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CHOICE OF LONGER OR STRONGER SIGNALLED SHOCK OVER SHORTER OR WEAKER UNSIGNALLED SHOCK[1]

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Unsignalled, inescapable shocks were presented to four albino rats in one study and to six rats in a second study. By pressing a lever, subjects could change the condition to signalled shock for 3 min after which unsignalled shock was automatically reinstated. All subjects changed frequently to the signalled shock schedule. After a minimum of three 6-hr sessions or after changeover responding stabilized at the previous values, higher values of signalled shock intensity or duration were introduced. In the first study, the duration of signalled shock was increased in increments of 0.5 sec. In the second study, the intensity of signalled shock was increased in increments of either 0.2 or 0.4 mA. Duration subjects chose signalled shock four (2.0 sec) to nine times (4.5 sec) longer than unsignalled shock (0.5 sec). Intensity subjects chose signalled shock two (2.0 mA) to three times (3.0 mA) more intense than unsignalled shock (1.0 mA).

Several studies have shown that subjects will choose a situation in which shock is signalled over one in which it is unsignalled (Badia, Culbertson, and Lewis, 1971; Badia and Culbertson, 1972). In these studies, subjects could change the schedule of shock from an unsignalled to signalled one for brief time periods by pressing a changeover lever. The frequency of changeover responding was marked and choice of the signalled schedule occurred whether shock was avoidable, escapable, or inescapable.

Two studies are reported here based upon the above findings. For both studies, inescapable and unavoidable shock was used. The first study investigated how much longer durations of shock a subject would endure to receive signalled rather than unsignalled shock. Subjects in this study were given the option of short durations of unsignalled shock over longer durations of signalled shock. The second study investigated how much greater shock intensity a subject would endure to receive signalled over unsignalled shock. In this study, subjects were given the option of a low-intensity unsignalled shock over a high-intensity signalled shock. For both studies, the unsignalled shock intensity or duration remained fixed throughout the experiment but that of the signalled shock intensity or duration was systematically increased.

EXPERIMENT I: VARYING THE DURATION OF SIGNALLED AND UNSIGNALLED SHOCK.

METHOD

Four experimentally naive female albino rats of the Sprague-Dawley strain (Holtzman) between 90 and 120 days old served as subjects.

All subjects were tested in a two-lever Foringer operant conditioning chamber modified so that the grid bars were perpendicular to the levers. It was 14 in. long, 10 in. wide, and 5 in. high (36.8 by 25.4 by 12.7 cm). The levers required about 20 g (0.196 N) to depress and were 2 in. (5 cm) from the side along the 10 in. (25.4 cm) wall, 3 in. (7.65 cm) above the grid floor. Both levers were effective for changeover responding. A 5-sec 1000-Hz tone (84 dB) served as the preshock warning stimulus and a 1 in. (2.54 cm) white jewelled houselight (24 V dc) mounted above the right lever served as the correlated stimulus. The termination of a 0.5 in. (1.3 cm) jewelled light situated above the left bar signalled the beginning of the experimental session and its onset signalled the end. The operant chamber

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was enclosed within an IAC acoustical chamber.

A constant wattage shock source (BRS Inc.) delivered a 75 mW shock. Grid bars were 0.25 in. (0.64 cm) stainless steel spaced 0.5 in. (1.3 cm) apart center-to-center. The walls and response levers served as one contact in the grid scrambling circuit.

Subjects were run in sessions 6 hr long every second day. Shock in all conditions was delivered on a VT 120-sec schedule with a range from 30 sec to 210 sec in 30-sec blocks. Shock was at all times unavoidable and inescapable.

Initial Training

All subjects were exposed for a minimum of three 6-hr sessions to a signalled schedule during which the correlated stimulus was always on and the 5-sec tone always preceded shock. Responses on the changeover levers and the consequent amount of time that would have been spent in the changeover condition were recorded, though these responses produced no stimulus change.

