CHOICE AND THE DEPENDABILITY OF STIMULI THAT PREDICT SHOCK AND SAFETY¹

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This study assessed whether choosing a signalled shock condition over an unsignalled one is controlled by a stimulus that predicts the presence of shock (Experiment I), or by a stimulus that predicts the absence of shock (Experiment II). The dependability of these stimuli as predictors of either the presence or the absence of shock was parametrically varied over a wide range, and subjects (rats) were given an option to change from an unsignalled to a signalled condition. In the first experiment, all shocks were preceded by signals; however, the probability of a signal being followed by shock varied from 1.0 to 0.02. The data obtained indicate that the dependability of the signal as a predictor of shock is unimportant. Rats changed to the signalled condition when the signal was completely dependable (all signals followed by shock) and when the dependability of the signal was systematically degraded. In the second experiment, all signals were followed by shock; however, some shocks were not preceded by a signal. The data show that the dependability of a stimulus predicting the absence of shock is important in that, as dependability decreases, changing to the signalled condition also decreases.

Key words: choice, dependability, predictability, signalled shock, changeover, rat

Much attention has been given to the analysis of stimuli that identify the presence of food or shock periods and to those that identify the absence of these periods. In those studies where the presence of a signal (CS) identified a shock period and its absence ($\bar{CS}$) identified a shock-free period, rats chose the signalled over the unsignalled condition whether shock was avoidable (Badia, Culbertson, and Lewis, 1971), escapable, or inescapable (Badia and Culbertson, 1972). In these studies, choice of the signalled condition was found with each subject, and it was strong and durable. Others have reported similar findings using different methods (*e.g.*, Lockard, 1963). Related research has also shown that subjects choose fixed-time over variable-time shock when shock is unsignalled, but that choice can be reversed if the variable-time shock is signalled. These findings suggest the importance of being able clearly to identify shock and shock-free periods (Badia, Harsh, and Coker,

1975). Choice of the signalled condition has also been found with humans (*e.g.*, Badia, Culbertson, and Harsh, 1974).

Stimuli that identify the presence or absence of shock have various other effects. For example, suppression of responding is greater when punishment is unpredictable than when it is predictable (Church, 1969; MacDonald, 1973). Similarly, when response-independent shock is superimposed on an appetitive baseline, overall suppression is greater when shock is unsignalled than when it is signalled (Brimer and Kamin, 1963; Davis and McIntyre, 1969; Harsh and Badia, 1974; Seligman and Meyer, 1970). Data from physiological studies provide other evidence concerning shock and shock-free periods. Although there are some exceptions, these data indicate that aversive situations are less physiologically debilitating when these periods are identifiable than when they are not (*e.g.*, Paré, 1964; Seligman, 1968; Weiss, 1971).

Studies of the behavioral importance of signalled shock schedules have typically occurred under conditions where stimuli identifying shock and its absence were completely dependable. That is, the presence of the signal dependably (always) identified a shock period

¹This research was supported in part by Grant GB-33725 from the National Science Foundation and funds from the Faculty Research Committee of Bowling Green State University. Reprints may be obtained from Pietro Badia, Department of Psychology, Bowling Green State University, Bowling Green, Ohio 43403.

and its absence dependably (always) identified a shock-free period. However, the relative importance of these periods in controlling choice and other behavior has not been fully assessed. Is choice of the signalled condition based on having identifiable shock periods, as the preparation hypothesis states (Perkins, 1955, 1968)? Is choice based on having identifiable shock-free periods, as the safety hypothesis states (Badia *et al.*, 1971; Seligman, Maier, and Solomon, 1971)? Or is choice based on both periods being identifiable, as certain information hypotheses state (*e.g.*, Bloomfield, 1972; Hendry, 1969)? In other words, what stimuli in the signalled shock situation control choice behavior?

One way of answering these questions is to use a choice procedure while varying separately and parametrically both the dependability with which a stimulus identifies shock periods and the dependability with which a stimulus identifies shock-free periods. The signalled situation could be arranged so that the signal's presence dependably (always) identified a shock period while its absence undependably (only sometimes) identified a safe period. If choice for the signalled condition depends on having identifiable safe periods, then making the stimulus identifying these periods undependable ought to reduce or eliminate this preference. Conversely, it could be arranged so that the signal's presence undependably identified a shock period while its absence dependably identified a shock-free period. If being able to identify shock periods is of primary importance, preference for signalled shock ought to decline as the dependability of the signal identifying shock periods is reduced. The results of such a study should indicate more clearly why subjects choose the signalled over the unsignalled condition.

