THE EFFECT OF SHOCK INTENSITY UPON RESPONDING UNDER A MULTIPLE-AVOIDANCE SCHEDULE¹

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The effect of two shock intensities (1.00 and 2.00 mA) were studied in the acquisition, maintenance, and extinction of unsignalled avoidance by albino rats. Single and multiple avoidance schedules were employed, with shock intensity being the principal condition that differed between schedule components. The higher shock intensity was generally more effective in producing avoidance. Higher response rates and lower shock rates were observed under high-intensity shock when performance stabilized. When the multiple schedule was introduced, the six rats trained under a single shock intensity all showed poorer performance under the new shock intensity, whether it was higher or lower than the training intensity. Performance under the original shock intensity did not change substantially with the introduction of a different shock intensity in the other multiple schedule component. Performance under the new shock intensity showed gradual improvement with continued exposure to it. All of the rats showed persistent "warm-up", receiving approximately 40% of the total session shocks in the first one-sixth of the session. The degree of warm-up was unrelated to avoidance shock intensity.

While most studies have reported that rate of avoidance responding is directly related to shock intensity (Campbell and Kraeling, 1953; Kimble, 1955; Denenberg, 1959; Boren, Sidman, and Herrnstein, 1959; Huff, Piantanida, and Morris, 1967), several investigators have found that avoidance responding decreased as shock intensity increased (Moyer and Korn, 1964; Levine, 1966). This conflict in results seems at least partially attributable to differences in procedure. In the latter two experiments, acquisition of avoidance was studied in different groups of animals at different shock intensities, whereas several of the earlier experiments studied changes in shock intensity after asymptotic performance was achieved (Boren *et al.*, 1959; Huff *et al.*, 1967).

Multiple schedules involve two or more independent schedules of reinforcement presented successively to the subject, with each schedule indicated by a different stimulus. Studies of multiple schedules have involved food presentation most frequently (Catania, 1961; Reynolds, 1961a, b; Williams, 1965; Nevin and Shettleworth, 1966; Bernheim and Williams, 1967), but shock postponement pro-

cedures have also been investigated (Appel, 1960a, b; Wertheim, 1965). The latter studies involved two-component multiple schedules of unsignalled (free-operant) avoidance. Wertheim observed that changes in response rate in each component were positively correlated in direction and magnitude with changes in the relative rate of shocks in that component.

Ferster and Skinner (1957) suggested that multiple schedules are a powerful control technique that allows the study of two or more variables within a single subject and a single session. For this reason, a multiple schedule was employed in the present experiment to study the effects of shock intensity upon the acquisition, maintenance, and extinction of unsignalled avoidance in rats. When multiple schedules are employed, the possible occurrence of interaction effects has to be taken into account. Interaction effects have typically occurred when the schedule components differed markedly in frequency of reinforcement (Reynolds, 1961a, b; Catania, 1961) or in the rate of responding produced (Reynolds and Limpo, 1968; Terrace, 1968; Weisman, 1969).

METHOD

Subjects

Twelve experimentally naive male albino rats, between 120 and 180 days old at the start

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of the experiment, were given free access to water and Purina Lab Chow in their home cages throughout the experiment.

Apparatus

A Gerbrands rat test chamber 8 in. (20 cm) by 9 in. (30 cm) by 7.5 in. (19 cm), with a single lever at the center of one end, 3 in. (7.6 cm) from the grid floor, was enclosed in a sound-attenuated chamber. A force of 17 g (0.16 N) was required to activate a microswitch connected to the lever. The experiment was scheduled by standard relay circuitry. White noise, produced by a Grason-Stadler noise generator, Model No. 901B, provided an auditory signal. Electric shock was provided by a 110-v ac shock source that included 200 K ohms resistance in series with the output and was scrambled to the grid floor of the test chamber. A special module was constructed, which provided for the delivery of two shock intensities during a session. This consisted of a relay operated rheostat. When the relay was open, the shock current was routed through the rheostat (low-intensity shock). When the relay was closed, the shock current was not affected by the rheostat (high-intensity shock). Data were recorded by digital counters and a Gerbrands cumulative recorder.

Procedure

The free-operant avoidance procedure originated by Sidman (1953) was used with all of the rats. Under this procedure, a fixed time interval occurs between the presentation of brief electric shocks in the absence of a lever press (shock-shock interval), and each lever press postpones the next shock for a fixed period of time (response-shock interval). Shock-shock and response-shock intervals of 10 and 20 sec, respectively, were employed with most of the rats. Briefer shock-shock intervals were used with four rats (5, 7, 8, 16) when they did not develop responding under the initial values. The shock duration was 0.5 sec. Responses in the presence of shock did not terminate it. Experimental sessions were 1 hr each day.

