CHOICE FOR SIGNALLED OVER UNSIGNALLED SHOCK AS A FUNCTION OF SHOCK INTENSITY¹

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Choice between a signalled shock schedule and an unsignalled one was examined at various shock intensities. Three rats were given the opportunity to change from the unsignalled schedule to the signalled one at intensity values between 0.15 mA and 1.0 mA. Steps were usually 0.15 mA and both ascending and descending series were given. For two other rats, shock intensity increased from 0.20 mA to 1.0 mA in 0.20-mA increments; for two additional rats, shock intensity was first 3.0 mA and was then reduced to 1.0 mA. Subjects tended to remain in the unsignalled schedule at the lower shock intensities, but spent most of each session under the signalled schedule at the higher intensities (1.0 mA and 3.0 mA). In addition, the time spent in the signalled schedule tended to vary systematically with shock intensity over at least part of the range of intensity values. It was concluded that the relationship between shock intensity and choice behavior is similar to the relationship between intensity and behavior in procedures involving avoidance, escape, and punishment.

Previous research has shown that shock intensity is important in controlling performance with experimental procedures involving omission (avoidance), termination (escape), or presentation (punishment) of shock. When steady state performance is studied, shock intensity and performance are monotonically related for avoidance (Boren, Sidman, and Herrnstein, 1959; D'Amato, Fazzaro, and Et-kin, 1968; Riess, 1970), escape (Dinsmoor and Winograd, 1958; Winograd, 1965), and punishment (Azrin, 1960; Azrin and Holz, 1961; Rachlin, 1967). The control exerted by stimuli correlated with shock is also influenced by shock intensity, whether the correlation is positive (Annau and Kamin, 1961) or negative (Rescorla, 1969).

The question asked in the present research relates to choice performance. Although several investigators have found that subjects prefer signalled over unsignalled shock conditions (*e.g.*, Badia and Culbertson, 1972; Badia, Culbertson, and Lewis, 1971; Lockard, 1963; Perkins, Seymann, Levis, and Spencer, 1966) the relationship between intensity and choice behavior has not been fully explored. It is not known if subjects will prefer signalled

shocks at all levels of shock intensity, nor is there information about the nature of the relationship between intensity and choice. In the present study, choice between signalled and unsignalled shock was examined at shock intensities ranging between 0.15 mA and 3.0 mA.

METHOD

Subjects

Seven naive female albino rats of the Sprague-Dawley (Holtzman Co.) strain served. Each subject was 90 to 120 days old at the start of the experiment.

Apparatus

Subjects were tested in a two-lever For-inger operant-conditioning chamber (enclosed within a sound-insulated chamber) modified so that the 0.64-cm stainless-steel grid bars were perpendicular to the levers and spaced 1.92 cm apart. The conditioning chamber was 35.6 cm long, 25.4 cm wide, and 12.2 cm high. The levers required about 20 g (0.20 N) to depress and were 5 cm from each side along the 25.4-cm wall, 7.65 cm above the grid floor, and 7.0 cm apart. A 5-sec tone (Sonalert—84 dB; 4500 Hz) served as the preshock warning stimulus (background noise level was 75 dB) and the illumination of a 24-V dc bulb (GE 313), located above the conditioning chamber 13.97 cm from the left lever and shielded by a trans-

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lucent plastic strip, served as the stimulus (hereafter referred to as the correlated stimulus), which identified when the signalled schedule was in effect. The termination of a 24-V dc bulb (GE 313) capped by a 1.3-cm white jewelled lens and located 6.35 cm above the left lever identified the beginning of an experimental session; its onset identified the end.

A Lehigh Valley constant-current (dc) shock source delivered shock of varying intensities. The walls and response levers served as one contact in the grid scrambling circuit.

Procedure

Subjects were tested in 6-hr sessions every other day. Shock (0.5-sec) was at all times arranged to be unavoidable and inescapable and was delivered on a variable-time (VT) 120-sec schedule with a range from 30 sec to 210 sec in 30-sec blocks.

Training (Baseline)

All subjects experienced both training and changeover (see below) conditions at each shock intensity. The training conditions consisted of a minimum of three 6-hr sessions, during which the correlated stimulus was always on and all shocks were preceded by a 5-sec signal.

The purpose of the training sessions was to ensure exposure to the signalled shock schedule at each shock intensity, and to determine what effects changes in shock intensity would have upon responding on the levers. Responses on the levers at this time produced no stimulus change; however, the amount of time that would have been spent in changeover had these responses been effective was recorded. All responses initiating timing circuitry were counted as changeover responses and the total time accumulated during the training sessions and during the changeover and extinction training described below was recorded as time spent in changeover.