Dependability and Conditional Probability

Conditional probabilities can be used to describe the dependability of stimuli identifying either the presence or absence of shock. The probability of shock given the presence of a stimulus (CS) may be represented by the expression $p(\text{US}/\text{CS})$. The probability of shock given the absence of that stimulus ($\overline{\text{CS}}$) may be represented by the expression $p(\text{US}/\overline{\text{CS}})$. In the present studies, CS and $\overline{\text{CS}}$ represent the presence and absence of the signal in the

signalled condition. Since $p(\text{US}/\text{CS})$ and $p(\text{US}/\overline{\text{CS}})$ are orthogonal, the value of each may range from zero to 1.0 independently. However, the shock periods are identified dependably only when the $p(\text{US}/\text{CS}) = 1.0$, while shock-free periods are identified dependably only when the $p(\text{US}/\overline{\text{CS}}) = 0$. Thus, the stimulus identifying the shock period can be made undependable by lowering the value of $p(\text{US}/\text{CS})$, while the stimulus identifying the shock-free period can be made undependable by raising the value of $p(\text{US}/\overline{\text{CS}})$.

It is important that dependability not be confused with the term "reliability". The two are not synonymous. There are two important differences. First, the level of dependability is completely specified by one conditional probability. Thus, the *dependability* of the signal as a predictor of shock depends for its value only upon $p(\text{US}/\text{CS})$ and is independent of the value of $p(\text{US}/\overline{\text{CS}})$. The *reliability* of the signal as a predictor of shock, on the other hand, depends for its value upon specification of *both* conditional probabilities. Because the value of reliability changes as a function of both, it fails to distinguish between the methods employed to vary it. This suggests that variations in $p(\text{US}/\text{CS})$ and $p(\text{US}/\overline{\text{CS}})$ are behaviorally equivalent. There is, however, no logical necessity that this be true, and to assume its truth before the data are in would be presumptuous. Use of the term "dependability" avoids this difficulty. The second difference involves the computation of probabilities. Since reliability requires specification of two conditional probabilities, it is necessary to define both on comparable time bases. Both probabilities then refer to the probability of shock per unit of time under a given stimulus condition. Dependabilities need not be defined upon comparable-time bases, but may instead emphasize other regularities. For the purpose of this study, the probability of shock per stimulus presentation (*i.e.*, the probability that a shock will occur given that a stimulus has occurred) is a preferable base of comparability because the probabilities so computed then reflect the frequency with which the occurrence of shock or safety is correctly identified by the signal or its absence. The probabilities expressed here are thus "per-stimulus" probabilities rather than "time-based" probabilities.

Table 1

The values used when varying the dependability of a stimulus identifying when shock would occur.

p (US/CS)	1.0	0.25	0.10	0.02	0
p (US/ $\overline{\text{CS}}$)	0	0	0	0	0
Number of Shocks	180	45	18	3	0
Number of Signals	180	180	180	180	180
Mean Intershock Interval	2 min	8 min	20 min	120 min	—
Mean Intersignal Interval	2 min	2 min	2 min	2 min	2 min

EXPERIMENT I DEPENDABILITY OF A STIMULUS IDENTIFYING A SHOCK PERIOD

The first experiment varied the dependability of the signal as a predictor of shock and used values of p (US/CS) ranging from 1.0 to 0.02. Dependability was varied by holding the number of signals constant at 180 and varying the number of shocks from 180 to three. The value of p (US/ $\overline{\text{CS}}$) under the signalled condition remained constant at zero for all conditions of the first experiment.

METHOD

Subjects

Twelve naive female albino rats (90 to 110 days) of the Sprague-Dawley strain (Holtzman Co.) were housed individually and maintained on a 12-hr light/dark cycle with free access to food and water.

Apparatus

Foringer operant conditioning units were modified so that the grid bars were perpendicular to the levers. Each unit (35.6 cm long, 25.4 cm wide, and 12.2 cm high), housed in IAC acoustical chambers, contained two levers mounted on the 25.4-cm wall 7.6 cm above the grid floor and 5.1 cm from either side. They were separated by 7.0 cm and each required 20 g (0.20 N) to depress. Termination of a 28-V bulb (#28ESB), with a 1.3-cm white lens caps and located 5.08 cm above the left lever, identified the beginning of each session and its onset identified the end. A 1400-cps tone served as the signal. When programmed to occur, it preceded shock by 5.0 sec and terminated with shock cessation. A constant wattage shock source (BRS, Inc.) delivered inescapable and unavoidable 0.5-sec shock (75-mW) through 0.6-cm stainless-steel grid bars spaced 1.3 cm apart. The walls and the response levers served as one contact in the grid

scrambling circuit. The correlated stimulus for the signalled schedule was a 24-V bulb (#509K) with a 2.5-cm white lens cap mounted 15.24 cm above the right lever. Absence of this light (darkness) served as the correlated stimulus for the unsignalled schedule.

Procedure

Subjects were tested in 6-hr sessions every other day. Shock was delivered independently of responding on a variable-time (VT) basis. The VT shock schedules were generated by the Fleshler and Hoffman (1962) tables modified to accommodate the minimum inter shock interval of 9 sec.

Training-baseline condition. Each subject was exposed to a minimum of three 6-hr sessions during which the designated signalled condition was in effect. At this time, responses on the changeover levers produced no stimulus changes, but responses and the time that would have been spent in the changeover condition had these responses been effective were recorded and served as baseline data.