Two shock intensities were used at various times in the experiment, with the presence of each intensity always associated with the following stimulus conditions: (a) 1.00-mA 15-w white houselight, and white noise present at approximately 85 db. (b) 2.00-mA 7.5-w green

houselight and also no white noise. Thus, a much lower level of illumination in addition to no noise was associated with the high-intensity shocks.

Rats were assigned to any of three groups, which were trained under the following shock intensities: (a) 1.00 mA (low-intensity shock); (b) 2.00 mA (high-intensity shock); (c) 1.00 mA and 2.00 mA, with the intensities presented as components in a multiple schedule. The intensities alternated in sequence every 10 min; thus, the rat was exposed to 30 min of each avoidance shock intensity in a session. In addition, the first component (shock intensity) changed every day, so that low-intensity shock was presented first one day and high-intensity shock first the next day.

Animals were studied as long as response rates increased and/or shock rates decreased. If a rat received 200 or more shocks and the number increased during five consecutive sessions, it was withdrawn from the study.

Rats that learned to avoid were studied until performance stabilized. Stability was defined as a range of 15 or fewer shocks over five consecutive sessions; *i.e.*, the largest number of shocks in any of the five sessions could not exceed the fewest shocks by more than 15. A less stringent criterion had to be employed with Rat 3, which was trained with the multiple schedule procedure. This animal showed highly variable performance over many sessions, and no improvement could be observed. Therefore, criterion performance for this rat was set at a range of 30 shocks or fewer over six consecutive sessions.

All eight rats that attained the avoidance criterion were next studied with either low- or high-intensity shock present throughout the session, or with both intensities present in a multiple schedule. The following sequence of 1-hr sessions was followed in every case:

1. Multiple schedule—low-intensity shock presented first
2. Multiple schedule—high-intensity shock presented first
3. Single schedule—low-intensity shock only
4. Single schedule—high-intensity shock only

Components in the multiple schedule alternated every 10 min, so the rat was exposed to 30 min of each avoidance shock intensity during these sessions. Each rat was studied for

10 blocks of the four-session sequence, except for Rats 5 and 6. Because the performance of these animals varied markedly, the four-session sequence was continued through 16 blocks.

When this sequence was completed, two of the rats (2, 8) trained under high-intensity shock and all of the rats trained under low-intensity shock were studied for 10 additional 1-hr sessions, with the original training conditions in effect.

Warm-up effects during avoidance conditioning can be characterized as a persistent tendency to receive a disproportionate number of shocks early in the experimental session. Warm-up has been reported in both signalled avoidance (Hoffman, Fleshler, and Chorny, 1961) and unsignalled avoidance situations (Ulrich, Holz, and Azrin, 1964; Powell and Peck, 1969). Domesticated rats show this behavioral pattern indefinitely, regardless of their terminal performance during the preceding session. Hoffman *et al.* (1961) found that a marked increase in avoidance shock intensity had no significant effect upon the warm-up displayed by four rats. Since the rats in the present study were successively exposed to two different shock intensities over many sessions, the present results provided an op-

portunity to study warm-up as a function of shock intensity on a within-subject basis, exclusive of order effects.

Extinction of responding as a function of avoidance shock intensity was studied in six of the rats (1, 2, 3, 4, 7, 8) by withdrawing shock during the third and sixth 10-min components of 1-hr multiple schedule sessions. The conditions under the multiple schedule were the same as described earlier. The sequence of low- and high-intensity shock components alternated from session to session, so that order effects were counterbalanced. Extinction was studied for 10 sessions in each rat.

RESULTS

Acquisition

Eight rats eventually developed avoidance, while four animals had to be discarded from the study because of infrequent responding. Three of the non-avoiders were in the low-intensity shock group (Rats 10, 13, 16). The acquisition data for all 12 rats, which are presented in Table 1, show the high-shock intensity generally produced higher response rates, lower shock rates, and all of the animals met the avoidance criterion. The rats trained with

Table 1

The mean performance for each rat during the sessions in which the criterion for stable performance was achieved. Responses and shocks under the low- and high-shock intensities are identified as R_1 , R_2 , and S_1 , S_2 , respectively. The terminal shock-shock interval was 10 sec in all cases.