Changeover and Shock Intensity

After the level of responding on the levers had stabilized under the training conditions, subjects began the next session under the unsignalled schedule (correlated stimulus off and shocks unsignalled). Responding on either lever at this time, however, produced a 1-min (Subjects HI 1, HI 2, LI 30, LI 31) or 3-min (Subjects LI 5, LI 11, LI 12) changeover period,

during which the correlated stimulus was on and shocks were signalled. At the end of the changeover period, the correlated stimulus terminated and shocks were again unsignalled. Subjects could then remain in the unsignalled schedule or re-instate the signalled one by making additional changeover responses.

The amount of time spent in the changeover condition was examined as shock intensity was systematically varied. Intensity values for three subjects (LI 5, LI 11, LI 12) were: 0.15, 0.30, 0.45, 0.60, 0.75, 0.90, and 1.0 mA. Both an ascending and descending series of shock values were given and two of these subjects (LI 11 and LI 12) were tested a third time at 0.45 mA, 0.60 mA, and 0.75 mA. Two subjects (LI 30 and LI 31) received intensity levels of 0.20, 0.40, 0.60, 0.80, and 1.0 mA in two ascending series. Two additional subjects (HI 1 and HI 2) received an intensity of 3.0 mA followed by an intensity of 1.0 mA. All subjects remained at each intensity level for a minimum of three testing days.

Extinction

Subjects HI 1 and HI 2 were exposed to an extinction procedure to demonstrate the control exerted by the stimuli of the signalled schedule. During the procedure, neither the correlated stimulus nor the signal followed a changeover response. Subjects always remained in the unsignalled condition. As in the training condition, however, responses on the levers and the amount of time that would have been spent in changeover were recorded.

Stability Criterion

All subjects remained under each training and changeover condition until a stability criterion was met. This criterion was three consecutive sessions, during which the time spent in changeover during the third session did not vary more than 10% from the time spent in the preceding sessions. Exceptions to this criterion were allowed when variability persisted for 10 or more sessions.

RESULTS

Data obtained from Subjects LI 5, LI 11, and LI 12 are presented in Table 1 and Figure 1. The per cent time spent in changeover (CO) during the last three days of each training and CO condition is shown in Table 1; Figure 1

Table 1

Per cent time spent in changeover is shown for last three days of each condition. Shock intensity was increased or decreased in 0.15-mA steps in the order in Column 1. Numbers in parentheses refer to the number of 6-hr sessions spent in that condition.

Intensity	Subjects					
	LI 5		LI 11		LI 12	
	Training	Changeover	Training	Changeover	Training	Changeover
0.15mA	9 8 3 (3)	11 14 10 (4)				
0.30mA	4 1 4 (4)	36 29 33 (10)	3 0 0 (3)	16 12 11 (3)	5 4 6 (3)	22 20 23 (4)
0.45mA	13 15 18 (3)	48 43 41 (11)	7 8 4 (6)	16 14 15 (4)	16 15 10 (5)	25 11 18 (12)
0.60mA	13 5 10 (3)	67 65 66 (6)	4 4 4 (4)	93 84 91 (9)	9 8 5 (3)	74 79 78 (11)
0.75mA	6 10 9 (3)	73 75 74 (5)	18 13 22 (4)	97 94 98 (3)	19 17 18 (5)	85 84 85 (3)
0.90mA	22 13 20 (3)	62 68 69 (13)	16 20 11 (3)	93 96 96 (3)	11 14 9 (3)	86 88 91 (3)
1.00mA	14 20 11 (3)	72 69 71 (5)	12 13 9 (3)	96 95 95 (3)	23 20 16 (3)	95 94 91 (3)
0.75mA	15 19 14 (3)	80 79 76 (5)	19 21 22 (3)	94 96 94 (5)	9 7 12 (3)	84 83 79 (9)
0.60mA	23 18 21 (6)	80 79 80 (6)	28 22 28 (6)	94 96 93 (3)	17 18 8 (3)	91 89 92 (3)
0.45mA	29 29 29 (14)	38 46 45 (11)	6 8 6 (3)	83 88 88 (8)	4 12 10 (3)	69 64 69 (12)
0.30mA	14 5 14 (4)	37 41 34 (14)	3 3 1 (3)	39 41 31 (11)	10 6 3 (3)	22 20 27 (3)
0.45mA			8 4 5 (3)	69 76 75 (10)	25 23 22 (3)	76 76 76 (5)
0.60mA			5 9 8 (3)	84 86 85 (3)	24 23 23 (3)	86 89 90 (3)
0.75mA			8 16 14 (3)	91 93 92 (3)	17 20 17 (3)	90 88 87 (13)

contains the data obtained only during the CO conditions.