The training-baseline conditions varied depending on: (a) the dependability of the signal as a predictor of shock, p (US/CS); and (b) the number of shocks presented during a session. The various conditions of the experiment are found in Tables 1 and 2. The specific condi-

Table 2

The values used when varying the inter shock interval for control purposes.

p (US/CS)	1.0	1.0	1.0
p (US/ $\overline{\text{CS}}$)	0	0	0
Number of Shocks	180	18	3
Number of Signals	180	18	3
Mean Intershock Interval	2 min	20 min	120 min
Mean Intersignal Interval	2 min	20 min	120 min

tions that each subject received are described below in detail.

The value of $p(\text{US}/\text{CS})$ was varied by maintaining a constant number of signals (180) with a 2-min mean intersignal interval while omitting different numbers of shock (Table 1). Under the signalled condition, shock occurred only in the presence of the compound of signal and correlated stimulus, but with the value of $p(\text{US}/\text{CS})$ varying (Table 1). Shock never occurred in the absence of the compound at any time during the signalled condition. Therefore, the presence of the correlated stimulus alone in the absence of the signal always identified a shock-free period, i.e., $p(\text{US}/\overline{\text{CS}}) = 0$.

Changeover (CO) condition. Following the training-baseline sessions, subjects were given the option to change from the unsignalled to the signalled condition. Under this option, subjects were placed in the unsignalled condition but could change to the signalled one by pressing either of the levers. This changeover response resulted in the immediate onset of the correlated stimulus identifying the signalled condition. The signalled condition remained in effect for 1-min and additional responses during this period were ineffective, although they were recorded. During the signalled condition, the probability of shock following a signal depended on the particular condition in effect (see Tables 1 and 2). At the end of the 1-min CO period, the correlated stimulus and the signalled condition terminated and the unsignalled condition was reinstated. The subject remained in the unsignalled condition unless the signalled one was re-instated by another changeover response. Responses during a 2.5-sec period following shock onset did not produce changeover periods. This delay was imposed to avoid production of changeover periods by shock-elicited responses. Changing from the unsignalled to signalled condition had no effect on shock density.

Extinction. Under the extinction procedure, subjects were placed in the unsignalled condition and neither the correlated stimulus nor the signalled schedule followed a CO response. However, as in the training-baseline condition, responses on the levers and the amount of time that would have been spent in the signalled conditions had the responses been effective were recorded.

Criterion for change. Subjects remained under each condition until responding stabilized. The requirement for stability was three consecutive sessions in which the per cent of time in the changeover condition varied no more than 10% between sessions. Exceptions to this criterion were allowed if performance variability persisted over many sessions.

Subjects with training-baseline of $p(\text{US}/\text{CS}) = 1.0$. Subjects IS7, IS8, and IS12 initially chose between the signalled and unsignalled conditions after first receiving the training-baseline condition with the value of $p(\text{US}/\text{CS}) = 1.0$ (the value of $p[\text{US}/\overline{\text{CS}}]$ remained at zero for all subjects). Under these conditions, the average intershock interval and intersignal interval were both 2 min (180 signals, 180 shocks per session). After changeover responding became stable under the changeover condition, these subjects were given an extinction condition in which no signals, but 180 shocks, occurred. When responding again became stable, the changeover condition was repeated with $p(\text{US}/\text{CS}) = 1.0$. The dependability of the signal as a predictor of shock was then reduced to $p(\text{US}/\text{CS}) = 0.10$. Under these conditions, the intershock interval averaged 20 min and the mean intersignal interval remained at 2 min (180 signals, 18 shocks per session). After CO responding became stable under the latter conditions, signal dependability was further reduced to a value of $p(\text{US}/\text{CS}) = 0.02$. Under these conditions, the intershock interval averaged 120 min and the intersignal interval remained at an average of 2 min (180 signals, three shocks per session). After responding stabilized, an extinction condition in which no signals and three shocks occurred was given. Finally, subjects were again given the option to change to the signalled condition with $p(\text{US}/\text{CS}) = 0.02$.

Subjects with training-baseline of $p(\text{US}/\text{CS}) \neq 1.0$. The subjects above each initially received dependable signal conditions, $p(\text{US}/\text{CS}) = 1.0$. Only after completion of testing was the dependability of the signal reduced. To eliminate possible carry-over effects from the dependable condition, Subjects S2, S3, S4, and S5 were initially trained under an undependable signal conditions with $p(\text{US}/\text{CS}) = 0.25$ (180 signals, 45 shocks per session). They were then given the changeover option with $p(\text{US}/\text{CS}) = 0.25$ followed by extinction (zero signals, 45 shocks). Then they were given a

second opportunity to change over at $p(\text{US}/\text{CS}) = 0.25$. For two of these subjects, signal dependability was then reduced to a value of $p(\text{US}/\text{CS}) = 0.10$. Following this, they were given a control condition of light and tone only ($p[\text{US}/\text{CS}] = 0$) to evaluate the effects of sensory stimulation. As a further check on carry-over effects, Subjects S9, S10, and S17 received initial training under an undependable signal condition with $p(\text{US}/\text{CS}) = 0.02$. The changeover option followed with $p(\text{US}/\text{CS}) = 0.02$, then extinction (zero signals, three shocks), and finally a second changeover option with $p(\text{US}/\text{CS}) = 0.02$.

