**EFFECTS ON RESPONDING OF MIXED AND MULTIPLE
SCHEDULES OF SIGNALLED AND UNSIGNALLED
RESPONSE-DEPENDENT ELECTRIC-SHOCK
DELIVERY¹**

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Responding in two rats was maintained under mixed and multiple variable-interval 35-sec variable-interval 35-sec food delivery schedules. Similar rates and patterns of responding occurred in each component of the two schedules. Mixed and multiple variable-interval 65-sec variable-interval 65-sec schedules of response-dependent shock delivery were superimposed on the mixed and multiple baseline food schedules, respectively. In one component, a 5-sec stimulus was presented on the average of once every 65 sec. Offset of the stimulus arranged that the next response would produce shock. In the other component, no stimulus was presented during the 5-sec period. The mixed schedule of signalled and unsignalled dependent shock delivery yielded similar degrees of response suppression in each component, but the multiple schedule of shock delivery revealed differential degrees of response suppression. Considerably more suppression occurred in the component not associated with the preshock stimulus, thus implicating the discriminative functions of the correlated stimulus.

Key words: electric shock, punishment, multiple schedule, mixed schedule, rats

Badia (Badia, Coker, and Harsh, 1973; Badia and Culbertson, 1972; Badia, Culbertson, and Harsh, 1973) exposed rats to intermittent response-independent shock delivery. Changeover responses produced a correlated stimulus (light) in the presence of which a brief tone preceded each shock. If no changeover responding occurred, neither the correlated stimulus nor the preshock stimulus were presented. In Badia's studies, the animals consistently changed over from unsignalled to signalled shock delivery.

The role of the correlated stimulus in Badia's studies merits attention. When the correlated stimulus was omitted, *i.e.*, the chamber remained dark during signalled as well as unsignalled shock delivery, little changeover responding occurred. Biederman and Furedy (1973) suggested that the onset of the correlated stimulus, rather than the signalling of shock, *per se*, may have been responsible for the changeover responding (*i.e.*, photic reinforcement).

There may be another reason why the correlated stimulus was so necessary for change-

over responding. With the correlated stimulus, the presence and absence of the preshock stimulus was correlated with shock and shock-free periods, respectively. Without the correlated stimulus, it was considerably more difficult to discriminate the period of time in which shock delivery was always preceded by the tone. While the occurrence of the tone was still reliably associated with the advent of shock, the absence of the tone was no longer reliably associated with the absence of shock.

Studies of the behavioral effects of signalled and unsignalled response-dependent shock delivery may bear on the question of the discriminative functions of the correlated stimulus. Hymowitz (1973) compared the suppression of food-maintained responding in groups of rats exposed either to signalled or unsignalled shock. For rats exposed to signalled shock, a 5-sec stimulus (light) was presented on the average of once every 65 sec. Offset of the stimulus arranged that the next response would produce shock. For rats exposed to unsignalled shock, no stimulus was presented during the 5-sec preshock period. More suppression of lever pressing was found for groups of rats exposed to unsignalled shock delivery. Unsignalled shock suppressed responding throughout the session, but response suppression during signalled shock occurred primarily

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in the presence of the preshock stimulus. In the absence of the stimulus, high rates of responding were maintained.

The difference in response suppression may reflect the clear distinction between shock and shock-free occasions under signalled, response-dependent shock. Would differential response suppression occur if the absence of the preshock stimulus no longer was reliably correlated with the absence of shock? The present study attempted to answer this question by studying the suppression of responding under mixed and multiple schedules of signalled and unsignalled electric-shock delivery. With multiple schedules, correlated stimuli distinguish the components. Hence, animals may readily discriminate that component in which the absence of the preshock stimulus is associated with shock-free periods. No correlated stimulus distinguishes the component of mixed schedules. Hence, the absence of the preshock stimulus no longer reliably specifies the absence of shock.

METHOD

Subjects

Two naive male Sprague-Dawley albino rats, 267 and 238 g, were housed individually and maintained at 80% of initial free-feeding weights on Purina Laboratory Rat Chow. Water was freely available in the home cage.

Apparatus

A Grason-Stadler sound-attenuated operant rat chamber, Model 1101, contained a response lever, pellet dispenser, and white masking noise. Electromechanical equipment was located in a separate room, and responses were recorded by counters and a cumulative recorder. Electric current to the grid floor and response lever was provided by a Grason-Stadler shock generator (Model 700) and grid scrambler. Noyes laboratory pellets (0.045 g) served as food reinforcers.