<i>Subjects</i>	<i>Range of S-S Intervals (sec)</i>	<i>No. of Sess.</i>	<i>Resp/hr</i>	<i>Shocks/hr</i>	<i>Range of Shocks</i>			
LOW-INTENSITY SHOCK GROUP (1.00 MA)								
Rat 1	10	13	251	52	49-55			
Rat 4	10	11	250	63	51-66			
Rat 7	1-10	51	411	72	65-79			
Rat 10	10	12	11	337	335-340*			
Rat 13	10	21	162	239	175-306*			
Rat 16	5-10	19	127	277	250-320*			
HIGH-INTENSITY SHOCK GROUP (2.00 MA)								
Rat 2	10	17	257	50	44-57			
Rat 5	5-10	39	285	25	18-33			
Rat 8	5-10	39	502	38	33-44			
LOW-HIGH INTENSITY SHOCK GROUP (1.00 MA AND 2.00 MA)								
			<i>R</i> ₁	<i>R</i> ₂	<i>S</i> ₁	<i>S</i> ₂		
Rat 3	10	31	337	335	75	66	27-58	24-44
Rat 6	10	22	374	423	12	9	4-8	1-9
Rat 9	10	7	5	19	325	310	157-168	147-167*

*Below criterion.

both low- and high-intensity shock (multiple schedule) also responded more and received fewer shocks under 2.00-mA shock than under 1.00-mA shock. Three of six animals trained under low-intensity shock did not attain criterion performance. As a whole, the data indicate that, in rats, avoidance is more likely to develop, the higher the shock intensity, at least up to 2.00 mA.

Single and Multiple Avoidance Schedules

The complete data for each rat, summarized in blocks of eight sessions, are presented in Table 2. The rats trained with a single shock intensity (1, 2, 4, 5, 7, 8) generally responded less and received more shocks under the new

shock intensity, than the training shock intensity. This effect is shown clearly in Fig. 1, which presents the group data for these six rats. Although the rats responded more and avoided more shocks with continued exposure to the new shock intensity, the group still had a higher response rate and a lower shock rate under the training shock intensity, at the conclusion of this procedure. When performance is compared before and after exposure to the multiple schedule procedure (Baseline I and II), a moderate increase in the response rate of the group is seen, but the mean number of shocks received is exactly the same.

The data for the two rats (3, 6) originally trained under the multiple-avoidance schedule

Table 2

Responses and shock per hour for each rat over blocks of eight sessions. The two shock intensities identified as in Table 1. The training condition for each rat is identified as (H) high-intensity shock, (L) low-intensity shock, (H-L) high-low intensity shock.

Blocks of Eight Sessions	Schedule	Rat 1 (L)				Rat 2 (H)				Rat 3 (H-L)				Rat 4 (L)			
		R ₁	R ₂	S ₁	S ₂	R ₁	R ₂	S ₁	S ₂	R ₁	R ₂	S ₁	S ₂	R ₁	R ₂	S ₁	S ₂
1	Single	432	416	39	34	242	245	51	35	258	340	83	67	307	343	51	60
	Multiple	536	491	42	61	279	267	34	42	337	315	64	67	352	349	59	85
2	Single	383	302	42	51	238	246	55	38	285	304	55	49	296	316	36	38
	Multiple	492	428	38	56	274	253	34	32	319	292	57	57	340	339	40	42
3	Single	379	338	40	44	255	252	31	40	266	305	56	59	292	318	46	49
	Multiple	426	377	42	49	275	293	36	36	263	283	79	69	328	327	37	40
4	Single	412	374	28	42	248	265	40	34	276	337	49	47	290	359	51	42
	Multiple	438	366	38	53	248	268	37	36	261	258	70	76	335	319	44	36
5	Single	443	390	33	36	255	268	38	33	245	291	68	74	347	352	51	50
	Multiple	385	363	61	80	280	268	38	29	267	280	74	70	349	346	50	41

Blocks of Eight Sessions	Schedule	Rat 5 (H)				Rat 6 (H-L)				Rat 7 (L)				Rat 8 (H)			
		R ₁	R ₂	S ₁	S ₂	R ₁	R ₂	S ₁	S ₂	R ₁	R ₂	S ₁	S ₂	R ₁	R ₂	S ₁	S ₂
1	Single	202	249	89	38	395	395	19	12	281	240	114	155	460	492	53	38
	Multiple	85	306	276	41	335	396	23	18	358	303	103	156	422	540	71	45
2	Single	271	304	69	54	335	337	29	35	362	319	100	122	553	582	55	43
	Multiple	276	327	96	57	334	365	39	24	404	326	93	148	567	546	65	66
3	Single	218	293	117	65	318	351	39	27	376	387	81	99	490	631	44	41
	Multiple	239	324	135	89	346	320	45	33	401	359	78	126	550	629	59	42
4	Single	198	299	135	70	321	296	54	45	462	523	82	89	435	489	47	36
	Multiple	279	303	105	89	309	288	80	71	495	489	69	89	515	623	53	44
5	Single	230	354	141	59	284	294	72	68	548	511	45	93	475	560	49	43
	Multiple	260	366	102	84	295	292	77	64	509	492	64	87	505	552	55	45
6	Single	235	378	140	82	289	296	73	83								
	Multiple	289	337	127	94	261	278	110	94								
7	Single	284	344	88	69	305	341	84	59								
	Multiple	319	342	89	65	317	310	82	79								
8	Single	338	324	54	50	297	301	87	84								
	Multiple	338	352	54	60	311	345	97	81