Shock density control. Since varying the value of $p(\text{US}/\text{CS})$ also required varying the intershock interval, Subjects S13 and S14 were tested at different times with several different intershock intervals but each with a constant value of $p(\text{US}/\text{CS}) = 1.0$ (see Table 2). For Subjects S13 and S14, the intershock intervals were the same as those used for Subjects IS7, IS8, and IS12. Subjects S13 and S14 received the following conditions: for the first training-baseline condition, the intervals for the signals and shocks averaged 2 min (180 signals, 180 shocks per session). Extinction (no signals, 180 shocks) and a second exposure to the changeover condition (180 signals, 180 shocks) followed. Next, the changeover condition was changed to an average intershock and intersignal interval equal to 20 min (18 signals, 18 shocks per session). This was followed by a changeover condition in which the intershock and intersignal intervals were 120 min (three signals, three shocks per session), an extinction condition (zero signals, three shocks), and a second exposure to the final changeover condition completed the sequence for these subjects.

RESULTS

Signal Dependability and Changeover

The data presented in Figures 1 and 2 show the relationship between preference for a signalled shock schedule and the dependability of the signal as a predictor of shock. During the conditions shown (except for extinction sessions), the probability of a shock given the occurrence of a signal ($p[\text{US}/\text{CS}]$) was either 1.0, 0.25, 0.10, 0.02, or 0. As noted, with these conditions, the number of signals remained constant at 180 but the number of shocks de-

creased from 180 to 45, 18, 3, and 0, respectively. For the signalled condition, shock occurred only in the presence of the signal and never in its absence.

As seen in Figure 1, with 180 signals and 180 shocks, *i.e.*, $p(\text{US}/\text{CS}) = 1.00$, Subjects IS7, IS8, and IS12 changed over at a rate sufficient to spend more than 80% of their time under the signalled schedule. This rate of changing over was much higher than either the training condition or extinction (Figure 1), during both of which the changeover contingency was not in effect. These subjects continued changing to the signalled condition at a high rate when the value of $p(\text{US}/\text{CS})$ was reduced to 0.10 (180 signals, 18 shocks). No appreciable change was observed in the performance of Subjects IS8 and IS12 when the dependability value dropped further to 0.02 (180 signals, three shocks; Figure 1). However, the rate of changing over for Subject IS7 decreased to a point where about 60% of the session was spent under the signalled condition. Following several extinction sessions, the condition with 180 signals and three shocks was repeated and the results were similar to those previously obtained (Figure 1).

Subjects S2, S3, S4, and S5 were given their initial training-baseline condition with an undependable signal (*i.e.*, $p[\text{US}/\text{CS}] = 0.25$) and then given the opportunity to change from the unsignalled to the signalled schedule. It can be seen that these subjects spent most of each session under the signalled schedule when the changeover contingency was first introduced and later when it was re-instated following an extinction condition (Figure 2). No effect was observed on changeover when the dependability of the signal was reduced from $p = 0.25$ to 0.10 for Subjects S3 and S4. (Subjects S2 and S5 died before completing this condition.) However, when shock was eliminated ($p = 0$) and only the 180 signals and correlated stimulus were presented, the rate of changing over dropped to baseline levels (Figure 2).

Three additional subjects received their initial training and subsequent changeover conditions at a signal dependability of $p = 0.02$. These subjects also spent most of each session under the signalled schedule during both changeover conditions (Table 3). During an extinction condition in which no signals were presented, however, changeover responding fell to baseline levels.

Effects of Shock Frequency on CO Behavior

The probability that a shock would follow a signal was varied in the present study by holding constant the number of signals occurring within a session while reducing the number of shocks. Therefore, any observed effects when the dependability of the signal was decreased could also be attributed to a reduced frequency of shocks or, alternatively, to an extended intershock interval. Additional subjects were tested to assess the effects of reducing shock frequency while holding the dependability of the signal constant. The data obtained are presented in Figure 3.

Subjects S13 and S14 were first exposed to a condition during which 180 shocks and 180 signals were delivered. This condition was identical to that given to Subjects IS7, IS8, and IS12, and similar results were obtained (Figures 1 and 3). The number of both signals and shocks was then reduced from 180 to 18 and these subjects continued spending between 80% and 90% of their time in the signalled condition (Figure 3). However, reducing the number of signals and shocks to three had a marked effect on performance. Rate of changing over dropped for these subjects to a point where about 50% of time for S14 and 35% of time for S13 was spent in the signalled

Fig. 1. Per cent of session time spent in the changeover condition for the last three days of each condition as a function of the dependability of the signal predicting shock [$p(US/CS)$]. The number of signals under each condition remained constant at 180. Dependability of the signal was varied by reducing the number of shocks given in a session from a maximum of 180 to a minimum of three. Numbers on the abscissa represent the sessions from which the data points were taken.

condition. Similarly, very low levels of changing over were observed when the changeover condition was repeated after several extinction sessions (Figure 3). The low level of changing over by Subjects S13 and S14 when three signals and three shocks were delivered contrasts with the high level of changing over by Subjects IS7, IS8, and IS12 when 180 signals and three shocks were delivered (Figure 1).

