. Both of these factors would tend to reduce fear or anxiety during the intertrial interval.

There is also evidence that learned helplessness, originally reported by Seligman and associates (Overmier & Seligman, 1967; Seligman & Beagley, 1975; Seligman & Maier, 1967), played a part in the rats' low proficiency ratios, most obviously in some of the very low ones. The re-exposure of Rat 51 to the 16-sec WrS offers a striking example. In the original exposure, his proficiency ratios for this schedule ranged between .56 and .71; in the second exposure, between .06 and .17. This animal's proficiency ratio took a precipitous drop during exposure to the 2-sec WrS, and it never recovered. If not for the attempted recovery, the rat's continued inefficiency could have been seen as a function of working under a "difficult" schedule (short WrS). But, the failure to recover previous proficiency ratios during re-exposure to the 16-sec WrS favors a helplessness interpretation, despite the fact that the analogy is imperfect: *learned helplessness* is defined as the proactive interference on avoidance behavior of previous exposure to inescapable shocks. Obviously, the rats in the present study were never exposed to inescapable shocks. However, it is not unreasonable to assume that, since the rats consistently failed to avoid all potential shocks, the shocks were inevitable from their point of view. Furthermore, Rat 51 was a descending group animal, and was, therefore, exposed to a progressively shortened WrS duration, a factor that made his task progressively more difficult. Other instances of learned helplessness may have occurred, particularly with Rat 76, but they cannot be so clearly brought out.

It is important to realize that the three explanations that have been proposed for the rats' relative inefficiency at the avoidance task—preparedness theory, emotionality, and learned helplessness—are not mutually exclusive. It is reasonable to conclude that all three of these factors contributed to the rats' inefficiency in performing the avoidance task.

REFERENCES

Anger, D. (1963). The role of temporal discriminations in the reinforcement of Sidman avoidance behavior. *Journal of the Experimental Analysis of Behavior*, **6**(Suppl.), 477-506.

Berger, D. F., & Brush, F. R. (1975). Rapid acquisition of discrete-trial lever-press avoidance: Effects of signal-shock interval. *Journal of the Experimental Analysis of Behavior*, **24**, 227-239.

Bolles, R. C. (1970). Species-specific defense reactions and avoidance learning. *Psychological Review*, **77**, 32-48.

Brogden, W. J. (1969). Acquisition of conditioned avoidance response by cats, dogs and rabbits. *Journal of Comparative & Physiological Psychology*, **68**, 343-347.

Church, R. M. (1984). Properties of the internal clock. In J. Gibbon & L. Allen (Eds.), *Timing and time perception: Annals of the New York Academy of Sciences*. (Vol. 23, pp. 566-582).

Deni, J., Budzek, L., McDermott, J., Silvers, M., & Costantini, F. (1981). Acquisition of leverpress shock avoidance in juvenile Norway rats and spiny mice. *Bulletin of the Psychonomic Society*, **18**, 111-112.

Hurwitz, H. M. B., & Bounds, W. (1968). Response specification and acquisition of free operant avoidance behavior. *Psychological Reports*, **23**, 483-494.

Hurwitz, H. M. B., & Herrmann, T. F. (1984). The ineffectiveness of shock avoidance under short and long R-S intervals. *Animal Learning & Behavior*, **12**, 350-354.

Hyman, A. (1971). Sequential effects on latency and other indices in free operant discriminated avoidance. *Psychonomic Science*, **23**, 38-40.

Krieckhaus, E. E., & Wagman, W. J. (1967). Acquisition of the 2-way avoidance response in chicken compared to rat and cat. *Psychonomic Science*, **8**, 273-274.

Navarick, D. J. (1979). *Principles of learning: From laboratory to field*. Reading, MA: Addison-Wesley Publishing Co.

Overmier, J. B., & Seligman, M. E. P. (1967). Effects of inescapable shock upon subsequent escape and avoidance learning. *Journal of Comparative & Physiological Psychology*, **63**, 23-33.

Powell, R. W. (1972). Analysis of warm-up effects during avoidance in wild and domesticated rodents. *Journal of Comparative & Physiological Psychology*, **78**, 311-316.

Seligman, M. E. P. (1970). On the generality of laws of learning. *Psychological Review*, **77**, 406-418.

Seligman, M. E. P., & Beagley, G. (1975). Learned helplessness in the rat. *Journal of Comparative & Physiological Psychology*, **88**, 535-541.

Seligman, M. E. P., & Maier, S. F. (1967). Failure to escape traumatic shock. *Journal of Experimental Psychology*, **74**, 1-9.

Sidman, M. (1954). The temporal distribution of avoidance responses. *Journal of Comparative & Physiological Psychology*, **47**, 399-402.

Sidman, M. (1966). Avoidance behavior. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 448-498). New York: Appleton-Century-Crofts.

Van Lawick-Goodall, J. (1970). Tool-using in primates and other vertebrates. In D. S. Lehrman, R. A. Hinde, & E. Shaw (Eds.), *Advances in the study of behavior* (pp. 195-249). New York: Academic Press.

NOTES

1. Additional details of the research may be obtained from the author.

2. Species and apparatus differences made an exact replication of Hyman (1971) impossible. Details of such differences will be supplied by the author upon request.

(Manuscript received August 1, 1988.)