Initial Changeover

After the operant level on the changeover levers had stabilized under the "training" condition, subjects began the next session in the unsignalled condition. Under the unsignalled schedule, the correlated stimulus was not on and tone was not presented before shock. A changeover response at this time produced the correlated stimulus and the signalled schedule for a period of 3 min. Additional changeover responding during this 3-min period was recorded but had no effect. At the end of the 3-min period, the correlated stimulus and the signalled schedule terminated and the subject could either remain in the unsignalled condition or reinstate the signalled condition by making another changeover response. Responding at no time had any effect on the arranged schedule of shock presentation.

Changeover with Timeout (CO-TO)

After three consecutive days of stable changeover responding, a 10-min timeout (TO) component was added at the end of each hour in the 6-hr session. During the timeout, the contingency was withdrawn and responses produced no stimulus change, *i.e.*, the correlated stimulus and signal schedule were not presented after a changeover response and shock duration was always 0.5 sec. Responses during this period were recorded separately. The TO component was included in all further sessions and served to ensure that subjects made contact with the unsignalled condition for a minimum of 50 min during each 6-hr session. Since TO was identical to the extinction condition (see below), no scheduled TO occurred during extinction.

Changeover to Longer Shocks

After three days of stable performance in the CO-TO condition, a series of conditions was initiated in which signalled shock duration was increased in 0.5-sec steps. Unsignalled shock always remained at 0.5 sec. Subjects were run at each shock duration for a minimum of three 6-hr sessions or until changeover responding stabilized. An extinction condition (see below) followed the initial series of shock increments. Following extinction, a second series of increments was initiated during which shock duration was again increased in 0.5-sec steps. Several additional shock duration conditions were also arranged.

Extinction

Under the extinction procedure, subjects were placed in the unsignalled condition and neither the correlated stimulus nor signal followed changeover responding. However, responses on the changeover levers and the amount of time that would have been spent in the changeover condition were recorded. This extinction procedure allowed evaluation of the effects on changeover responding exerted by both correlated stimulus and signal. A more complete analysis of the control exerted by either the correlated stimulus or signal alone can be found elsewhere (Badia and Culbertson, 1972).

RESULTS

All subjects chose signalled over unsignalled shock. Subjects began changing over from unsignalled to signalled shock on the first day that the changeover contingency was available and within a few sessions changeover responding stabilized at a high level (Table 1, row 2). Adding the 10-min TO period (Table 1, row 3) had little, if any, effect on changeover responding when the contingency was reinstated. However, responding during the TO condition was high relative to the regular changeover condition. As noted, a TO period was used to ensure that subjects continued to have contact with the unsignalled condition in the event that changeover responding occurred at very high frequencies. Figure 1 shows a relatively complete record of time spent in the signalled shock schedule for the various conditions of the experiment for Subject U81. Table 1 contains data for all subjects. The data indicate the high degree of control that was acquired by the signal schedule.

Acquisition of the changeover response showed the same pattern reported by Badia *et al.*, (1971) and Badia and Culbertson (1972). Once contact with the contingency was made, changeover responding increased immediately. The degree of stimulus control exerted by the correlated stimulus was reflected in the pattern of responding in that when the changeover period timed out (termination of correlated stimulus), subjects generally reinstated it immediately. Also, in the presence of the correlated stimulus few non-functional responses were made.

Increases in the duration of signalled shock were introduced only after changeover responding had stabilized under the previous condition. As noted, the duration of unsignalled shock remained at 0.5 sec for the entire experiment. The effect that increasing the duration of signalled shock had on changeover responding can be seen in Table 1. All four subjects continued changing over to the signal condition for the first three 0.5-sec increments in shock duration (Table 1, rows 4, 5, and 6). At this point, duration of signalled shock was 2.0 sec and rate of changeover responding for Subject U88 dropped to a point where about 50% of the time was spent under the signal schedule (Table 1, row 6). An effort was made to re-establish the previous high level of changeover responding for Subject U88 by reducing the signalled shock duration back to 0.5 sec. This effort was

Table 1

Per cent of time spent in changeover (CO) is shown for last three days of each condition. Shock duration for the unsignalled condition remained at 0.5 sec for the entire experiment but shock duration for the signal conditions was increased in 0.5-sec increments (far left column) for the first shock series. Increments varied for the second shock series. Numbers in parenthesis refer to the number of 6-hr sessions spent in that condition. Except for the initial CO condition, all CO sessions included a timeout (TO) component in which only unsignalled shock (0.5 sec) was scheduled.