EXPERIMENT II DEPENDABILITY OF A STIMULUS IDENTIFYING A SHOCK-FREE PERIOD

It is clear from the preceding experiment that choice of the signalled condition was relatively unaffected by varying the dependability of a stimulus identifying a shock period. The present experiment assessed the extent to which choice is affected by the dependability

Fig. 2. Per cent of session time spent in the changeover condition for the last three days of each condition as a function of the dependability of the signal predicting shock [$p(US/CS)$]. The number of signals under each condition remained constant at 180. Dependability of the signal was varied by reducing the number of shocks given in a session from a maximum of 180 to zero. Numbers on abscissa represent the sessions from which the data points were taken.

Table 3

Per cent of session time in the changeover condition for the last three days in each condition for subjects experiencing a dependability of the signal predicting shock of $p(US/CS) = 0.02$. Total number of days spent in each condition is indicated by the number in parentheses.

Subject	Baseline ($p = 0.02$)	CO	Extinction	CO
		180 Signals 3 Shocks ($p = 0.02$)	0 Signals 3 Shocks	180 Signals 3 Shocks ($p = 0.02$)
S9	21	89	14	91
	4	85	17	85
	11 (5)	89 (8)	12 (4)	85 (14)
S10	31	83	22	82
	23	86	16	83
	15 (7)	84 (5)	24 (6)	90 (5)
S17	25	88	25	84
	16	92	19	90
	18 (5)	91 (8)	17 (9)	87 (7)

Fig. 3. Per cent of session time spent in the changeover condition for the last three days of each condition as a function of the mean intershock and intersignal intervals. Intervals of 2 min, 20 min, and 120 min were used. Numbers on the abscissa represent the sessions from which the data points were taken.

of a stimulus identifying a shock-free period.

In the previous experiment, while in the signalled condition, the probability of shock in the presence of a signal varied while the probability of shock in its absence remained constant at zero. The reverse held in the present experiment, in that the probability of shock in the presence of a signal remained constant, but the probability of shock in its absence varied. That is to say, for the present experiment, the probability with which a stimulus (signal) identified that shock would occur was $p(\text{US}/\text{CS}) = 1.00$, while the probability with which a stimulus (signal's absence) identified a shock-free period varied from $p(\text{US}/\overline{\text{CS}}) = 0$ through 0.25, 0.50, 0.75, 0.90, 0.98. This was accomplished by holding the number of shocks constant (180) while varying the number of signals. An illustration of two of these values may be helpful. The value of $p(\text{US}/\overline{\text{CS}}) = 0$ indicates that, under the signalled condition, the signal's absence identified a completely dependable shock-free period, because shocks were never scheduled to occur at this time. On the other hand, the value of $p(\text{US}/\overline{\text{CS}}) = 0.75$ indicates that three of four (0.75) of the $\overline{\text{CS}}$ intervals (the intervals between signals during the signalled condition) contained shock. Therefore, the absence of the signal under this condition did not dependably identify a shock-free period. In all instances, the subject chose between the signalled condition (180 shocks), in which some or all of the shocks were signalled, and the unsignalled condition (180 shocks), in which none of the shocks was signalled.

METHOD

Subjects

Twenty-nine experimentally naive female albino rats of the Sprague-Dawley strain

(Holtzman Co.) served. Ages ranged from 85 to 130 days. Five subjects went through several conditions repeatedly. The remaining 24 were randomly divided into four groups of six subjects and received only one condition.

Procedure

The procedure, apparatus, and criterion for changing conditions were the same as in Experiment I, except that the number of signals was varied instead of the number of shocks. The number of shocks received during each session remained constant at 180 for the entire experiment. Table 4 denotes the various conditions of the experiment. The dependability of the shock-free period was altered by systematically removing signals so that the designated proportion of $\overline{\text{CS}}$ intervals contained shock. For example, starting with 180 signals and 180 shocks (*i.e.*, $p[\text{US}/\text{CS}] = 1.0$ and $p[\text{US}/\overline{\text{CS}}] = 0$, the value of $p(\text{US}/\overline{\text{CS}}) = 0.50$ was achieved by removing 90 signals. The removal of 90 signals yielded a condition in which 90 of the 180 shocks were signalled and 90 were unsignalled. The 90 unsignalled shocks were delivered in the 90 $\overline{\text{CS}}$ intervals (intersignal intervals) so that half (0.50) of the $\overline{\text{CS}}$ intervals were free of shock. This meant that the remaining half of the $\overline{\text{CS}}$ intervals often contained more than one shock. Note that the removal of signals does not affect the value of $p(\text{US}/\text{CS})$, since whenever a signal occurred, shock always occurred. However, when signals were removed, shocks also occurred in the absence of signals.