Although there were some individual differences in performance and also some variability,

a fairly clear and consistent relationship between intensity and choice behavior can be seen. For all subjects, the per cent time in CO was much higher at the highest intensity levels

Fig. 1. Per cent of session time spent in changeover during the last three days of each intensity condition for Subjects LI 5, LI 11, and LI 12. Each changeover condition was preceded by a training condition. The data obtained during training and the number of days spent in training are presented in Table 1.

than at the lowest intensity levels. In addition, the amount of time in CO tended to increase as shock intensity was increased and to decrease as shock intensity decreased over at least part of the range of intensity values. Consider, for example, the data obtained from Subject LI 5. During the initial ascending series of shock intensities (Columns 1 to 7, Figure 1), time in CO slowly increased from around 10% at 0.15 mA to around 70% at 0.75 mA. Further increases in intensity to 0.90 mA and 1.0 mA produced some variability, which persisted through the first part of the descending series (Columns 8 to 11, Figure 1). Decreases to 0.45 mA and to 0.30 mA during the descending series, however, systematically decreased time in CO. Note that time in CO for this subject varied little across training conditions (Column 1, Table 1). Similar relationships between intensity and CO responding can be observed in the data from Subjects LI 11 and LI 12. Unlike Subject LI 5, however, time in CO for these subjects during the initial shock series tended to remain close to baseline at values of 0.30 mA and 0.45 mA and to increase substantially at the 0.60-mA value (Columns 2, 3, and 4, Figure 1).

Comparison of performances of Subjects LI 11 and LI 12 across the ascending and descending shock series indicates that the behavior observed during the initial series (Columns 1 to 7, Figure 1) differed from that of the second (Columns 8 to 11, Figure 1) and third series (Columns 12 to 14, Figure 1). Note that the time spent in CO for Subjects LI 11 and LI 12 during initial exposure to the 0.45-mA condition was only slightly above baseline levels. However, during the second and third exposures to this intensity value, the time spent in the signalled condition was well above baseline (see Columns 3 and 5, Table 1). A similar but much less-marked tendency may be observed by comparing initial exposures to the 0.30-mA and 0.60-mA CO condition with later ones (Columns 2, 4, 9, and 11—Figure 1; Columns 3 and 5—Table 1).

The data from Subjects LI 30 and LI 31 are presented in Figure 2. Shock intensity for these subjects increased in 0.20-mA steps during two ascending series.

It can be seen that the performance of Subjects LI 30 and LI 31 was similar to that of the previous three subjects, in that the per cent of time spent in the signalled condition

tended to increase as shock intensity increased. It can also be seen that these subjects, like Subjects LI 11 and LI 12, spent little time in CO at the lowest shock intensities, but showed substantial increases in changing over at one of the higher intensities. Further increases in intensity led to smaller but usually consistent increments in CO time. Differences between the first and second series of shock intensities did not stand out as clearly for Subject LI 31 as they did for Subjects LI 11 and LI 12. Subject LI 30 was peculiar in this respect: the initial exposure to the 0.60-mA value resulted in from 70% to 75% of the time spent in CO. Subsequent exposure to this intensity value resulted in only 10% to 25% of time spent in CO. An intensity value of 0.80 mA was needed before this subject was again spending 70% to 75% of time under the signalled schedule.

Subjects HI 1 and HI 2 were given the opportunity to changeover to signalled shock when shock intensity was set at 3.0 mA and then reduced to 1.0 mA. When shock was 3.0 mA, both subjects responded at a level sufficient to maintain the signalled schedule from 75% to 90% of the time. This responding was not maintained during extinction when the CO contingency was removed. Reducing shock intensity from 3.0 mA to 1.0 mA had little effect on the time spent in CO.

The pattern of CO responding during individual sessions at the higher shock intensities was similar to that observed in earlier investigations dealing with choice between signalled and unsignalled shock (e.g., Badia and Culbertson, 1972). That is, responses usually occurred soon after the previous CO period terminated and occurred only seldomly at other times. The time between termination of a CO period and the next CO response tended to be longer at the lower shock intensities.