Subject	*U80*			*U81*			*U88*			*U89*		
	Last Three Days											
Exp. Condition	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Baseline	0	0	0(4)	3	1	3(4)	22	11	0(3)	10	1	5(3)
CO 0.5-sec	82	86	80(4)	95	96	95(3)	54	96	96(6)	70	80	89(4)
CO 0.5-sec With TO	80	82	82(8)	92	92	90(6)	86	84	87(4)	88	88	93(4)
CO 1.0-sec	82	88	89(5)	87	87	93(4)	93	80	85(5)	89	84	85(5)
CO 1.5-sec	82	79	83(6)	86	81	86(6)	76	72	75(5)	80	83	84(5)
CO 2.0-sec	81	82	82(4)	87	87	84(4)	53	47	48(10)	81	82	87(7)
CO 2.5-sec	77	78	80(6)	89	88	85(4)				82	90	86(5)
EXT with 0.5 sec	46	44	43(8)	32	25	22(4)				25	17	8(12)
CO 0.5-sec	93	87	90(5)	91	93	94(4)	24	29	24(10)	94	93	93(3)
CO 2.5-sec	96	85	86(5)	95	90	93(4)				91	89	91(3)
CO 3.5-sec	85	86	82(6)	91	87	91(3)				57	63	58(7)
CO 4.5-sec	63	61	68(7)	95	92	90(3)						
EXT with 0.5 sec	9	13	17(11)	37	35	24(3)						
CO 4.5-sec				85	88	90(4)						
EXT with 4.5 sec				34	25	23(3)						
CO 4.5-sec				89	79	84(3)						

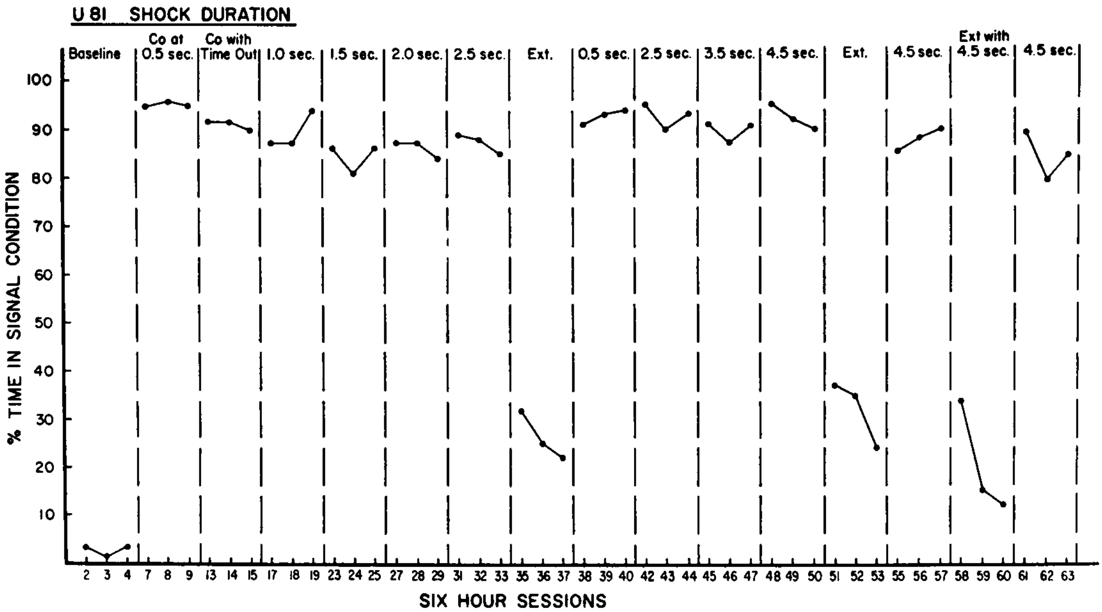

Fig. 1. Per cent of session time spent in the signalled shock schedule for the last three sessions of each shock duration condition. Conditions appear in the order they were administered.

discontinued without success after 10 days (Table 1, row 6).