Procedure

Table 1 shows the major procedural steps. Following weight reduction and response shaping, lever pressing was maintained during 25 daily 50-min session under mixed variable-interval 35-sec variable-interval 35-sec (*mix* VI 35-sec VI 35-sec) food delivery. The components of the mixed schedule do not assume

Table 1
Experimental Procedure

Session(s)	Block of Shock Sessions	Schedule(s)	Shock Intensity
1- 25		mix-food	
26		mix-food-shock	0.16 mA
27		mix-food-shock	0.20 mA
28		mix-food-shock	0.25 mA
29		mix-food-shock	0.30 mA
30- 39	1	mix-food-shock	0.40 mA
40- 44		mix-food	
45- 54	2	mix-food-shock	0.40 mA
55- 59		mix-food	
60- 69	3	mix-food-shock	0.40 mA
70- 74		mix-food	
75- 84	4	mix-food-shock	0.40 mA
85- 89		mix-food	
90- 99	5	mix-food-shock	0.40 mA
100-109		mult-food	
110		mult-food-shock	0.16 mA
111		mult-food-shock	0.20 mA
112		mult-food-shock	0.25 mA
113		mult-food-shock	0.30 mA
114-123	6	mult-food-shock	0.40 mA
124-128		mult-food	
129-133	7	mult-food-shock	0.40 mA
134-138		mult-food	
139-143	8	mult-food-shock ¹	0.40 mA
144-148		mult-food ²	
149-153	9	mult-food-shock ²	0.40 mA
154-158		mix-food	
158-163	10	mix-food-shock	0.40 mA
164-168		mix-food	

¹Preshock stimulus occurs during light component.

²Condition under which M-2 was not studied.

importance until the shock is introduced. Ten 5-min components alternated throughout the session. The chamber was dark during each component. A fan for ventilation and white masking noise remained on during the session.

In Session 26, a *mix* VI 65-sec VI 65-sec schedule of response-dependent electric-shock delivery was superimposed on the baseline food schedule. In one component, a 5-sec stimulus (red jewelled light located above and to the right of the response lever) was presented on the average of once every 65 sec. Offset of the red light arranged that the next response would produce shock. The animals never received shock in the presence of the red light. In the other component, no stimulus was presented during the 5-sec preshock period. Otherwise, the food and shock delivery schedules were identical.

As shown in Table 1, shock intensity initially was increased gradually from 0.16 mA

to 0.4 mA. Blocks of successive food and shock sessions at a constant shock intensity (0.4 mA) then alternated with blocks of food sessions. The distribution of shock in time ranged from 5 to 130 sec. Shock duration remained constant (0.5 sec).

In Session 100 (see Table 1), lever pressing was maintained under multiple variable-interval 35-sec variable-interval 35-sec (*mult VI 35-sec VI 35-sec*) food delivery. The onset of a green jewelled light located above and to the left of the lever served to distinguish the components. The dark and light components of the multiple schedule assumed importance when the *mult VI 65-sec VI 65-sec* shock delivery schedule was superimposed on the baseline food schedule (Table 1). Initially, a preshock stimulus (5-sec onset of red jewelled light) preceded shock delivery during the dark components. During the light component, no preshock stimulus was presented. During Reversal, the preshock stimulus was presented during the light component and no signal was presented in the dark component.

Again, shock intensity initially was increased gradually from 0.16 mA to 0.4 mA (Table 1). Blocks of successive food and shock sessions at a constant shock intensity (0.4 mA) and duration (0.5 sec) then alternated with blocks of food sessions. The distribution in time of shock was the same as the distribution under mixed shock delivery. The component in which the session was initiated alternated daily.

RESULTS

Figure 1 shows the mean per cent of the total number of responses emitted per session in the component associated with the preshock stimulus. During the baseline shock-free food-delivery sessions, responding was distributed evenly between the dark components of the mixed schedule and the light and dark components of the multiple schedule.