Fig. 1. Group data for the six rats trained under a single shock intensity during single (S) and multiple (M) schedule sessions. The mean response rates and shocks rates under the original shock intensity are represented by points connected by solid lines. Data points representing performance under the new shock intensity are connected by dotted line. The data points corresponding to Baseline I represent the mean performance for each rat during the final five sessions of acquisition. Data points corresponding to Baseline II represent the mean performance for each rat except No. 5, during the final five sessions, of 10 sessions in which the original training conditions were in effect.

show a marked change in performance for Rat 6 when single and multiple schedule sessions alternated. The responding of this animal decreased, and the number of shocks increased, through the first six blocks of sessions. The performance of Rat 3 was generally stable throughout this procedure. Both rats received fewer shocks, on the average, during the single schedule sessions at the conclusion of this procedure. The mean number of shocks per hour, over the final three blocks of sessions, was as

follows: Rat 3—single schedule = 59, multiple schedule = 74; Rat 6—single schedule = 78, multiple schedule = 91.

Analysis of Warm-up Effects

Warm-up effects were analyzed by calculating the number of shocks that each rat received in the first 10 min of the 1-hr sessions in relation to the total number of shocks in the session. The 10-min period corresponded to the multiple schedule sessions. Each rat showed a

Fig. 2. Analysis of warm-up effects for each rat, with group data for the low-intensity shock (1.00 mA) trained and high-intensity shock (2.00 mA) trained animals. Each data point represents the mean percentage of shocks during the first one-sixth (10 min) of the sessions as compared to the total number of shocks in the session. The data presented are from the last 12 sessions in which single (S) and multiple (M) avoidance schedules were presented in the four-session sequence.

warm-up effect. If warm-up had not occurred, the animal would have received approximately 17% of the shocks in the initial one-sixth of the session. Figure 2 shows that the percentages of shocks actually received under all conditions ranged from 25% (Rat 2) to 48% (Rat 1).

The data for all rats show that on the average, a slightly higher percentage of shocks occurred in the initial 10 min under low shock (41%) than under high shock (39%). Also, a somewhat higher percentage of shocks was received during the first 10 min of the single schedule (42%) than the multiple schedule (38%) sessions. Analyses of variance showed that neither of these differences was statistically significant.

Extinction

A summary of the extinction data, which are presented in Table 3, shows that responding in the absence of shock was higher for all rats under both shock conditions during the sixth cycle than the third, except for Rat 8 under high-intensity shock conditions. A Kruskal-Wallis analysis of variance showed that the overall difference in responding between the third and sixth cycles was significant beyond the 0.05 level of confidence.

In addition, all of the rats except No. 7 made more responses under conditions associated with high-intensity shock when shock was

removed during the third cycle. However, no consistent differences in responding occurred under the two conditions when shock was absent during the sixth cycle.

A comparison of responding during the third and sixth cycles of multiple schedule sessions with shock present (avoidance) and absent (extinction), shows that response rates during avoidance were slightly higher in the sixth cycle than the third, but the differences were not statistically significant. When shock was absent, responding showed a greater decrease during the third cycle than the sixth for every rat except No. 8, as compared to asymptotic avoidance responding during these cycles. The latter difference was significant beyond the 0.05 level of confidence, according to a Kruskal-Wallis analysis.

DISCUSSION

Rats generally acquired avoidance responding more consistently when trained under the higher of the two shock intensities (2.00 *vs* 1.00 mA) employed in this experiment. In addition, higher response rates and lower shock rates occurred under high-intensity shock, when asymptotic performance was achieved. This was true whether an animal was trained with only one (1.00 or 2.00 mA) or both shock intensities. The present results generally agree with a number of earlier findings which showed

Table 3

The mean response rates per minute in the third and sixth cycles during avoidance and extinction under multiple schedules. Response rates under low- (1.00 mA) and high-intensity shock (2.00 mA) are identified as R_1 and R_2 , respectively.