The remaining three subjects continued changing over throughout the first series of 0.5-sec increments, which ended at 2.5 sec. Changeover responding for these three subjects appeared unaffected by this five-fold increase in signalled over unsignalled shock duration (Table 1, row 7). At this point (2.5 sec), the changeover contingency was withdrawn and only unsignalled shock of 0.5 sec was presented during this extinction period. The effect of removing this contingency was a marked decrement in changeover responding (Table 1, row 8) for all subjects. Rate of changeover responding increased to previous levels for these subjects when the signalled schedule contingency was reinstated (Table 1, row 7). After changeover responding stabilized for these three subjects, signalled shock duration was abruptly shifted from 0.5 sec to 2.5 sec. This abrupt shift in duration produced no noticeable effect on changeover responding. Following this, additional 1-sec increments in shock duration were added. As shown in Table 1, changeover responding decreased to about 60% at 3.5 sec for Subject U89 (Table 1, row 11), but Subjects U80 and U81 continued responding at fairly high levels with a signalled shock duration of 4.5 sec. This duration of signalled shock represents nine times the duration of unsignalled shock.

Subject U81 was least affected by the increases in signalled shock duration (Figure 1). The last three conditions of the experiment are especially interesting. When the changeover contingency was removed for the second time (Table 1, row 13) rate of responding decreased as it had previously. The changeover contingency was then reinstated but with a signalled shock duration of 4.5 sec. Subject U81 quickly reacquired the changeover response with this abrupt increase in shock duration and responded at a rate sufficient to spend between 85 and 90% of time in the signalled schedule (Table 1, row 14). To determine whether shock duration *per se* had any effects on changeover responding, the signal contingency was again removed, but shock duration remained at 4.5 sec. As shown in Figure 1 and Table 1, row 15, changeover responding decreased markedly. This latter condition illustrates that changeover responding was controlled by the signal contingency and that responding was relatively unaffected by shock duration *per se*. The final condition for this subject consisted of reinstating the contingency with a shock duration again at 4.5 sec. Again, a marked increase in changeover responding occurred (Figure 1).

EXPERIMENT 2: VARYING THE INTENSITY OF SIGNALLED AND UNSIGNALLED SHOCK

METHOD

Six experimentally naive female albino rats of the Sprague-Dawley strain (Holtzman) between 90 and 120 days old served as subjects.

The apparatus was identical to that used in Experiment 1 except that a Lehigh Valley constant current (dc) shock source was used and a sonalert (84 dB) served as the preshock warning stimulus. Conditions were the same during "initial training", "initial changeover", and "changeover with timeout" (CO-TO). The inescapable and unavoidable shock (1.0 mA) was of 0.5-sec duration.

Changeover to More Intense Shock

After three days of stable performance in the CO-TO condition, a series of conditions was initiated in which the intensity of signalled shock was increased in either 0.4-or 0.2-mA steps. The intensity of unsignalled shock remained at 1.0 mA. An extinction condition (same as in Duration experiment) followed the initial series of signalled shock increments. After extinction, a second series of increments was initiated during which shock intensity again increased from 1.0 mA. Two subjects (U71 and U91) were given an additional extinction and reacquisition session.

RESULTS

All subjects began changing over to the signalled shock schedule the first day the contingency was introduced and changeover responding stabilized within a few sessions. Adding the TO component had little effect on performance for five of the six subjects. However, the TO condition did affect Subject U67 and the per cent of time spent under the signalled shock schedule with TO (Table 3, row 3) stabilized at about 10 to 15% lower than in the changeover condition without the TO component (Table 3, row 2). After responding stabilized under the condition with TO, the intensity of signalled shock was increased. As previously noted, the intensity of unsignalled shock remained at 1.0 mA throughout the experiment. Figure 2 contains a relatively complete record for Subject U91 under the various conditions of the experiment. Tables 2 and 3 contain data for all subjects.