Fifty-five sessions under *mix VI 65-sec VI 65-sec* shock delivery (0.40 mA) failed to reveal differential rates of responding for either animal. Response suppression and recovery during shock sessions occurred equally in the components associated with signalled and unsignalled shock delivery. In fact, there was some evidence (Figure 1) of slightly less responding in the component associated with

Fig. 1. Mean per cent of the responses emitted per session in the component associated with the preshock stimulus. Each bar represents the mean of five or 10 sessions under a given experimental condition (see Table 1). The hatches indicate a block of shock-free sessions. The asterisks indicate the Reversal condition in which the preshock stimulus was presented in the light component.

the preshock stimulus. This was probably due to the marked cessation of responding during the onset of the preshock stimulus. Whereas repeated exposure to mixed shock delivery failed to generate differential rates of responding, *mult VI 65-sec VI 65-sec* shock delivery readily led to higher rates of responding in the signalled than in the unsignalled shock components (60% yields χ^2 of 4; $p < 0.05$) (Figure 1). The differential rate of responding was found for both animals when the preshock stimulus was presented in the dark component and when it was presented in the light component (Reversal).

Table 2 shows mean suppression ratios ($a/a + b$, where a is the number of responses emitted during a shock session, and b is the mean number of responses emitted during the five preceding food sessions) for each block of shock sessions. A suppression ratio of 0.5 indicates no suppression, and a ratio of 0.0 indicates total response suppression (*cf.*, Church, 1969). For conditions in which the animals were studied for 10 sessions, relatively greater degrees of response suppression occurred during Sessions 1 to 5 than during Sessions 6 to 10. This indicates some recovery of responding within each block of successive shock sessions.

For shock delivery under the mixed schedule, the degree of response suppression in the component associated with the preshock stimulus was quite similar to the degree of overall suppression in the unsignalled shock compo-

Table 2

Suppression ratios under signalled and unsignalled shock.

Schedule	Block	Sessions			
		Signalled		Unsignalled	
		1-5	6-10	1-5	6-10
ANIMAL					
mix	1	0.39	0.56	0.41	0.60
mix	2	0.03	0.22	0.06	0.16
mix	3	0.24	0.30	0.29	0.38
mix	4	0.33	0.37	0.36	0.39
mix	5	0.24	0.34	0.20	0.43
	x	0.27	0.36	0.26	0.39
mult	6	0.45	0.61	0.22	0.50
mult	7	0.36		0.17	
mult (Reversal)	8	0.20		0.10	
mult	9	0.36		0.21	
	x	0.34	0.61	0.18	0.50
mix	10	0.26		0.25	
ANIMAL M-2					
mix	1	0.32	0.59	0.29	0.59
mix	2	0.25	0.40	0.24	0.41
mix	3	0.39	0.36	0.36	0.39
mix	4	0.54	0.54	0.52	0.54
mix	5	0.32	0.51	0.31	0.51
	x	0.36	0.48	0.34	0.49
mult	6	0.49	0.56	0.41	0.40
mult	7	0.47		0.35	
mult (Reversal)	8	0.27		0.20	
	x	0.41	0.56	0.32	0.40
mix	9	0.39		0.35	

nent. For the multiple shock schedules, considerably greater degrees of response suppression occurred in the component associated with unsignalled shock delivery. During Reversal, in which the preshock stimulus was presented during the light component, responding was considerably more attenuated in the signalled component than during the original shock conditions. Most suppression occurred in the component in which the preshock stimulus was not presented.

Figure 2 shows representative cumulative records of responding under each experimental condition for Rat M-1. The behavior of Rat M-2 was quite similar. Characteristic high steady rates of responding were maintained under mixed (Figure 2A) and multiple (Figure 2C) VI 35-sec VI 35-sec food delivery. Responding was nearly identical in each component of the mixed and multiple schedules.

The records of responding under shock are for the third session of exposure to shock

(0.4 mA) under *mix* VI 65-sec VI 65-sec (Figure 2B) and *mult* VI 65-sec VI 65-sec (Figures 2D and 2E). Hence, they reveal considerable response suppression. Under the mixed shock-delivery conditions, similar attenuation and