Each of five subjects was initially given training-baseline and changeover conditions in which the shock-free period was dependably identified, *i.e.*, $p(\text{US}/\overline{\text{CS}}) = 0$. After an extinction condition and a second changeover condition with $p = 0$, these subjects were then

Table 4

The values used for the signalled condition when the shock-free period was made undependable.

$p(\text{US}/\text{CS})$	1.00	1.00	1.00	1.00	1.00
$p(\text{US}/\overline{\text{CS}})$	0	0.50	0.75	0.90	0.98
Number of Shocks	180	180	180	180	180
Number of Signals	180	90	45	18	3
Mean Intershock Interval	2 min	2 min	2 min	2 min	2 min
Mean Intersignal Interval	2 min	4 min	8 min	20 min	120 min

given training-baseline and changeover conditions in which the shock-free period was identified undependably, *i.e.*, S4 and S8 experienced $p(\text{US}/\overline{\text{CS}})$ values of 0.50 and 0.75 while S1, S2, and S7 experienced $p(\text{US}/\overline{\text{CS}})$ values of 0.75, 0.90, and 0.98. In contrast, the 24 subjects assigned to the four groups were given training-baseline and changeover conditions at only one of four $p(\text{US}/\overline{\text{CS}})$ values, either 0.25, 0.50, 0.75, or 0.90. Each group received the following sequence for a minimum of three 6-hr ses-

sions under each condition: training-baseline, changeover, extinction, changeover. As in the previous experiment, during extinction the unsignalled schedule was always in effect because the changeover responses were ineffective.

RESULTS

As noted, five of the 29 subjects experienced several values of $p(\text{US}/\overline{\text{CS}})$. Data from these subjects are presented in Figures 4 and 5.

Fig. 4. Per cent of session time spent in the changeover condition for the last three days of each condition as a function of the dependability of the stimulus identifying the shock-free period. The number of shocks remained constant under each condition at 180. Dependability was varied by reducing the number of signals given in a session from a maximum of 180 to a minimum of three. Numbers on the abscissa represent the sessions from which the data points were taken.

When shocks were delivered only in the presence of the signal and at no other time, all subjects changed over at a rate sufficient to remain in the signalled condition about 80% to 90% of the time (Figures 4 and 5). During extinction, rate of responding dropped to a low level but returned to a high level for four of the five subjects when the signal contingency was re-instated (Figures 4 and 5). The remaining subject (S4) did not return to previously high levels for undetermined reasons. This subject, however, continued to change over at a rate sufficient to remain in the signalled condition about 60% of the time (Figure 5).

The effects on changeover performance of removing signals varied among subjects. Subjects S4 and S8 (Figure 5) were given training-baseline and changeover conditions in which

half of the shock-free periods contained shocks ($p[US/\overline{CS}] = 0.50$). For Subject S8, the rate of changing over was only slightly lower than when the shock-free period was dependably identified. For Subject S4, however, changing to the signalled condition dropped markedly (Figure 5). Both the dependable ($p[US/\overline{CS}] = 0$) and the undependable ($p[US/\overline{CS}] = 0.50$) conditions were repeated for Subject S4 and again it was found that changing over was markedly reduced during the undependable condition (Figure 5). When more signals were removed, thus making the stimulus identifying safety even more undependable ($p[US/\overline{CS}] = 0.75$), changing to the signalled condition dropped to baseline levels for both Subjects S4 and S8 (Figure 5). Similarly, changeover performance for Subject S2 (Figure 4) dropped

Fig. 5. Per cent of session time spent in the changeover condition for the last three days of each condition as a function of the dependability of the stimulus identifying the shock-free period. The number of shocks remained constant under each condition at 180. Dependability was varied by reducing the number of signals. Numbers on the abscissa represent the sessions from which the data points were taken.

from a high rate when the stimulus identifying safety was dependable down to baseline levels when it was made undependable ($p[US/\bar{CS}] = 0.75$). However, changeover performance for Subjects S1 and S7 was not markedly affected until the value of $p(US/\bar{CS})$ was increased to $p = 0.90$. When the stimulus identifying safety was made more undependable ($p = 0.98$), changing over dropped to baseline levels for both subjects (Figure 4).