Changing over to the signalled shock schedule continued at a high rate for all subjects until signalled shock intensity reached a level between 1.8 and 2.0 mA, *i.e.*, about twice that of unsignalled shock (Tables 2 and 3). Addi-

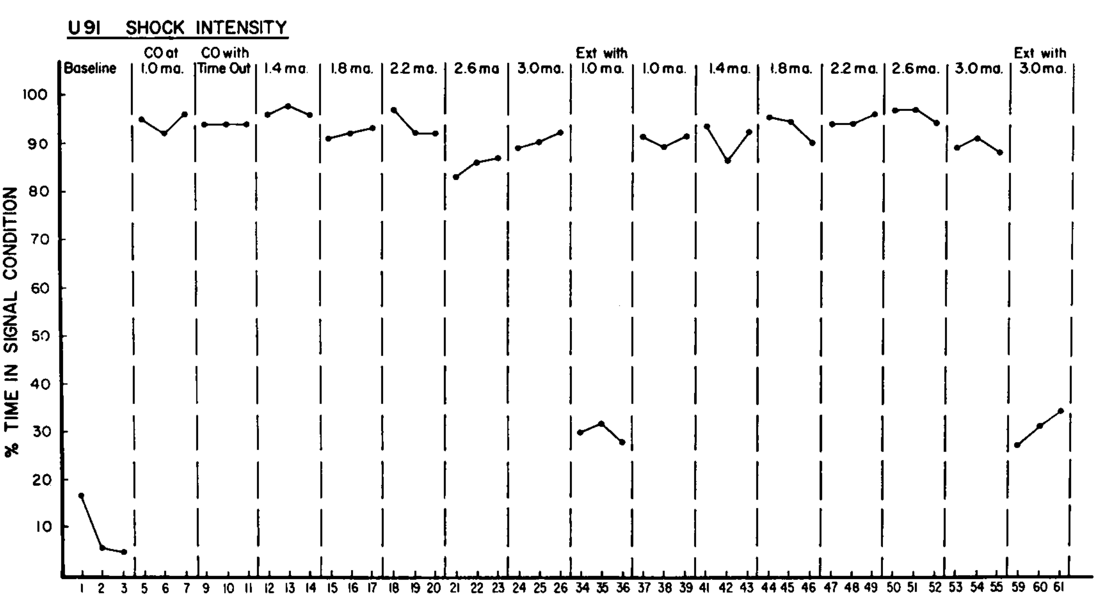

Fig. 2. Per cent of session time spent in the signalled shock schedule for the last three sessions of each shock intensity condition. Conditions appear in the order they were administered.

Table 2

Per cent of time spent in changeover (CO) is shown for last three days of each condition. Shock intensity for the unsignalled condition remained at 1.0 mA for the entire experiment but shock intensity for the signal condition was increased in 0.4-mA increments (far left column). Numbers in parentheses refer to the number of 6-hr sessions spent in that condition. Except for the initial CO condition, all CO sessions included a timeout (TO) component in which only unsignalled shock (1.0-mA) was scheduled.

Subject	*U90*			*U91*			*U92*			*U93*		
	Last Three Days in Condition											
Exp. Condition	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Baseline	21	14	5(3)	18	6	5(3)	21	0	5(3)	7	18	27(4)
CO at 1.0 mA	83	89	97(6)	95	92	96(4)	86	92	96(4)	91	92	92(4)
CO at 1.0 mA With TO	72	74	75(4)	94	94	94(4)	95	92	92(3)	86	88	95(3)
CO 1.4 mA	75	80	84(3)	96	98	96(3)	93	94	95(3)	95	99	96(3)
CO 1.8 mA	58	65	61(5)	91	92	93(3)	95	92	93(3)	99	87	89(3)
CO 2.2 mA	71	67	65(3)	97	93	93(3)	58	58	57(9)	47	43	26(8)
CO 2.6 mA	39	19	9(6)	83	86	87(3)	16	26	22(6)			
CO 3.0 mA				89	90	92(3)						
EXT with 9.5 sec				30	32	28(10)						
CO 1.0 mA	70	75	72(7)	91	89	91(3)	52	52	47(11)			
CO 1.4 mA	74	66	66(8)	93	86	92(4)						
CO 1.8 mA	52	60	53(9)	95	94	90(3)						
CO 2.2 mA	30	15	3(9)	94	94	96(3)						
CO 2.6 mA				97	97	94(3)						
CO 3.0 mA				89	91	88(3)						
EXT with 3.0 mA				27	31	34(6)						
CO 3.0 mA				88	92	92(3)						