Fig. 2. Representative cumulative records for Rat M-1 of responding during (A) Session 25, *mix* VI 35-sec VI 35-sec food delivery; (b) Session 32, *mix* VI 35-sec VI 35-sec food and *mix* VI 65-sec VI 65-sec shock delivery (0.40 mA); (C) Session 109, *mult* VI 35-sec VI 35-sec food delivery; (D) Session 116, *mult* VI 35-sec VI 35-sec food and *mult* VI 65-sec VI 65-sec shock delivery (0.40 mA); and (E) Session 141, *mult* VI 35-sec VI 35-sec food and *mult* VI 65-sec VI 65-sec shock delivery (0.40 mA) in which the preshock stimulus was presented in the light component (Reversal). The vertical movement of the response pen indicates responses, and the downward deflection of the response pen indicates shock delivery. The asterisks indicate the component associated with the preshock stimulus. Arrows show the cessation of responding during the preshock stimulus. The response pen reset to the bottom of the paper after each component.

recovery of responding occurred in each component (see Table 2). Marked cessation of responding during the onset of the preshock stimulus (arrows) was apparent. This cessation of responding after onset of the preshock stimulus was quite prolonged during the initial sessions of exposure to mixed signalled shock delivery. During the later sessions, in which low steady rates of responding were maintained in each component, the latency between offset of the preshock stimulus and initiation of the next response was much shorter.

Figures 2D and 2E reveal clear differential degrees of response suppression in the signalled and unsignalled components of the multiple shock-delivery schedules. While the records reveal response suppression in both the components, the emerging pattern of responding during signalled shock delivery is apparent. The animals maintained a high rate of responding, ceased responding when the preshock stimulus was presented (arrows), produced a shock, and resumed their high rate of responding. In the unsignalled shock component, responding occurred at a much lower rate, often occurring as bursts after shock delivery.

DISCUSSION

For each schedule of shock delivery, performances of the animals during the 5-sec preshock stimulus were similar; responding ceased as soon as the stimulus was presented. Previous studies (Harsh and Badia, 1974; Hymowitz, 1973) revealed similar disruption of responding in the presence of the preshock stimulus. The present data also are compatible with studies of discriminative punishment (*cf.* Church, 1969). With the discriminative punishment procedure, responses in the presence of a discriminative stimulus produce shock. Depending on the intensity of shock, responding may be considerably disrupted during the stimulus and remain relatively unaffected in the absence of the stimulus (*e.g.*, Gibbon, 1967). Although the present animals never produced shocks in the presence of the preshock stimulus, it is important to note that the preshock stimulus specified the contingency between lever pressing and shock delivery, as well as the advent of shock.

The differential rate of responding under

mult VI 65-sec VI 65-sec signalled and unsignalled shock delivery serves as a within-animal replication of Hymowitz' (1973) finding of greater response suppression in groups of rats exposed to unsignalled than to signalled shock delivery. The present data also are consistent with the findings of MacDonald (1973), who studied responding in the rat under a two-component multiple schedule in which each component consisted of a two-link chained schedule. When signalled and unsignalled response-dependent shock were scheduled in the separate terminal links, the rats responded at lower rates in the initial and terminal links associated with unsignalled shock.

The mixed-schedule of signalled and unsignalled shock delivery in the present study failed to reveal differential rates of responding in the signalled and unsignalled shock components. To the extent that 55 sessions of exposure to the mixed schedule is an adequate test, the present study supports the hypothesis that correlated stimuli are necessary determinants of differential response suppression under signalled and unsignalled dependent-shock delivery.

In considering the differences in responding under the mixed and multiple shock-delivery schedules in the present study, the importance of the correlated stimulus is apparent. The correlated stimulus may facilitate the discrimination of periods of time in which the absence of the preshock stimulus indicates the absence of shock (*cf.* Denny, 1971; Seligman, 1968). Thus, it is likely that the correlated stimulus in Badia's studies (Badia *et al.*, 1973; Badia and Culbertson, 1972; Badia *et al.*, 1973) served a similar discriminative function. A number of studies that demonstrated preferences in the rat for signalled over unsignalled shock did not employ a correlated visual stimulus (*e.g.*, Gliner, 1972; Lockard, 1963; Perkins, Levis, and Seymann, 1963; Perkins, Seymann, Levis, and Spencer, 1966). These studies typically employed a shuttle-box arrangement. The location of the animal in the box may have served as the correlated stimulus. On only one side of the box did the absence of the preshock stimulus specify the absence of shock.

Hence, correlated stimuli seem to be necessary determinants of differential responding under signalled and unsignalled electric shock delivery. Whether one measures "preference" or response suppression, the absence of the

pres shock stimulus must be reliably associated with the absence of shock. When animals are not able to discriminate that period of time in which shock is not available, little, if any, differential responding is observed.

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