	Third Cycle			Sixth Cycle		
	<i>Avoid.</i>	<i>Ext.</i>	<i>Decrease during Ext.</i>	<i>Avoid.</i>	<i>Ext.</i>	<i>Decrease during Ext.</i>
Rat 1						
R_1	6.76	3.20	-3.56	9.02	7.30	-1.72
R_2	6.90	3.46	-3.44	7.16	7.00	-0.16
Rat 2						
R_1	4.28	1.38	-2.90	4.64	2.82	-1.82
R_2	4.40	1.92	-2.48	5.12	2.18	-2.94
Rat 3						
R_1	4.28	0.68	-3.60	4.66	3.38	-1.28
R_2	4.76	1.18	-3.58	4.64	1.60	-3.04
Rat 4						
R_1	5.64	0.92	-4.72	6.12	4.02	-2.10
R_2	6.00	2.98	-3.02	5.36	3.94	-1.42
Rat 7						
R_1	8.88	5.40	-3.48	9.56	6.32	-3.24
R_2	7.52	2.56	-4.96	8.50	7.30	-1.20
Rat 8						
R_1	8.62	5.54	-3.08	10.48	6.16	-4.32
R_2	9.98	10.02	+ .04	11.32	7.84	-3.48
Mean						
R_1	6.41	2.85	-3.56	7.41	5.00	-2.41
R_2	6.59	3.69	-2.91	7.02	4.98	-2.04

that animals learned to avoid a greater number of shocks, the higher the shock intensity employed (Campbell and Kraeling, 1953; Kimble, 1955; Brush, 1957; Denenberg, 1959). The relationship between shock intensity and avoidance responding was usually observed to be negatively accelerated. The two shock intensities employed here were well within the range of intensities where improved performance was observed in earlier studies.

When the multiple schedule with two shock intensities was introduced, the six rats trained under one intensity all avoided less successfully at the new shock intensity, whether it was higher or lower than the training intensity. Performance under the original training conditions was disrupted throughout this procedure for Rat 5; Rat 7 showed a temporary disruption. With continued exposure to the new shock intensity, response rates increased and shock rates decreased, but the greatest improvement in shock avoidance occurred in the early stages of the multiple schedule procedure. It seems noteworthy that even after many hours of exposure to the new shock in-

tensity, five of the rats still received fewer shocks under the original training intensity, while the sixth rat (No. 4) showed no consistent difference in shock rates under the two intensities.

Hoffman, Fleshler, and Chorny (1961) also observed a temporary disruption of responding during signalled avoidance when shock intensity increased. The generality of this effect is difficult to judge, because most research reports present asymptotic performance and omit temporary behavioral changes. Other considerations in the present case were the changes in auditory and visual stimuli that accompanied the changes in shock intensity, and might also result in temporary disruptions of ongoing behavior.

Consistent warm-up effects were displayed by all of the rats, with approximately 40% of the total session shocks occurring in the initial one-sixth of the session, on the average. Shock intensity was unrelated to the degree of warm-up. This finding agrees with the results of Hoffman *et al.* (1961), who studied warm-up during signalled avoidance.

Response rates were significantly lower during the third cycle than the sixth, when shock was withdrawn for these 10-min periods of the 1-hr multiple avoidance sessions. The decline in responding during extinction was also greater in the third cycle than the sixth, as compared to pre-extinction rates. Five of the six rats studied had higher extinction response rates in the third cycle, under the stimuli associated with high shock, but there was no consistent difference in responding under the two shock conditions when shock was removed during the sixth cycle. The temporal differences in responding appear to occur as a function of the warm-up effect. The more rapid decline of responding under extinction during the earlier cycle suggests that the presentation of shocks is of greater importance in maintaining responding early in the session than later.

Previous results pertaining to the effect of avoidance shock intensity upon subsequent extinction responding have been equivocal. Kimble (1955) found no difference in extinction among four groups trained at different shock intensities, while Boren, Sidman, and Herrnstein (1959) found that extinction responding increased as shock intensity increased. The latter investigators utilized a procedure involving repeated conditioning and extinction of the animal's responding, which was analagous to the extinction procedure used in the present experiment. The great difference in the duration of the extinction periods in the two experiments (10 min vs. 3 hr) severely limits any direct comparison of the results, however.

Historically, the intensity of shock during avoidance conditioning has been regarded as a variable that influences motivation, primarily. The present results suggest that electric shock has associative properties also, which affect behavior. Avoidance behavior is disrupted, at least temporarily, by both increases or decreases in shock intensity. With exposure to the new shock intensity, performance usually shows gradual improvement. Consequently, a very important factor in avoidance is the animal's history of exposure to various shock intensities.

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