tional increments in the intensity of signalled shock produced varied results for different subjects. For Subject U90, changeover responding dropped to a very low level at a signalled shock intensity of 2.6 mA (Table 2, row 7). When the intensity of signalled shock was reduced for this subject to the level of unsignalled shock (1.0 mA), changeover responding again increased (Table 2, row 10). However, in the replication of the shock increment series, changeover responding decreased to baseline levels at an intensity value of 2.2 mA (Table 2, row 13). The performance of Subjects U67, U92, and U93 was similar to Subject U90. For each of these subjects, a marked reduction in frequency of responding occurred around 2.2 mA. Unlike Subject U90, an attempt to increase the frequency of changeover responding for Subjects U67 and U92 by reducing signalled shock to 1.0 mA was unsuccessful (Table 2, row 10; Table 3, row 11). No attempt was made to do this for Subject U93.

Subjects U71 and U91 performed differently from the others. For Subject U71, increments of 0.2 mA were used for the first series of signalled shock to an intensity level of 2.0 mA. At this shock level (2.0 mA), Subject U71 continued responding at a high rate and remained under the signalled schedule about 90% of the time (Table 3, row 8). The signal contingency was then removed, *i.e.*, all shocks were unsignalled at 1.0 mA (EXT), and, after responding stabilized under this condition, a second series of shock increments was initiated. For this second series, shock intensity went from 1.0 to 3.0 mA in increments of 0.4 mA. As shown in Table 3, Subject U71 continued responding at a high rate through the entire shock series with only a slight reduction in frequency at 3.0 mA (Table 3, row 16). To rule out the effect of high intensity shock *per se* on changeover responding for Subject U71, the changeover contingency again was removed (EXT) but with shock scheduled at 3.0 mA. Changeover responding showed a marked drop in rate (Table 3, row 17) as it had under the previous extinction condition at 1.0 mA. It is apparent that shock intensity in the absence of the contingency had little effect on changeover responding.

Table 3

Per cent of time spent in changeover (CO) is shown for last three days of each condition. Shock intensity for the unsignalled condition remained at 1.0 mA for the entire experiment but shock intensity for the signal condition was increased in 0.2-mA increments (far left column) for the first shock series. 0.4-mA increments were used in the second series. Numbers in parentheses refer to the number of 6-hr sessions spent in that condition. Except for the initial CO condition, all CO sessions included a timeout (TO) component in which only unsignalled shock (1.0 mA) was scheduled.

Subject	*U67*			*U71*		
	Last Three Days in Condition					
Exp. Condition	*1*	*2*	*3*	*1*	*2*	*3*
Baseline	0	0	0(4)	3	1	2(4)
CO at 1.0 mA	83	86	84(6)	85	90	90(5)
CO at 1.0 mA With TO	70	67	73(14)	90	88	91(3)
CO 1.2 mA	71	67	71(5)	92	86	91(8)
CO 1.4 mA	60	70	67(5)	93	93	93(5)
CO 1.6 mA	72	71	65(3)	95	93	93(4)
CO 1.8 mA	67	59	61(5)	94	90	92(3)
CO 2.0 mA	57	47	51(9)	91	85	89(3)
CO 2.2 mA	35	20	20(4)			
EXT with 1.0 mA				47	29	30(6)
CO 1.0 mA	22	37	32(13)	94	96	98(5)
CO 1.4 mA				96	98	98(3)
CO 1.8 mA				95	94	95(3)
CO 2.2 mA				93	93	92(3)
CO 2.6 mA				90	84	87(3)
CO 3.0 mA				67	73	74(8)
EXT with 3.0 mA				30	18	27(4)