The subjects just described were given a series of conditions in which the stimulus identifying a shock-free period was made systematically more undependable. These subjects were initially exposed to a dependable predictor, which was then gradually made undependable. A procedure such as this risks "carry over" effects. Subjects in the various conditions may have persevered longer in the task than they would had they been tested un-

Fig. 6. Per cent of session time spent in the changeover condition for the last three days of each condition as a function of the dependability of the stimulus identifying the shock-free period. Groups of six subjects were trained and repeatedly tested at a single value of dependability of either $p(US/\bar{CS}) = 0.25$ or 0.50 . Numbers on the abscissa represent the sessions from which the data points were taken.

der only one value of dependability. Therefore, 24 additional subjects were divided into groups of six, each of which experienced only one of the following values of $p(US/\bar{CS})$: 0.25, 0.50, 0.75, or 0.90. The results of these conditions are found in Figures 6 and 7.

These data also indicate that changeover performance is related to the dependability with which a stimulus identifies a shock-free

period. The more dependably the signal identified a shock-free period, the more effectively it controlled changing to the signal condition. More specifically, when the absence of the signal in the signalled condition (correlated stimulus alone) identified a shock-free period 75% of the time ($p[US/\bar{CS}] = 0.25$), changing to the signalled condition continued to occur at a high rate for the six subjects in this group

Fig. 7. Per cent of session time spent in the changeover condition for the last three days of each condition as a function of the dependability of the stimulus identifying the shock-free period. Groups of six subjects were trained and repeatedly tested at a single value of dependability of either $p(US/\bar{CS}) = 0.75$ or 0.90 . Numbers on the abscissa represent the sessions from which the data points were taken.

(Figure 6). However, changeover performance was noticeably poorer for the six subjects given the condition in which the shock-free period was dependable only 50% of the time ($p[\text{US}/\overline{\text{CS}}] = 0.50$). Several of these subjects failed to return to previous levels of changeover responding following the extinction condition (Figure 6).

Changeover responding for the six subjects given the condition in which the shock-free period was identified only 25% of the time ($p[\text{US}/\overline{\text{CS}}] = 0.75$) was less than the group tested with the p value of 0.50. Only four of the six subjects changed over to the signalled condition when given their first opportunity, and only three did so during the second changeover condition. In addition, the level of changeover was low relative to that observed when the p value equalled 0.50 (Figure 6). Finally, changing over occurred least frequently for the six subjects in which the shock-free period was dependable only 10% of the time ($p[\text{US}/\overline{\text{CS}}] = 0.90$). For this latter group, changing over remained nearly at baseline levels (Figure 7) when the changeover condition was first introduced and later when it was repeated.

GENERAL DISCUSSION

The first experiment showed that subjects chose a signalled condition over an unsignalled one when the signal predicting shock was dependable (*i.e.*, $p[\text{US}/\text{CS}] = 1.0$) or when it was made systematically undependable to a point as low as $p[\text{US}/\text{CS}] = 0.02$ (180 signals, three shocks). Carry-over effects were ruled out because it was shown that rats chose the signalled situation, even though their only experience with the signal occurred under undependable conditions. These findings suggest that dependability of the signal as a predictor of shock is relatively unimportant as a factor determining choice. The second experiment varied the dependability of the stimulus identifying the shock-free period. In contrast to the first experiment, the second one found that the dependability of the shock-free (safe) period was importantly related to choice of the signalled condition. That is, as the dependability of safety was systematically degraded, the amount of time spent in the signalled condition systematically decreased. The findings were similar with subjects tested at

all values of dependability (within comparison) and with those tested at only a single value (between comparison). Data from Experiments I and II are consistent with data obtained using a conditioned suppression procedure (Nageishi and Imada, 1974).

These data allow several theoretical views to be evaluated. While the data do not refute the preparation and information hypotheses, they provide little, if any, support for either view. The preparation view clearly identifies the signal predicting shock as critically important for choosing the signalled condition (Perkins, 1955, 1968). Yet, varying the dependability of the signal as a predictor of shock (Experiment I) had little effect on choice performance. If preparation were a factor in choosing, then rate of changing to the signalled condition might be expected to decrease as dependability decreased. It is particularly difficult for the preparation view to account for the finding that preference was strong when 180 signals and three shocks were given ($p[\text{US}/\text{CS}] = 0.02$; Figure 1 and Table 3), but weak when three signals and three shocks were given (Figure 3). Stated differently, the preparatory view would have to claim that preference was strong when most preparatory responses were inappropriate (when signals were followed only occasionally by shock) but weak when all preparatory responses were appropriate (when all signals were followed by shock). The findings of the second experiment also provide difficulties for the preparation view. In the latter instance, preparatory responses were always appropriate regardless of the value of $p[\text{US}/\overline{\text{CS}}]$, since whenever a signal occurred shock always followed ($p[\text{US}/\overline{\text{CS}}] = 1.0$). Yet, choosing the signalled condition began to occur less frequently when the shock-free period was dependable only 50% of the time ($p[\text{US}/\overline{\text{CS}}] = 0.50$). Under this condition, the number of subjects that failed to change over at a high level was particularly obvious on the second changeover opportunity. Choosing the signalled condition occurred with even less frequency when the shock-free period was dependable only 25% of the time ($p[\text{US}/\overline{\text{CS}}] = 0.75$), and changing over was all but eliminated when the shock-free period was dependable only 10% of the time ($p[\text{US}/\overline{\text{CS}}] = 0.90$). If preparation were the critical factor governing choice, then, even under the latter values,