DISCUSSION

The present findings suggest that strength of preference for signalled over unsignalled shock is related to shock intensity. At the lowest shock-intensity values for each subject (0.15 mA, 0.20 mA, or 0.30 mA), the amount of time spent in the signalled shock schedule remained at about baseline levels. At the higher intensity values (1.0 mA or 3.0 mA), however, subjects were spending most of each session under the signalled schedule. In ad-

Fig. 2. Per cent of session time spent in changeover during the last three days of each intensity condition for Subjects LI 30 and LI 31. Two ascending series were given and Subject LI 30 received a third exposure to the 0.60-mA condition.

dition, time in CO tended to vary systematically with shock intensity over at least part of the range of intensity values.

As noted earlier, previous research has shown a direct relationship between shock intensity and behavior maintained by avoidance (e.g., Boren *et al.*, 1959; D'Amato *et al.*, 1968; Riess, 1970), escape (e.g., Dinsmoor and Winograd, 1958; Winograd, 1965) and punishment (Azrin, 1960; Azrin and Holz, 1961; Rachlin, 1967) procedures. Riess (1970) found that avoidance behavior was positively monotonic across intensity values of 0.25 mA to 4.0 mA,

with the region of greatest sensitivity between 0.25 mA and 1.0 mA. The present findings indicate a similar relationship between intensity and choice behavior, in that choice behavior tended to increase as intensity was increased and intensity variations between 0.15 mA and 1.0 mA produced more-marked changes than variations between 1.0 mA and 3.0 mA.

Some variability between subjects was observed. One factor contributing to this variability may have been the tendency of some subjects to spend almost the entire session in

the signalled schedule, even at relatively low intensity values (LI 11, Figure 1, for example). Further increases in intensity for this subject could produce only small, if any, increments in the time spent in CO. Another factor contributing to variability between subjects relates to the stability criterion used. Perhaps a more-stringent criterion would have assured greater homogeneity among subjects. Finally, the differences in the per cent time spent in the signalled schedule between initial and later exposures to the same intensity values for Subjects LI 5, LI 11, and LI 12 may have been due to the use of both ascending and descending shock series, *i.e.*, during the ascending series, the prior exposure to the lower-intensity shocks may have diminished the effects of higher-intensity shocks and, conversely, during the descending series, prior exposure to higher-intensity shocks may have enhanced the effects of the lower-intensity shocks (*cf.* Church, 1969; Hake, Azrin, and Oxford, 1967; Miller, 1960).

A number of investigators have found that subjects choose signalled over unsignalled shocks under a variety of conditions. These findings are difficult to interpret, relative to the findings of aversive procedures dealing with response-produced termination (escape), omission (avoidance), or presentation (punishment) of shock. Data obtained using the latter procedures can be readily interpreted as indicating the reinforcing value of reduction in shock or the punishing value of increases in shock. In the present procedure, choice responses, however, were not scheduled to produce changes in shock parameters, but only changes in stimulus conditions. Interpretations of preference for signalled shock must appeal to the properties acquired by stimuli prevailing during the choice situation; however, it is not clear what these properties are. One possibility is that stimuli that precede shocks (signals) act as cues for preparatory responses (*e.g.*, freezing, grasping grid bars), which serve to minimize the aversiveness of the imminent shock (Perkins, 1968). Another possibility is that preference is due to the information provided by the stimuli of the signalled schedule about the occurrence of shock. According to this view, stimuli that reduce uncertainty acquire reinforcing properties (*e.g.*, Berlyne, 1960).

An alternative account of preference for

signalled over unsignalled shock emphasizes shock and shock-free periods (Badia and Culbertson, 1972). According to this view, a signalled shock condition is composed of discriminable shock (unsafe) and shock-free (safe) periods whether shocks are delivered on a fixed or variable-time basis (Badia, Harsh, and Coker, *in press*). Further, the shock periods are usually brief, lasting only as long as the signal, while the shock-free periods (identified by the absence of the signal) are as long as the inter-shock interval minus the signal duration. In contrast, the unsignalled schedule is unsafe throughout, since shock and shock-free periods are not separately identifiable; this is especially so with the variable-time shock used here. Changing from an unsignalled to a signalled schedule may, therefore, be reinforced by periods of safety. The safety view is similar to the analysis presented by Seligman, Maier, and Solomon (1971) and is supported by analyses of the stimulus factors controlling preference for predictable over unpredictable shock conditions (Badia, Coker, and Harsh, 1973; Badia and Culbertson, 1972; Badia, Culbertson, and Harsh, 1973; Dinsmoor, Flint, Smith, and Viemeister, 1969; Harsh and Badia, 1974), by investigations concerning timeout from shock schedules (*e.g.*, Verhave, 1962), as well as by research dealing with the behavioral properties of the CS— in aversive Pavlovian procedures (Rescorla, 1969; Weisman and Litner, 1969, 1971).

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