Frequency of responding for Subject U91 was least affected by increments in the intensity of signalled shock. This latter subject went through two shock series from 1.0 to 3.0 mA in increments of 0.4 mA. These series were separated by extinction sessions in which the changeover contingency was removed. For both series there were no noticeable decreases in frequency of changeover responding at any shock level. As with Subject U71, Subject U91 was given additional extinction sessions with shock at 3.0 mA following the second series of shock increments. Under this extinction condition, frequency of changeover responding dropped to a level as low as it had been with extinction at 1.0 mA (Table 2, row 16). Following these extinction sessions, the changeover contingency was reinstated for a third time, but with signalled shock at 3.0 mA. Changeover frequency again increased to a point where Subject U91 was spending about 90% of time under the signalled schedule (Table 2, row 17—not included in Figure 2).

DISCUSSION

The results can be briefly summarized. Subjects in the duration experiment responded to receive signalled shock from four to nine times longer in duration than unsignalled shock. Similarly, subjects in the intensity experiment responded to receive signalled shock two to three times more intense than unsignalled shock. It is apparent that the signalled shock contingency was a powerful reinforcer in these studies.

Several interpretations of why subjects endured longer and stronger values of signalled shock are possible. The results are not discrepant with a preparatory response interpretation (Perkins, 1955). However, it does not seem plausible that preparation could attenuate the aversiveness of shock at levels as high as 3.0 mA or as long as 4.5 sec. Even if one were to concede that preparation did occur, it is unlikely that the aversiveness of signalled shock (3.0 mA and 4.5 sec) could be reduced to below that of unsignalled shock (1 mA and 0.5 sec) by preparatory responses.

These results are compatible with the analysis offered by Badia *et al.*, (1971) and Badia and Culbertson (1972). Their analysis is a variant of Seligman's (1968) safety hypothesis and stresses that stimuli that identify periods of time free from aversive stimulation (shock-free periods) acquire reinforcing properties. This analysis can be applied to the present findings. When subjects were in the signal condition the compound of correlated stimulus and signal identified a shock (unsafe) period while the correlated stimulus in the absence of the signal identified a shock-free (safe) period. The shock period relative to the shock-free period was brief, lasting only as long as the signal duration (5 sec). In contrast, the shock-free period, identified by the correlated stimulus alone, was much longer, consisting of the total intershock time (120 sec mean) minus the signal duration. These above characteristics of the signalled situation must be considered relative to the unsignalled one. In the unsignalled condition, neither shock nor shock-free periods could be identified and the entire intershock interval may have acquired the properties of a shock period. If the above considerations did prevail, then the signalled situation may have been chosen over the unsignalled one because only under the signal condition could a relatively long shock-free period be identified. An implicit assumption of this interpretation is that the reinforcement derived from the safe periods (correlated stimulus alone) within the signal condition was greater than the aversiveness associated with increases in shock intensity or duration that subjects had to endure to obtain the signal schedule.

While the validity of this analysis of shock-free periods has not been firmly established, related data do provide additional support. It has been shown that less lever holding and more exploration occur with rats when shock and shock-free periods are discriminable (Badia and Culbertson, 1970). Other studies have shown that operant responses can be maintained by stimuli that identify shock-free periods (Azrin, Holz, Hake, and Ayllon, 1963; Hendry, 1967; Sidman, 1962; Verhave, 1962). In addition, results related to the present findings have been published by Rescorla and LoLordo (1965) and Weisman and Litner (1971). The former authors showed that a stimulus identifying a shock-free period suppresses avoidance responding; the latter authors showed that the duration of the shock-free period is related to its suppressive effect on avoidance.

An obvious question concerning the present results relates to difference thresholds for shock aversiveness. There are apparently no data available dealing with the difference limen for duration, but the findings of Campbell and Masterson (1969) bear directly on the question of intensity. These investigators defined the aversion difference limen as the difference in intensity between two aversive stimuli when one of them is preferred over the other 75% of the time. Their findings indicate that with a standard shock of 1.0 mA, a difference of 0.2 mA is discriminable. Relative to the subjects of the present study, the first 0.2-mA increment in signalled shock should have been discriminably different from the constant 1.0-mA unsignalled shock.

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