subjects should have continued changing over, since appropriate preparation could be made for 18 of the shocks. However, as the dependability of the safety signal is degraded, the proportion of signalled to unsignalled shocks in the signalled condition decreases and, with it, the proportion of shocks whose noxiousness can be reduced via preparatory responses. Simply by assuming that preparatory responses are only moderately effective, the obtained quick decline in changeover performance with decreasing dependability of the safety signal could be predicted under the preparation view. Other data, however, require the assumption that preparatory responses are highly effective in reducing shock aversiveness if they are to be explained by preparation. It has been shown that subjects choose signalled shocks up to nine times longer, six times stronger, or two to eight times more frequently than unsignalled ones (Badia, Coker, and Harsh, 1973; Badia, Culbertson, and Harsh, 1973). For the signalled condition to be preferred, the preparatory response would have to reduce the aversiveness of these shocks below that of the unsignalled shocks. Responses as effective as this should have maintained changeover responding at high levels as long as even a few could be appropriately performed.

The information hypothesis does not fare much better than the preparatory one. Presumably, this view would hold that the information about shock and shock-free periods are of equal importance in controlling performance, since both reduce uncertainty. Yet, the present data show that the dependability of the stimulus predicting a safe period was important, whereas the dependability of the stimulus predicting a shock period was not. Data from other studies also conflict with the information view (Defran, 1972; Dinsmoor, Flint, Smith, and Viemeister, 1969). These studies have shown that subjects respond for stimuli that identify shock-free periods, but they do not respond for stimuli that identify shock periods (to which preparation could be made). Other findings solely within the appetitive situation are also incompatible with the information view (Dinsmoor, Browne, and Lawrence, 1972).

Of the various interpretations available, the safety analysis seems most strongly supported by the data. Unfortunately, however, the hy-

pothesis is relatively undeveloped and various interpretations can be derived from it, depending on the circumstances. For example, while it is clear that this view predicts that safety is an important factor, it is not at all clear how choice would be affected when the dependability of safety is degraded. It would seem that, in the absence of complete dependability (as in some of the conditions presented here), identifying a specific period as either safe or unsafe could no longer occur. It is difficult to imagine a subject relaxing (Denny, 1971) or inhibiting fear (Seligman, 1968) in the presence of a stimulus undependably identifying safety. Yet, subjects continued to change to the signalled condition under these conditions. Obviously, further theoretical development is needed. However, the data obtained are consistent with the safety analyses of choice to the extent that the dependability of the safe stimulus ($\overline{CS}$) was more important for choice than was the dependability of the unsafe stimulus (CS). Furthermore, other findings also support the importance of safe periods in controlling different behavior (Arabian and Desiderato, 1975; Badia and Culbertson, 1970; Nageishi and Imada, 1974), thus also lending credence to the theory.

While the importance of safe periods is thus supported, the present data do not support the notion that safety is something absolute—either present or absent but not available in degrees. This raises an important question: how is safety to be defined? Is safety a discriminable period of shock absence? Or simply a reduction in shock frequency? Both approaches can be treated within the framework of the correlational-based law of effect (Herrnstein, 1969; Rachlin, 1970). Herrnstein (1969) argued that going from a high- to a low-density shock schedule is reinforcing. In the present case, shock frequency in the unsignalled condition was always higher than that experienced in the absence of the signal in the signalled condition. Alternatively, it may be reinforcing to change from a schedule of zero density of shock-free periods (unsignalled condition) to a schedule with a higher density of shock-free periods (signalled condition). The higher the density of these periods, the more reinforcing the schedule. Additional research will be necessary to determine whether one or both of these possible definitions of safety is correct.

One finding was surprising. As described earlier, when only three signals and three shocks were contrasted with three shocks alone (ISI = 120 min), changing to the signalled condition occurred infrequently. However, when the signal was undependable (180 signals, three shocks), subjects chose with great frequency the signalled condition. These findings are puzzling and difficult to interpret. It is obvious that three signal-shock pairings contrasted with three shocks alone over the 6-hr session were not sufficient to maintain high levels of changing over. Why performance was maintained at a high level under the condition of undependable signals is open to speculation. A photic stimulation or sensory change hypothesis seems to be ruled out because subjects stopped changing over when the correlated stimulus, along with 180 signals, was presented without the three shocks. Also, the correlated stimulus followed each response under all conditions except extinction, but this stimulation was insufficient to maintain responding when three signals and three shocks were given. It may be that the attractiveness of safety is dependent on the degree of aversiveness and that the aversive level is related to the number of signals within the entire situation. Some data support the notion that the value of safety is a function of the aversiveness of the stimulus situation and, at lower levels of aversiveness, discriminable periods of safety are not reinforcing (Harsh and Badia, 1975).

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Received 7 August 1975.

(Final Acceptance 2 March 1976.)